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Comparing Justification Techniques for the Selection of an Acquired Automation Technology: an Empirical Study

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Submission date: June 2016
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Acknowledgements

This master's thesis is submitted as the final part of the Master of Science program in Mechanical Engineering at the Department of Production and Quality Engineering at NTNU. The thesis is a part of the NAP-project led by the company SINTEF Raufoss Manufacturing AS, which is a Norwegian manufacturing research centre. NAP is a Norwegian abbreviation, meaning zero defect production in autonomous production system. I am grateful for the opportunity of taking part in this interesting research project.

I would like to thank my supervisors Erlend Alfnes at NTNU, Maria Kollberg Thomassen at SINTEF Technology and Society and Per Aage Nyen at SINTEF Raufoss Manufacturing AS for their feedback and guidance. They have been a great support in the work with this master's thesis and their enthusiasm has been a motivating effect.

I would also like to thank representatives from the case company Nammo Raufoss AS at their department of Medium and Large Caliber Division of Ammunition for finding time to participate in interviews and workshop, answering my questions and giving me an insight into their process of acquiring automation technologies. I have greatly appreciated the hospitality on my visits and the cooperation from the whole department.

Last, but definitely not least, I would like to thank my fellow students for making the five years as a master student the best time of my life, and my closest ones for great support and motivation during these years. I have deeply appreciated it.

Trondheim, 09.06.2016

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Summary

Manufacturing companies are forced to look for progressive automation technologies to remain competitive in their market. An acquisition of automation technology can entail large investments, which will need justification. Justification techniques can support and guide an acquisition of automation technology in challenging production processes to avoid any unsuccessfully implementations.

The overall objective of this thesis is to compare justification techniques from the literature focusing on the selection of an acquired automation technology. Two research questions are answered to reach the overall objective:

1. What makes a justification technique supportive for a manufacturing company selecting an acquired automation technology?
2. What are the strengths and weaknesses of the justification techniques used in the selection process when acquiring automation technology in a manufacturing company?

The thesis is carried out with a theoretical part and an empirical part. The theoretical part consists of a literature review which covers and evaluates justification techniques in the research field. The empirical part consists of a case study conducted in a case company through interviews, workshop and mail correspondence which practice and evaluates the findings in the literature review.

The literature review emphasises the importance of a justification technique and presents a selection of the techniques available in the literature. Further, a division of the acquisition process leads to a collection of techniques concerning the selection process of an acquired automation technology. These techniques are evaluated upon the ability of guiding a selection process. Two justification techniques with different approaches are found satisfactory to be performed in an empirical study. These techniques are presented more thoroughly than the others and are included in the case study. Important elements making a justification technique supportive are established and presented in a table for further evaluation of the two justification techniques.

The case study consists of a company with challenging processes to automate to reveal the strengths and weaknesses of the techniques. The practitioner executes and evaluates the two

techniques performed on the same processes and the results are used to document their degree of fulfilling the important elements for being supportive. The evaluation is further presented in a table with strengths and weaknesses and followed by a list of situations assumed to be best supported by the techniques.

Justification techniques appropriate for a manufacturing company can support and guide a selection of an acquired automation technology. By establishing the important elements for a justification technique to be supportive, two techniques suitable for a selection process were executed and evaluated to find their strengths and weaknesses.

Sammendrag

Industribedrifter blir tvunget til å se etter fremtidsrettet automasjonsteknologi for å forbli konkurransedyktige i sitt marked. Anskaffelse av automasjonsteknologi kan innebære store investeringer og burde derfor bli rettferdiggjort. Teknikker for rettferdiggjøring kan støtte og veilede en anskaffelsesprosess for å unngå mislykket implementering av automasjonsteknologi i krevende produksjonsprosesser.

Det overordnede målet med denne avhandlingen er å sammenligne ulike teknikker for rettferdiggjøring som finnes i litteraturen og som fokuserer på utvelgelsen av en automasjonsteknologi. To forskningsspørsmål blir besvart for å nå det overordnede målet:

1. Hva gjør en teknikk for rettferdiggjøring støttende for en produksjonsbedrift som skal velge ut en automasjonsteknologi for implementering?
2. Hva er styrkene og svakhetene til teknikkene for rettferdiggjøring som brukes i utvelgelsesprosessen av en automasjonsteknologi i en produksjonsbedrift?

Studiet gjennomføres med en teoretisk del og en empirisk del. Den teoretiske delen består av en litteraturgjennomgang som dekker og evaluerer teknikker for rettferdiggjøring som finnes i forskningsfeltet. Den empiriske delen består av et case-studie ved bruk av en case bedrift gjennom intervjuer, seminar og e-post korrespondanse som utfører teknikkene funnet i litteraturgjennomgangen og evaluerer disse.

Litteraturgjennomgangen understreker viktigheten av en teknikk for rettferdiggjøring og presenterer et utvalg av teknikker som er tilgjengelig i litteraturen. En oppdeling av anskaffelsesprosessen fører til et utvalg av teknikker som berører utvelgelsesprosessen av en automasjonsteknologi. Disse teknikkene blir deretter evaluert og to av teknikkene gir en tilfredsstillende forklaring av utvelgelsesprosessen. Disse teknikkene blir deretter presentert mer grundig enn de andre og er senere inkludert i et case-studie. Viktige elementer som tilsier at teknikkene er støttende er etablert og presentert i en tabell. Disse blir videre brukt til evaluering av de to teknikkene for rettferdiggjøring.

Case-studiet består av en bedrift med utfordrende prosesser å automatisere for å avdekke styrker og svakheter ved de ulike teknikkene. Bedriften utfører de to teknikkene på de samme prosessene og evaluerer de. Resultatene benyttes for å dokumentere teknikkenes grad til å oppfylle kravet om å inneholde de viktige elementene. Denne evalueringen er deretter presentert i en tabell med styrker og svakheter, etterfulgt av en liste over situasjoner som antas å være best støttet av teknikkene.

Teknikker for rettferdiggjøring som er passende for en industribedrift kan støtte og veilede utvelgelsesprosessen av en automasjonsteknologi. Ved å etablere de viktigste elementene for en støttende teknikk for rettferdiggjøring, ble to teknikker som er egnet for en utvelgelsesprosess utført og evaluert for å finne deres styrker og svakheter.

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1 Introduction

This chapter will introduce the motivation for this master's thesis research area by presenting the problem statement, research objectives and questions, research scope and the report structure.

1.1 Problem statement

Manufacturing companies are forced to look for progressive automation technologies to keep their market share and maintain competitiveness (Chan, Chan, Lau, & Ip, 2001; Sambasivarao & Deshmukh, 1997). The capability of the companies competitiveness is extremely important for their survival (Chan et al., 2001; Säfsten, Winroth, & Stahre, 2007). Automation technology has been the development key driver of processes in manufacturing plants since it entered the manufacturing industry (Jovane, Koren, & Boer, 2003; Ordoobadi & Mulvaney, 2001). Implementing an automation system can result in cost savings within production or increased efficiency, productivity and competitiveness (Frohm, Granell, Winroth, & Stahre, 2006; Groover, 2007). If cost is reduced together with increased efficiency and productivity, competitiveness will be increased as well (Chan et al., 2001; Frohm, 2008).

Although the arguments for automation are good, there are challenges facing automation technology. An introduction of automation technology will need time to achieve successive implementation (Frohm, 2008; Meredith, 1987b). It is also important to be aware that automation can bring problems and failures and not necessarily immediate success (Lindström & Winroth, 2010). Additionally, Frohm (2008) states that increasing level of automation in unforeseen production situations can be related to production disturbances, while Duncheon (2002) list challenging cases like innovative products or products with short life cycle because of the uncertainty related to such production. According to Beckman and Rosenfield (2008) there are solutions for these challenges that include flexible automation technology to cover multiple and different products.

Another option to acquiring automation technology is to achieve competitiveness by relocating the production geographically to foreign low labour cost locations (Stevenson, 2014). The study in this thesis should give a decision maker the confidence in deciding which automation technology to

acquire to retain the production in the country, which can keep and hopefully create employment in manufacturing plants. Developing new technical and organizational production systems based on autonomy is the main object in the NAP-project, which supports a zero error vision for industrial manufacturing (Nyen, 2015). As a part of this research project, the thesis will contribute with a support to the process of establishing a fully automated production line.

The developments in manufacturing systems will proceed in the future (Säfsten et al., 2007). This will entail large investments, which will require justification of any future decisions (Ordoobadi & Mulvaney, 2001; Parsaei & Wilhelm, 1989; Sambasivarao & Deshmukh, 1997). To be able to find the right process to automate, a method for the justification would be essential (Chan et al., 2001; Granlund & Jackson, 2013; Gregory, 1995; Suresh & Meredith, 1985). A technique, method, instrument or approach for an acquisition process of automation technology will further be referred to as a justification technique to ease the terminology. Justification technique is a commonly applied term in several research articles in the literature.

The literature consists of multiple different justification techniques for the acquisition of automation technology, and it becomes clear that the majority of these techniques needs to be verified in the industry (Shehabuddeen, Probert, & Phaal, 2006; Small & Chen, 1997). The research area could benefit an overview of these techniques to see the concurrent methods and to get an insight of the literatures' missing parts. There are several opinions on what is missing in the literature. Some claims there are time consuming and less user friendly methods (Thomassen, Sjøbakk, & Alfnes, 2014; Torkkeli & Tuominen, 2002), methods that lay too much weight on the financial aspects (Farooq & O'Brien, 2012), or has a lack of sufficient support to the decision maker in important areas (Baines, 2004; Durrani, Forbes, Broadfoot, & Carrie, 1998; Granlund & Jackson, 2013; Säfsten et al., 2007).

The selection process in the acquisition of automation technology will be in focus since this part is seen as the most critical one and will benefit guidance to ensure a suitable technology (Granlund & Jackson, 2013; Gregory, 1995; Stevenson, 2014). The purpose for this master's thesis is to evaluate justification techniques from the literature to extract a practical and user-friendly selection guide for which automation technology to acquire.

1.2 Research objectives and questions

The overall objective of this study is to compare justification techniques from the literature focusing on the selection of an acquired automation technology. The techniques will be executed in a case study and evaluated. The evaluation of the techniques will guide manufacturing companies when deciding which technique to apply to ensure an optimal selection of an acquired automation technology.

The objective can be divided into more specific objectives:

1. Identify 1-3 justifications techniques in the literature guiding the selection of an acquired automation technology in a manufacturing company.
2. Perform the justification techniques on a mature process in a manufacturing case company.
3. Present an evaluation of the justification techniques performed in the case study with focus on their strengths and weaknesses.

To accomplish the objectives, two research questions (RQ) are defined to guide the research:

RQ1: What makes a justification technique supportive for a manufacturing company selecting an acquired automation technology?

Justification techniques should be able to guide the selection process of an acquired automation technology for a chosen production process in a manufacturing company. An optimal selection process will require techniques including important elements to being supportive. These elements will therefore be addressed in addition to justification techniques in the literature.

RQ2: What are the strengths and weaknesses of the justification techniques used in the selection process when acquiring automation technology in a manufacturing company?

The study should give a comparison of the justification techniques used to acquire automation technology in production processes with specific challenges. This will contribute to the research field with a more practical evaluation of the techniques, which is a gap pointed out in scientific articles.

1.3 Research scope

The research scope for this study can be described by the three areas; 'automation of production processes', 'technology management in a selection process' and 'manufacturing environment'. The contribution of the three areas are illustrated in Figure 1.

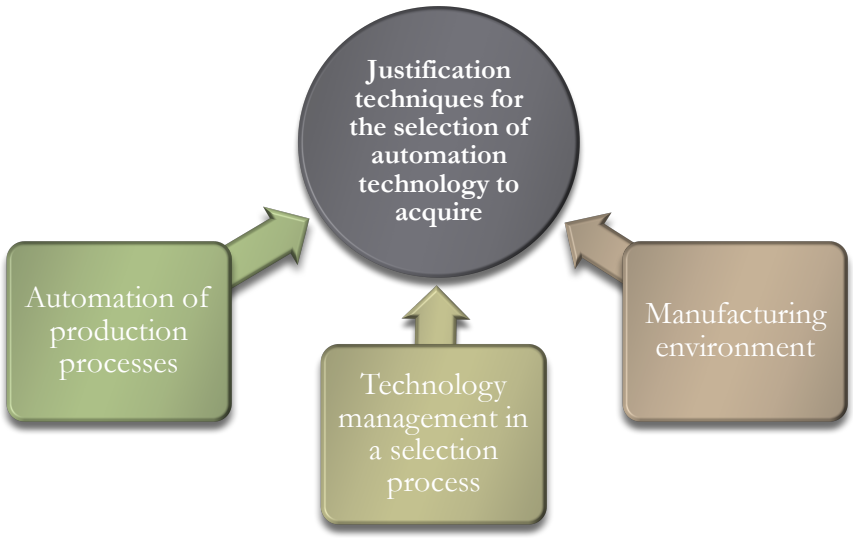


Figure 1: The three areas describing the research scope

'Automation of production processes' concerns automation technology contributing to improve production processes initially performed manually or semi-automated. By performing an improvement on an already existing production, the decision maker has a good foundation for acquiring an automation technology. Automation technology can be classified as fixed automation, programmable automation or flexible automation where the technology performs the necessary tasks (Groover, 2007; Stevenson, 2014). However, this study is not focusing on the specific types of automation technology a company would desire, but rather on how to approach the right choice of technology. Additionally, this study will focus on the degree of support to decision makers responsible for production systems having specific challenges. This is because characteristic production processes could have individual areas required to investigate in a selection of an automation technology. Technology 'of the shelf' will not necessarily fit its production and a supportive guidance will therefore be beneficial when searching for new technical and operational production systems. This scope area will therefore cover all of the three classifications of

automation technology, which is important to make the justification techniques applicable for a practitioner in a manufacturing company with characteristic production processes.

'Technology management in a selection process' concerns the management when selecting the right automation technology. Gregory (1995) articulates that technology management for a company acquiring an automation technology needs to involve the processes of identification, selection, acquisition, development, exploitation and protection of technologies. Further, the selection is identified as a critical process since it may result in a large amount of human and financial resources for the company. Stevenson (2014) argues that decisions regarding the technology selection will need guidance and suggests an approach of utilising models and establishing priorities. From a case study conducted by Granlund and Jackson (2013), the most difficult steps in acquiring an automation technology were the early steps. The focus in this thesis will therefore be given to the task of selecting an appropriate automation technology.

'Manufacturing environment' concerns manufacturing companies that find acquisition of automation technology necessary to survive or remain in a good market position. Guidance in the selection process of acquiring automation technology would give great support for companies with challenging processes to automate. Challenging processes are usually unique processes existing in a minority of the industry. These processes will require less accessible automation technologies commonly created for a specific production assignment. A justification technique can in these cases be especially supportive in helping the decision maker to rely on the selected automation technology. The case study will include one case company. This is because the company's environment fits the scope by its desire of establishing a fully automated production line, as well as fulfilling the requirements of having processes with specific areas to take into account when acquiring automation technology. In addition, the case company was a natural choice and was willing to participate since the master's thesis is connected to the NAP-project which the company is a part of.

This master's thesis is connected to the NAP-project and the justification techniques will aim to support Norwegian industry. The theoretical study will still include research based on industry in other countries, but the empirical study will be based on experiences from the Norwegian industry. Additionally, the manufacturing environment in this study will need appropriate justification techniques to ensure that the safety issues are attended and facilitated for implementation of a fully automated production line. Companies in this category would benefit a concrete recommendation

for a justification technique. Companies handling less dangerous products would also benefit a thorough technique, which means that all types of manufacturing companies are covered in this study.

1.4 Report structure

The project report consists of seven chapters and their content is briefly presented in Table 1.

Table 1: Report structure

Chapter 1 **Introduction**	Presents the problem statement, research objectives and questions, research scope and report structure.
Chapter 2 **Methodology**	Presents the research methods and justify them to prove that the results are valid. The chapter is divided into one theoretical study section, one empirical study section and one section explaining the structure of argumentation in the thesis.
Chapter 3 **Literature review**	Presents the collection of relevant data to answer the thesis research questions. The chapter starts by defining automation technology in manufacturing plants, followed by justification techniques guiding the selection of an appropriate automaton technology. Important elements in a supportive technique are established and a summary concludes the chapter.
Chapter 4 **Empirical study**	Presents the relevant outcome from the case study. The case company and the outcome from performing the justification techniques is presented. A summary concludes the chapter.
Chapter 5 **Empirical findings and discussion**	Presents the main findings in the case study and discusses the different justification techniques upon each other. A summary concludes the chapter.
Chapter 6 **Justification techniques supporting a selection process**	Presents the degree of fulfilling the important elements, strengths and weaknesses in the justification techniques addressed in the previous chapters. The main findings and the contribution to the research field is presented.
Chapter 7 **Conclusion**	Discusses to what degree the research has answered the research questions and fulfilled the research objectives. Suggestions for further work are included.

2 Methodology

This master's thesis will be carried out with a theoretical and an empirical part as a research based project. The methodology chapter presents the methods applied in the theoretical and empirical study, as well as explaining how the material is collected to contribute to the thesis. The structure of argumentation will be explained in the last section.

Research methods could be quantitative, qualitative or a combination of these two. Quantitative research answers the questions "what", "where" and "when" by including numbers and mathematics, while qualitative research answers the questions "why" and "how" by applying reasoning and explaining with words (Rajasekar, Philominathan, & Chinnathambi, 2006). The qualitative research method has been applied to reach the objective and cover the scope. Qualitative methods can also involve deductive reasoning, which means that the researcher explore the validity of general theories or principles (Charmaz & McMullen, 2011). Deductive reasoning has been applied in the empirical study, which will be further explained in this chapter.

This thesis has been carried out with a literature review and a case study as shown in Figure 2. The findings in the literature review and case study influence the final solution. The empirical study is based on the findings in the literature review, interviews, workshop and information from mail corresponds with the case company. The theoretical study is based on results from a recent specialisation project on this topic, in addition to information collected from search monitors and snowball sampling in the literature review. The study can later be repeated and give the same results by demonstrating the operations in the study, which increase the reliability in the research methodology (Yin, 2013). More detailed description of the applied research methods will be further presented in the following sections.

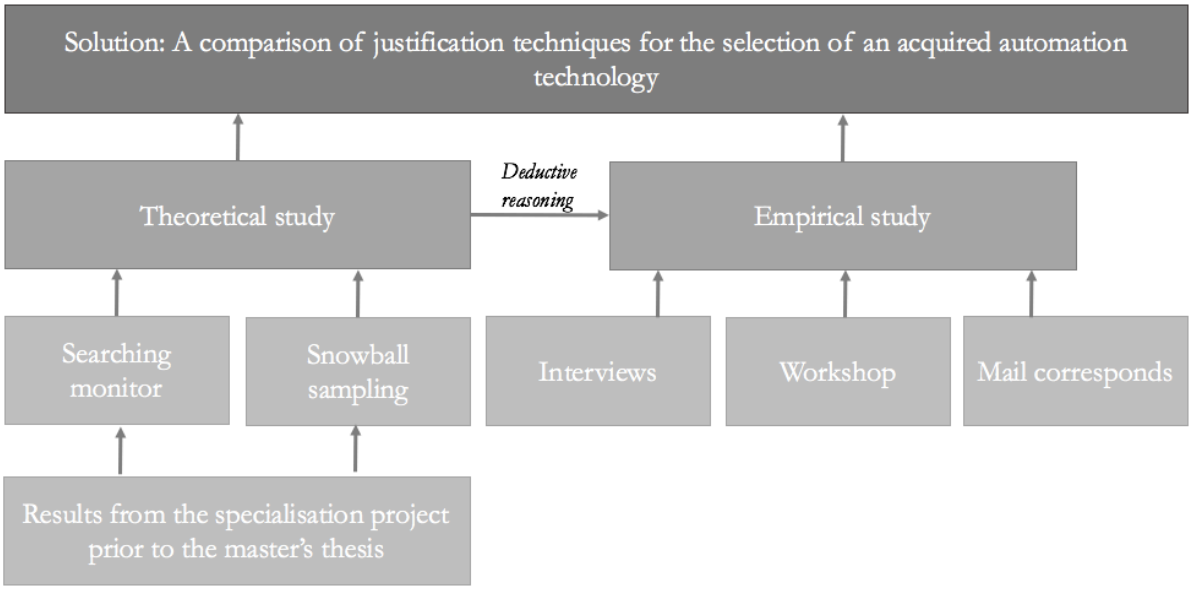


Figure 2: The utilisation of methodology

2.1 Theoretical study

The theoretical study consists of a necessary literature review with existing theories on the field. It is important to identify how other authors have approached the same research phenomenon and to avoid re-inventing the wheel. Previous research and suggestions for how to select an acquired automation technology can be scanned in the literature review and link the present study to a larger academic discussion. The literature review contributes to limiting the scope of the study and adjusts the research question (Bryman & Bell, 2015; Yin, 2013). As already mentioned, the theoretical study is based on a recent specialisation project on the topic. The project addressed the relevance of automation technology and the important considerations when acquiring automation technology, which is highly relevant for this study as well. Some of the findings have therefore been extended to this master's thesis. The theoretical study will answer RQ1 and the findings in the theoretical study will be further used in the case study in the empirical part of this study.

The problem description and research questions have formed the background for the search words used in the search functions. This was to identify the required information to answer the problem statement and research questions. The search functions were Google Scholar, ProQuest Entrepreneurship, Compendex (Ei Village 2), and NTNU BIBSYS. The search words are presented in Table 2.

Table 2: Search words in the literature search

The first set with main search words	The second set with additional search words
Automation	Production
Justification	Manufacturing
	Strategy
	Approach
	Framework
	Acquisition
	Selection process
	Technique
	Automation

One of the search words in the first set was combined with one or more search words in the second set. The second set was used to narrow the search scope and was combined in several ways. An example of a combination of the search words is shown in Figure 3. In the example, the results from the search had to include the word "automation", in addition to the word "production", "approach" or both of the words.

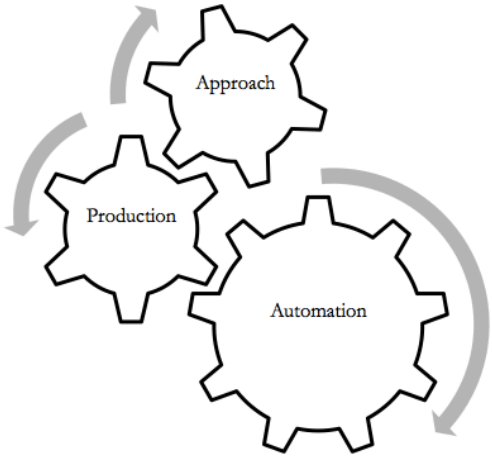


Figure 3: Example of a combination of the search words

If the abstract of a paper seemed relevant, the introduction and conclusion were read and its relevance was once again evaluated. If the paper was found interesting, the reference was stored in

the reference library EndNote and studied more thoroughly later. The quality of the articles was evaluated based on how many times the article had been quoted in other research articles. This was found in Google Scholar, or by finding the same article quoted in acknowledged articles within the field. In addition, an article published in a journal had fulfilled requirements for being a serious one. This ensures quality of the scientific articles. Most of the articles used in this study were found through references from other relevant papers. This method is called the snowball sampling (Noy, 2008). Snowball sampling is a qualitative research method and is the most widely employed method of sampling (Noy, 2008). At the end of the literature search, all relevant findings and statements from the stored literature in EndNote were collected.

The literature review was carried out before the workshop in the empirical study took place. This was to establish a theoretical foundation for the upcoming case study. The executed search in the literature in the specialisation project prior to this master's thesis was included in the theoretical study. In addition, new search words were added to be as thorough as possible to find relevant literature for the scope in this thesis. Validity of the study was ensured by using several types of sources. The variety of sources also secured overlap of data.

2.2 Empirical study

The choice of research method depends on the nature of the research problem (Noor, 2008). Since this research aims to compare justification techniques' guidance for decision makers in the industry, a case study was chosen as strategic methodology. According to Yin (2013), the questions 'how' and 'why' are preferred to be answered with a case study. It was important to gain information about previous acquisitions of automation technology in the case company, as well as its current process of acquiring automation technology. It was also desirable to test some of the findings in the theoretical study in the case company and observe the company's experiences. In this way, the aim to find justification techniques suitable in the process of selecting an acquired automation technology was achievable. The empirical study will therefore contribute to answering RQ2.

The weakness of a single case study is the lack of addressing issues of generalisability since it is performed in only one case company, but on the other hand it enables the researcher to get an holistic view and go in the depth on the subject (Noor, 2008). A single case study limits its results to the context in which it is examined, which means that further investigation will be needed to see

if the results apply to other similar situations. To ensure credibility of a single case study, one must not misinterpret a single event or overstate the importance of readily available data (Voss, Tsikriktsis, & Frohlich, 2002). Just because such available data are easy to obtain does not necessarily mean that these should be emphasized the most through the study (Voss et al., 2002). An awareness of this was therefore necessary during the case study. To ensure the quality of the study, the gathered material was well documented, which according to Yin (2013) is an important factor for the reliability of a case study. In addition, the reliability of the case study informants is evaluated to be high because of their close relation and high responsibility in the automation project in the case company. These persons also had good knowledge and experience from other automation projects during their career.

As already mentioned, the case company was chosen due to its fit to the scope by its desire of establishing a fully automated production line. In addition, the case company has specific challenges that need to be taken into account during the evaluation of technology alternatives. The performed case study included two interviews, one workshop and mail correspondence after the workshop. An overview of the date and length of the communication with the case company is presented in Appendix A. The types of communication will be explained in the following sections.

2.2.1 Interviews

The interviews were held early in the process to get to know the case company and to collect basic information for the company description. This information was also valuable for the preparation of the case study since it identified their earlier experience in the field, as well as their current status in the process of acquiring automation technology. These findings are presented in Section 4.1.

The interviews were conducted with a semi-structured interview approach. A semi-structured interview is typically used when there is some knowledge of the topic, but further facts, attitudes or opinions are needed (Wilson, 2013). The case company had some information available on its homepage on the internet and the NAP-project had detailed information regarding the desired processes to automate. This information was therefore collected before the interviews, as well as the information of whom to contact in the case company. The first interview was with the project manager to inform about the master's thesis and get the overall information about their project, as well as getting an official confirmation to include the company in the case study. The second

interview had two participants, the project manager and a process engineer. These participants were chosen because of their close relation to the automation project, as well to establish a good communication prior to the workshop. Both of the interviews were held via telephone. Telephone interviews can be performed semi-structured and are usually applied when one or several participants are located geographically far away (Wilson, 2013). Both participants from the case company were asked to schedule one hour for answering the questions. The timeframe allowed them to answer the questions without causing undue burdens in their time schedule.

The strengths of a semi-structured interview is the insurance of important points to investigate since a list of questions is followed, but at the same time give the possibility to add other types of information (Wilson, 2013). The weaknesses are that the interviewed participant could have reasons for not revealing certain information or that the participant's answers are limited as a result of too much guidance (Wilson, 2013). An interview guide was created based on findings in the literature and information collected from other sources. The questions were not intended to control the conversation, but rather guide the conversation in the right direction (Wilson, 2013). The interview guides are presented in Appendix B and C.

The interviews were recorded if permitted by the participant. Some notes were written during the interviews, but the main processing of the outcome was transcribed from the records later. The behaviour of the interviewer under the semi-structured interview was minimal encouragement. This is to not affect the participants, but rather to express understanding and let the interview participants speak freely (Wilson, 2013). Useful information was detected from the interviews and included in the case company description. The information had to explain the company's necessity for automation and challenges related to it.

2.2.2 Workshop

The findings in the theoretical study were tested in the case company during a workshop. The workshop was performed with the project manager in the company's office building. The case company was not able to involve any other employees in the workshop. However, the project manager is the most knowledge and experienced person in the company on the field and is therefore seen as a good choice for the workshop.

The literature had presented the justification techniques to be tested in advance of the workshop. The workshop had therefore a well-documented plan for the execution of the justification techniques. Bryman (2015) categorises this type of research as a structured approach to data collection, which is when the researcher establishes a broad outline of what to be investigated in advance of the observation. This outline is a designed research instrument, which in this case is the document with guidance to each justification technique. The document is presented in Appendix D.

Parts of the justification techniques were simplified during the workshop. The first technique was thoroughly executed in the steps concerning the scope of the study, while the steps not directly relevant for the case study was rapidly examined. The second technique was simplified in its second part to get a more efficient execution. These simplifications were made to ensure that both of the techniques could be carried out and at the same time thoroughly evaluate the interesting parts of the techniques during the specified timeframe of the workshop. The results from the workshop were noted parallel to the execution of the techniques. Additionally, the practitioner's impression of the techniques was expressed and questions related to the execution experience were answered. These results were valuable for the case study since it formed the basis of the final evaluation of the justification techniques and their technology alternatives received from suppliers. The evaluation of the case study was based on the statements from the practitioner and observations.

2.2.3 Mail correspondence

The workshop provided the case study results that needed processing before an evaluation of the justification techniques. The project manager in the case company had executed the techniques and had been guided in new ways of selecting an acquired automation technology. After evaluating the experience together in the workshop, it was necessary to give both parts time to evaluate the workshop separately and then communicate after the workshop session. The researcher opened a mail correspondence with the project manager asking for feedback on the result's influence on their process. Mail correspondence had only been used as a planning tool for the interviews and workshop earlier.

The information collected in the mail correspondence was valuable for the final evaluation of the justification techniques. The practitioner shared thoughts and information about the selection of

automation technology. This type of communication involves advantages and disadvantages. If the question is misunderstood or insufficient, desired information will be lost, which is a great disadvantage. The advantage is that the receiver can be precisely questioned, hence unnecessary time consumption is reduced. The receiver can also decide to answer the questions whenever it is suitable and excessive information is avoided. After executing the interviews and workshop with the project manager, the understanding of the assignment seemed to be concurrent. This made it possible for the researcher to execute the rest of the case study with mail correspondence. The mutual object made the communication easy to perform. The results from the mail correspondence were used to understand the case company's experience of the case study and how the practitioner had taken advantage of it afterwards.

The documentation and explanation of the case study will not be focusing on the content of the tenders, but on the results and the reasons for the evaluation in the two justification techniques tested in the workshop. The empirical study will be explained from Section 4.2.

2.3 The structure of argumentation

The literature review starts by introducing automation technology in a manufacturing plant and its importance, as well as highlighting the necessary considerations related to it. Further, justification techniques from the research field are presented. These techniques are presented in a table to get an overview of the techniques' ability to cover defined phases of an acquisition process. Further, a new table presents the techniques covering the technology phase of the acquisition process. This is because the technology phase includes the selection of an acquired automation technology, which is the focus in this study. An evaluation of these techniques is therefore performed to find the techniques guiding the selection process in addition to including the necessary considerations related to automation technology. Two justification techniques are found satisfactory for a further evaluation and are therefore explained more thoroughly in the literature review. The further evaluation will evaluate the techniques ability of fulfilling important elements making a justification technique supportive for the selection process. These important elements are therefore established in the end of the literature review.

The empirical study presents the case company and the case study. The two justification techniques are performed in the case study which is explained thoroughly. Further, the results, experiences

and the final decision for the case company are presented in the empirical findings and discussion chapter. The two justification techniques are evaluated according to the important elements established in the literature review chapter. These findings are further presented in a table with the degree of support in each element. In addition, the strengths and weaknesses of the techniques are presented as the final contribution in this study.

3 Literature review

This chapter presents the theoretical framework of the master's thesis with published and relevant literature to answer the research questions. The chapter will define automation technology for a manufacturing plant and present justification techniques for selecting appropriate automation technology in a manufacturing plant. A summary concludes the chapter.

3.1 Automation technology in a manufacturing plant

Groover (2007) defines the manufacturing process as a technological process with one or more operations. The operations are bringing a product closer to final state, which makes the whole process value adding and therefore necessary for the manufacturing plant. Equipment, people and procedures involved contribute to the manufacturing process (Säfsten et al., 2007). Typically, manufacturing plants with manual based labour and high product variation are nowadays seeking automation for their processes, which makes automation decisions more challenging (Shehabuddeen et al., 2006; Thomassen et al., 2014). This implies that acquisition of automation technology gets more common for a broader part of the industry, and that the manufacturing companies should prepare for such implementations.

Säfsten et al. (2007) define automation technology as: "The application of mechanical, electronic, and computer-based systems to operate and to control manufacturing". Automation can be an efficient way to reduce high cost and increase efficiency and reliability in the production, as well as relieving humans from dangerous or heavy work and protect them from human mistakes (Baldwin & Lin, 2002; Frohm, 2008; Parasuraman, 2000). This will improve the overall safety in the production processes. Further, it is stated that automated manufacturing usually has a reduced degree of human participation. Table 3 gives an indication of situations where automation technology can be appropriate and situations where humans have higher strengths (Groover, 2007).

Table 3: Relative strengths of humans and machines (Groover, 2007)

Relative Strengths of Humans	Relative Strengths of Machines
Sense unexpected stimuli	Perform repetitive tasks consistently
Develop new solutions to problems	Store large amounts of data
Cope with abstract problems	Retrieve data from memory reliably
Adapt to change	Perform multiple tasks simultaneously
Generalize from observations	Apply high forces and power
Learn from experience	Perform simple computations quickly
Make difficult decisions based on incomplete data	Make routine decisions quickly

Stevenson (2014) emphasizes that even though humans seem more flexible, automation technologies can fulfil other important criteria in a manufacturing plant. Level of Automation (LoA) classifies processes in manually, semi-automated and fully automated performance with the aim to find the best practice of sharing the tasks between humans and technologies in cooperation with the process requirements (Frohm, 2008; Groover, 2007; Parasuraman, 2000). The future is predicted to consist of a careful balance between fixed and flexible automation due to strong product individualisation (Jovane et al., 2003; Schlechtendahl, Keinert, Kretschmer, Lechler, & Verl, 2015), and the human operators would have to obtain new skills to successfully adopt the new technologies (Boothby, Dufour, & Tang, 2010; Chung, 1996). Fixed automation means that the equipment is specialised for a fixed sequence of operations, while flexible automation evolves from programmable automation (Stevenson, 2014). Necessary considerations when acquiring automation technology are further addressed.

Each manufacturing company will have its own path to success (Jiménez, Garrido-Vega, & González, 2011). Decisions concerning automation technology should be in line with the company's manufacturing strategy (Efstathiades, Tassou, & Antoniou, 2002; Granlund & Jackson, 2013; Gupta & Somers, 1993; Lindström & Winroth, 2010; Meredith, 1987a; Noori, 1997; Säfsten et al., 2007) and the process maturity for implementing an automation technology (Baines, 2004; Thomassen et al., 2014; Torkkeli & Tuominen, 2002). Further, company's position in the market will have an impact on the optimal selection of an acquired technology (Morgan & Daniels, 2001; Small & Yasin, 1997), as well as the technology trends in the industry (Beckman & Rosenfield, 2008; Noori, 1997; Thomassen et al., 2014). An innovative automation technology could give the company a major competitive advantage (Beckman & Rosenfield, 2008; Ford, 1988; Thomassen et

al., 2014; West, 2000) and contribute to uplift the whole automation technology field (Gellatly, 1999; Gregory, 1995). However, innovative technology can result in worse product performance if it is unsuccessfully implemented (Christensen, 2013; Torkkeli & Tuominen, 2002).

Labour cost in a high-cost country such as Norway is a disadvantage relative to international competitors and automated equipment can compensate for such threat (Frohm et al., 2006; Groover, 2007). Economic perspective therefore play an important role in an acquisition of a technology (Iakymenko, 2014; Karsak & Tolga, 2001; Noori, 1997), but investments and technologies are often challenging for managers to translate from their own gut feeling into finance and accounting (Raafat, 2002). Economic analysis are claimed to reveal the best suited technology (Chan et al., 2001; Farooq & O'Brien, 2012; Iakymenko, 2014; Samad, McLaughlin, & Lu, 2007; Small & Chen, 1997), but have been criticised for not covering all of the relevant information, i.e. costs after its implementation (Abdel-Kader & Dugdale, 2001; Accola, 1994; Baldwin & Lin, 2002). Beckman and Rosenfield (2008) argue that economic analysis should be used to compare different solutions rather than as an unchangeable cost limit, since final costs can be difficult to calculate in such projects.

An automation technology will in line with other technical implementations need justification of its application (Chan et al., 2001; Granlund & Jackson, 2013; Martin, Kivinen, Rijnsdorp, Rodd, & Rouse, 1991). Justification techniques can support decision makers in an acquisition of automation technologies (Shehabuddeen et al., 2006).

3.2 The selection of an acquired automation technology

There are several contributions in the literature that addresses selection and justification of automation technology (Chuang, Yang, & Lin, 2009; Phaal, Farrukh, & Probert, 2006; Thomassen et al., 2014), but there is a lack of concurrent methods in the literature for the justification techniques (Granlund & Jackson, 2013; Iakymenko, 2014). This contributes to new variants of tools in the literature, which not necessarily are applied in the industry (Kerr, Farrukh, Phaal, & Probert, 2013).

The decision process is usually individual for different manufacturing systems and it is a difficult process due to the increasing numbers of technologies (Torkkeli & Tuominen, 2002). A thorough

documentation of the selection of an automation technology ensures the ability to answer to potentially scepticism in the future (Shehabuddeen et al., 2006).

3.2.1 Justification techniques

There are several justification techniques in the literature with the aim of supporting the process of acquiring automation technology. Techniques are therefore structured in Table 4 to get a better overview of what part of the acquisition process they are guiding. The structure is based on the findings in the former specialisation project prior to this master's thesis, where guidelines were structured by the most important steps in the acquisition process of an appropriate automation technology. These steps were conducted as a result of findings in the literature regarding the most common steps in justification techniques (Bostad, 2015). The division of the steps is (1) to understand the strategy, (2) to get to know the existing production, (3) to search for the technology, and (4) to prioritise the processes. This division is also found in Thomassen et al. (2014) which divides the literature into the main phases strategic, operations, technology, investment and implementation. Even though the guidelines in the former specialisation project are divided in four steps, its last step includes the two last steps addressed in the Thomassen et al. (2014) article. Justification techniques in this thesis will therefore be divided in the same main phases as Thomassen et al. (2014) article, since it gives a good overview of the phases a technique should cover in an acquisition of an automation technology.

The first phase, strategic, includes mainly strategy concerning the manufacturing company. Additionally, some of the techniques consisting of this phase include market and trends, core competencies definition and strategic planning to be considered when acquiring a new technology. The next phase, operations, is where products are analysed upon their characteristics, resources and requirements. The techniques comprising of this phase consider the areas to make sure that a technology is suitable for the operations. The following phase, technology, concerns the selection of an automation technology. However, it is in varying forms where some techniques give more attention to the selection process than others. The phase commonly includes identification of technology alternatives with their performance and characteristics, as well as evaluating their ability to contribute to the process. The next phase, investment, has its focus on the financial areas of a technology. This area is evaluating the economical perspectives, and some techniques use this phase to justify a technology alternative. The last phase, implementation, normally concerns the

installation of technology and the utilisation of it. Additionally, some techniques include this area by developing a plan for the implementation to see if it is manageable.

Justification techniques covering one or multiple phases with the aim of supporting an acquisition process of a new technology in a manufacturing company are presented in Table 4. This table shows which main phases of the acquisition process the techniques cover and how they differ from each other.

Table 4: The main phases covered by the justification techniques in the literature

References	Strategic	Operations	Technology	Investment	Imple-mentation
Baines (2004)	X	X	X		X
Chan et al. (2001)	X	X	X	X	X
Chuang et al. (2009)	X	X	X		
Durrani et al. (1998)	X	X	X		
Efstathiades et al. (2002)	X	X	X	X	X
Farooq and O'Brien (2012)	X		X		
Iakymenko (2014)	X		X	X	
Raafat (2002)				X	
Sambasivarao and Deshmukh (1997)		X		X	
Shehabuddeen et al. (2006)			X		
Thomassen et al. (2014)	X	X	X	X	X
Torkkeli and Tuominen (2002)	X		X		X

The main phase 'technology' contains research articles focusing on the selection process of an acquired automation technology. The choice of technologies that should be supported and promoted within the organisation is covered in the selection process (Kerr et al., 2013). Appropriate techniques for the selection of an acquired automation technology can therefore be found in these articles.

3.2.2 Justification techniques covering the technology phase

The justification techniques considering the technology aspects are presented more thoroughly in Table 5 by listing the name of the techniques, its steps and reference to their scientific articles. The justification techniques consist of multiple steps to guide the decision maker towards an acquisition of an automation technology. The techniques are numbered to easily refer to them in the following text.

Table 5: Justification techniques considering the selection of an automation technology

No.	Name of the technique	Steps in the technique	Reference
1	Manufacturing technology acquisition process	1. Technology profiling 2. Establish requirements of technology 3. Find a technological solution 4. Form outline business case 5. Choose technology source 6. Demonstrate technology 7. Confirm business case 8. Implement technology 9. Post-investment audit	(Baines, 2004)
2	Seven-phase process for the core competence-based technology selection	1. Identification of existing core competencies 2. Establishment of the core competence agenda 3. Identification of alternative technologies 4. Mapping of selection criteria and determination of their importance 5. Assessment of alternative technologies 6. Analysis of results and selection of technology 7. Deployment, protection and defending of core competencies	(Torkkeli & Tuominen, 2002)
3	Automation Project Selection (APROS)	1. Technology strategy 2. Process analysis 3. Technology analysis 4. Technology/process ranking 5. Investment and implementation	(Thomassen et al., 2014)

4	The Technology Acquisition Process	1. Establish market-place requirements 2. Identify technology solutions 3. Classify the technology solutions 4. Assess sources of technology acquisition 5. Make the technology acquisition decision	(Durrani et al., 1998)
5	Technology justification approach	1. Determine if there is a need to perform the strategic evaluation of the technology 2. Perform strategic evaluation of technologies 3. Perform financial evaluation of technologies 4. Carry out risk analysis on the top ranking technology	(Iakymenko, 2014)
6	Justification Methodologies	1. Strategic justification approach 2. Economic justification approach 3. Analytic justification approach	(Chan et al., 2001)
7	Technology selection framework	1. Evaluation of current supply chain 2. Critical supply chain factors on which company plans to complete 3. Planning range/time horizon 4. Identification of manufacturing technologies 5. Detailed assessment of identified technologies 6. Risk assessment of technology alternatives	(Farooq & O'Brien, 2012)
8	Implementation of Advanced Manufacturing Technologies	1. The planning phase 2. The selection, transfer and pre-implementation phase 3. The post implementation phase	(Efstathiades et al., 2002)
9	A method for evaluating and ranking manufacturing system attributes	1. Analyse market evolution and trends 2. Set corporate mission or objectives 3. Determine market requirements, competitive strategies, operational strategies and manufacturing system attributes 4. Determine assessment terms 5. Apply relationship matrix and use linguistic terms to assess and translate 6. Infer relation-weights among market requirements, competitive strategies, operational strategies and manufacturing system attributes	(Chuang et al., 2009)

10	The technology selection framework	1) Requirements filter a) Technical b) Financial c) External pressures 2) Adoption filter a) Integratability b) Usability c) Supplier suitability d) Strategy alignment e) Risk 3) Internal and external factors a) Production function b) Financial function c) Human resource function	(Shehabuddeen et al., 2006)

It is decided to not evaluate all of the techniques addressing the selection of automation technology in depth. The empirical study should only perform a small number of techniques since an execution of a common justification technique is estimated to be time-consuming. Unnecessary use of time in the case company during the case study is not desirable. It is desirable to perform more than one, but not too many techniques. This is because one case company will be used to test the techniques, but at the same time not unnecessarily disturb their daily production and routines. In addition, a more thorough examination could be more easily performed with fewer techniques in the case study. In this way, a broader view of the techniques is achievable. A justification technique has to include a guide in the selection process that actually informs the practitioner of how to select an automation technology (Granlund & Jackson, 2013; Gregory, 1995; Stevenson, 2014). Techniques including such guidance will therefore be chosen for further evaluation in this study. In addition, strategic importance and economic considerations must be included in the chosen techniques since it is necessary considerations when acquiring automation technology. The main interest of this study is to find justification techniques that support the selection of an acquired automation technology. The justification techniques are evaluated based on the techniques' scientific articles. The chosen techniques for further analysing are presented below.

Two out of the ten listed justification techniques in Table 5, number three (3) and ten (10), are found satisfactory for an empirical study. Technique number three (3) guides a selection of an automation technology by visualising the alternatives in a scheme to compare them. The technique is described in multiple steps to support a practitioner in prioritising technology alternatives. In addition, this technique appears to be in line with the already addressed considerations important

when acquiring automation technology, such as strategic importance and economic perspectives. Technique number ten (10) is a framework with the only purpose of selecting one automation technology among multiple alternatives. The technique has composed a framework consisting of filters where decisions should be made based on technical, financial and external pressures. This technique explains the selection process through its filters and utilises a scoring model. In addition, this technique covers the previously addressed consideration, as strategic importance and economic perspectives. These considerations are covered in multiple sub-filters and evaluated from different points of view. The two justification techniques fulfil the criteria for further analysis and it will be interesting to test these techniques in a case study and evaluate them. In addition, the techniques perform the evaluation of technology alternatives with different approaches. In this way, the comparing of the techniques will cover the field of both visualising and calculating methods in the selection of automation technology. This is seen as an advantage to get a wider perspective of the possible approaches towards an acquired automation technology for a manufacturing company.

Technique number five (5) seems to be a combination of the two already mentioned techniques as it uses a scoring model similar to technique number ten and have the same focus areas, from considering the strategic importance to the investment of a technology, similar to technique number three. However, the method is not practiced in the industry and appears to take some shortcuts in the selection process compared to the other two techniques, i.e. not explaining how the scoring model works for a practitioner. This makes the technique insufficient concerning the ability to guide the selection process. In addition, a utilisation of similar techniques in the empirical study is not found reasonable since it is seen as unnecessary use of time.

The rest of the techniques include important areas to evaluate when analysing different technologies, even though some techniques are more supplementary than others. However, it is evident that technique number six (6), seven (7), eight (8) and nine (9) have shortcomings in the selection process area with only a small part of the selection process in their approaches. They do not describe the selection process for a user to adopt their method, which is essential for the aim of this study. In addition, other justification techniques include the same evaluation areas which make these techniques superfluously in the empirical study. Technique number one (1) aims to support project managers and engineers by explaining what, why, how, who, the outcome and risk of each step in an acquisition process, but it fails to explain the important part of how to select the automation technology. This justification technique has a good overview of what to look into, but is not sufficient for the aim of supporting decision makers in a selection process. Technique two

(2) and four (4) only include checkpoints for the criteria in the selection hence exclude any guidance. In addition, technique number two seems to narrow the focus on the core competence and ignoring some of the earlier addressed considerations. Further, technique number four does not include enough strategic importance or economic perspectives to be considered as an applicable technique for appropriate guidance to a decision maker.

The eight justification techniques evaluated to be insufficient for the empirical study will not be included any further in this study. Technique number three and ten explains the selection process of an acquired automation technology in depth and are according to their scientific articles easy to apply. In addition, these techniques appear to be utilising the selection with different approaches, which will be interesting to evaluate among other important elements in a justification technique.

3.2.3 Justification techniques guiding the selection of an automation technology

After an evaluation of the justification techniques including the main phase 'technology', two techniques remain suitable for guiding a selection of an acquired automation technology in a manufacturing company. This decision is based on the techniques' presentation in their scientific articles of how to perform the selection process and whether they fulfil addressed criteria of guiding the selection process and including the necessary considerations in the evaluation of technologies. In addition, evaluation of two techniques will not occupy too much time in a case study. The two justification techniques will be presented in the following sections to become familiar with their approach.

3.2.3.1 Automation Project Selection

The 'Technology selection approach' is also called the 'Automation Project Selection' (APROS) technique, which will be used further in this thesis. The five steps in technique number three (3) aim to appear as self-explanatory and simple to apply. Additionally, it will permit rapid prioritisation of automation initiatives. The technique is based on manufacturing companies desiring to maintain production in a high-cost country like Norway. The steps are presented in Table 6 with their inputs, assessments and decisions, and outputs.

Table 6: Automation Project Selection (Thomassen et al., 2014)

Step	Input	Assessments and Decisions	Output
1. Technology strategy	Business strategy, CSR strategy, Technology trends, Competence	Define manuf. competitive priorities and responsibility objectives, Define innovation position for main technologies	Technology strategy, Areas of interest for automation
2. Process analysis	Manuf. performance and responsibility requirements, Product processing requirements, Bill of manuf. processes	Map processes, Select labour intensive processes, Add candidates based on additional requirements	Manufacturing process candidate
3. Technology analysis	Literature and patents, Conferences, fairs, Expert knowledge, Internal documents and workshops	Identify alternative technologies, Assess technology maturity and performance, Select technologies for each candidate process	Technology/process combinations
4. Technology/ process ranking	Accumulated input from step 1-3	Assess strategic importance, Assess ease of implementation, Select project candidates based on strategic impact and ease of implementation	Ranked technology projects
5. Investment and implementation	Sales forecasts, Acquisition costs, Operating cost, Supplier quotations	Analyse investments, Assess suppliers, Assess competence requirements, Select projects and plan implementation	Time phased technology implementation plan

This technique is intended for the decision maker to understand the important areas to consider, from considering the strategic importance to visualising the product volume an automation

technology has to include. Since the steps start from the beginning of the whole acquisition process with the technology strategy to the investment and implementation, it can benefit the executer to make sure that all necessary information is covered in the steps prior to the selection of an acquired automation technology. The scientific article explaining the technique is additionally providing an example for the selection process. This can hopefully make it easier for the practitioner to understand both the method and the intention of each step. This technique is also evaluated to fit any desired type of manufacturing plant since it is not particularly specified which automation technology it is best suited for. The receptiveness in the steps will make the guiding adjustable for the specific requirement in any production desired to acquire automation technology.

It is important to be able to apply the same technique on different production processes. The practitioner will be more competent and familiar with the technique and time can be reduced. However, that the process can fail to cover important facts or areas, and that the practitioners can find the technique complicated, time consuming or insufficient, is of concern. The technique performs a selection three times based on seven criteria, while the other techniques have multiple criteria to look into. It is interesting to investigate whether technique number three (3) has enough evaluation areas and at the same time is easy to use, or if it fails to cover enough areas in the selection process. The research article has already received good feedback from two case companies, but perceive that further development and testing is needed to make the methodology more consistent. An execution of this justification technique in the case study will therefore fulfil this request.

3.2.3.2 The technology selection framework

Technique number ten (10), 'The technology selection framework', is a framework composed after it was revealed that there was a need for a technology selection tool in the industry. The framework concerns only the selection process and contains a detailed description of it. This allows the decision to be traced back and kept transparent. The aim is to give the practitioner the ability to select the most proper automation technology for a production process. The framework is presented in Figure 4 and followed by an explanation of the so-called filters, sub-filters and evaluation areas.

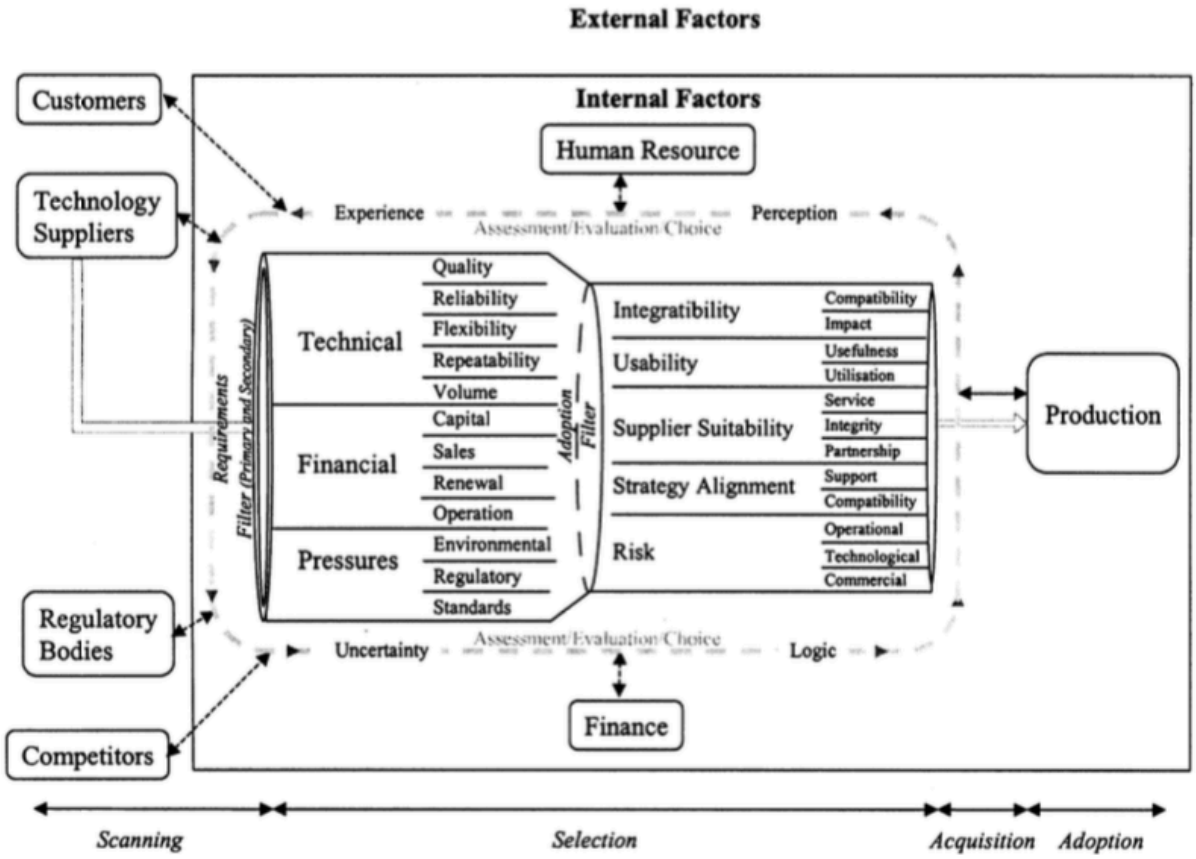


Figure 4: 'The technology selection framework' (Shehabuddeen et al., 2006)

The key elements in the framework are factors concerning technology selection decisions, concept of filtration, process view of technology selection and relevant processes, as well as systems view of internal and external agents. The technique utilises a scoring model, which forces the practitioner to reflect on each so-called sub-filter. The sub-filters contain the most important areas to include in the selection and support the process by guiding the decision maker in a direct and clear evaluation path. These sub-filters include areas important to consider. Additionally, the process consists of a practical decision making process and illuminate the role of experience, perception, logic and uncertainty in the choice of technology. The framework aims to give the practitioner confidence in the process and the weighting of different areas in the technology alternatives.

The justification technique evaluates the technology alternatives from suppliers by utilising a scoring model consisting of two filters, as illustrated in Figure 5. The evaluation areas in the first filter, requirement filter, are within technical, financial and external pressures. The technical sub-filter evaluates the quality, reliability, flexibility, repeatability and volume, the financial sub-filter evaluates the capital, sales, renewal and operation, and the external pressures sub-filter evaluates

the environmental, regulatory and standard areas. After evaluating the sub-filters, the score decides which technology alternative to be included in the next filter. The scoring model is demonstrated in Figure 6 to explain how the weighting of the sub-filters importance impact on the score. If the importance of an evaluation area is weighted high, its score will have a big impact, and vice versa.

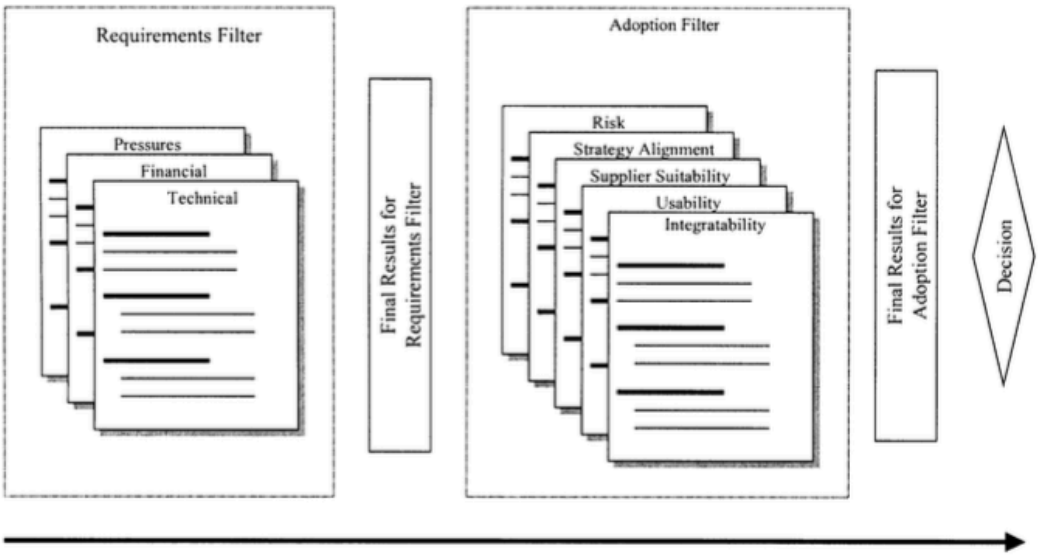


Figure 5: Illustration of the two filters in 'The technology selection framework' (Shehabuddeen et al., 2006)

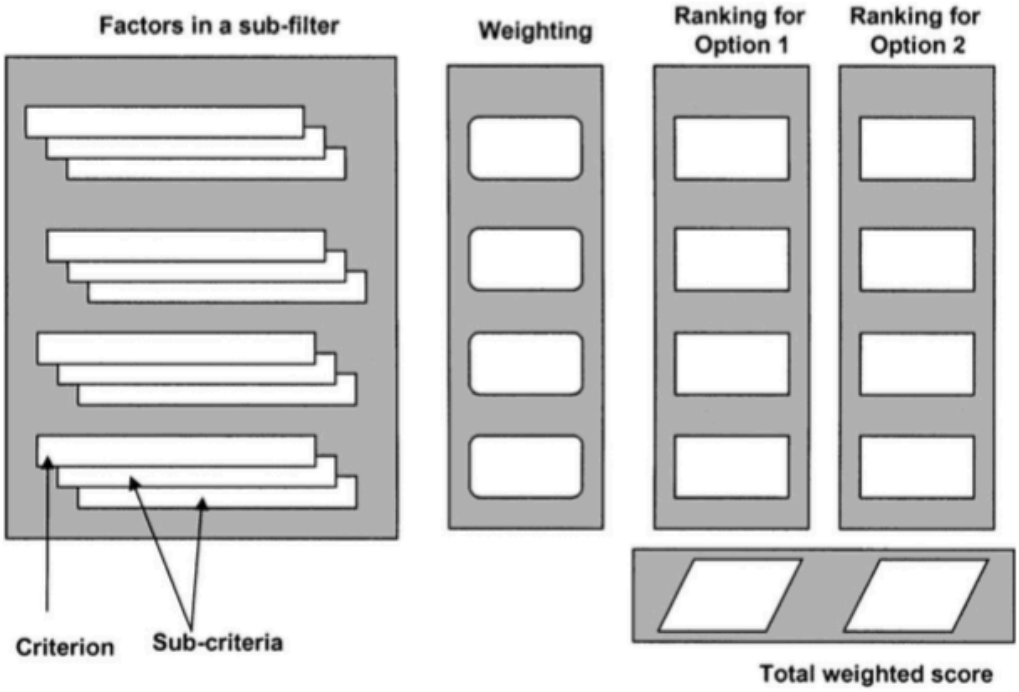


Figure 6: Demonstration of the scoring model in 'The technology selection framework' (Shehabuddeen et al., 2006)

The next filter, adoption filter, is within integratability, usability, supplier sustainability, strategy alignment and risk. The integratability sub-filter evaluates the compatibility and impact, the usability sub-filter evaluates usefulness and utilisation, the supplier sustainability sub-filter evaluates service, integrity and partnership, the strategy alignment sub-filter evaluates the support and compatibility, and the risk sub-filter evaluates the operational, technological and commercial areas. The score decides which automation technology to acquire to the production process, as seen in the framework in Figure 4.

The internal and external business agents are factors influencing the assessment and evaluation choices. The internal agents are production, finance and human resource function, while the external agents are customers, technology suppliers, competitors and regulatory bodies.

The advantage of testing this technique is to reveal whether the practitioner experience the framework to be time consuming, understandable or if it covers the necessary aspects in the selection process. The framework is comprehensive and can be difficult to manner for the practitioner and at the same time to take advantage of the fully potential of it. The scientific article aims to support the general industry in the company's execution of selecting an automation technology, which makes it suitable for multiple production types. The article claims that the framework is articulation, elaboration and extension of existing concept that additionally links the conceptual idea from the framework to the practical situation.

The justification techniques seem to give the selection process a good support with the guidance in forms of visualisation or scoring model. Their difference is the selection approach and the overall focus areas in the techniques. Both techniques seem to include the most important areas to look into, but technique number ten appears more thorough in evaluation than technique number three. The justification techniques APROS, referred to as technique number three (3), and 'The technology selection framework', referred to as technique number ten (10), will be tested in a case study to be able to compare the technique in relation to a company with processes that are challenging to automate. The interesting outcome will be the techniques' usability and if the focus areas and outcomes are the desired ones from a practical point of view in addition to several important elements a supportive justification technique should fulfil.

3.2.4 Important elements in a justification technique

Important elements in a justification technique guiding the selection process will further be addressed. Techniques consisting of several following elements are considered to be highly supportive in the selection process.

For a justification technique to be supportive in an acquisition of automation technology, it has to be applicable and well explained (Baines, 2004; Durrani et al., 1998; Farooq & O'Brien, 2012; Thomassen et al., 2014). Such technique will be easy to follow and prevent unnecessary use of time or expertise. Effective techniques will reduce the time and work load for a practitioner (Farooq & O'Brien, 2012; Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006; Thomassen et al., 2014; Torkkeli & Tuominen, 2002). Additionally, production processes with specific challenges will benefit justification techniques with the possibility of modifying evaluation areas (Shehabuddeen et al., 2006; Torkkeli & Tuominen, 2002).

Justification techniques should evaluate important areas when acquiring automation technology (Chan et al., 2001; Granlund & Jackson, 2013; Gregory, 1995; Suresh & Meredith, 1985). The important areas can vary in the different techniques, which depends on the techniques' aim of support. However, it is essential that a technique contributes with enough support in the acquisition process (Torkkeli & Tuominen, 2002), as well as evaluating the necessary area for the particular process (Baines, 2004; Durrani et al., 1998; Säfsten et al., 2007; Torkkeli & Tuominen, 2002).

Justification techniques can include one or multiple parts of the acquisition process (Baines, 2004; Durrani et al., 1998; Shehabuddeen et al., 2006; Thomassen et al., 2014). The techniques are focusing on the acquisition process differently, i.e. only the selection part of the process, or multiple parts from establishing a strategy to the implementation of the automation technology. Likewise, techniques utilise different models to justify the decisions, i.e. visualisation or scoring models. Axes representing considerations, as practiced in the research articles Durrani et al. (1998) and Thomassen et al. (2014), are established for evaluating the technology and placing the results relative to each other in a so-called visualisation model. Such model uses drawing and excludes numbers in the documentation. On the other hand, the scoring model evaluates technologies by calculating a score on multiple areas in them (Suresh & Meredith, 1985), often used to assess strategic characteristics of technologies (Iakymenko, 2014). However, the amount of work utilising the model may lead to not achieving accuracy in each case (Lowe, Ridgway, & Atkinson, 2000).

Nevertheless, this score contributes to selecting an acquired automation technology, as described in the research articles Chuang et al. (2009), Iakymenko (2014) and Shehabuddeen et al. (2006). Documentation types as visualisation and scoring models develop a company specific process model for important decisions in manufacturing companies (Granlund & Jackson, 2013).

Decisions regarding automation technology in the industry have a tendency of not following any formal structure (Durrani et al., 1998; Granlund & Jackson, 2013; Lindström & Winroth, 2010; Shehabuddeen et al., 2006), and that the decisions is based on instincts (Shehabuddeen et al., 2006). A justification technique can ensure that the acquisition process is unaffected by personal feelings and rather selecting the best documented automation technology (Chan et al., 2001; Granlund & Jackson, 2013; Gregory, 1995; Suresh & Meredith, 1985).

Chan et al. (2001) classifies justification techniques into three groups; strategic, economic or analytic approach, which can be used separately or combined. Strategic and economic approaches are a common combination. The strategic approach has direct connection to the goals of the firm and the possibility of overlooking the economical and tactical impacts is covered by the economic approach (Chan et al., 2001; Karsak & Tolga, 2001; Ordoobadi & Mulvaney, 2001). The strategic approach involves analysis of competitive advantages, business objectives, research and development, and technical importance (Chan et al., 2001; Small & Chen, 1997). The economic approach is based on an evaluation of the economic aspects and can contribute to the final decision of choosing an automation technology (Chan et al., 2001; Durrani et al., 1998; Granlund & Jackson, 2013; Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006; Small & Chen, 1997; Suresh & Meredith, 1985; Säfsten et al., 2007; Thomassen et al., 2014). The use of strategic and economic approach attains higher levels of success in automation technology projects than the cases using only one of the approaches (Small & Chen, 1997). In addition, experience shows that this combination of the approaches is thorough and simple to use (Chan et al., 2001; Small & Chen, 1997).

It should be possible to be guided through the choice between different types of automation technologies and prioritise them relative to each other, since the selection is usually between different technologies. Prioritisation and focus on the most important aspects among the alternatives are an important part of the selection process (Baines, 2004; Durrani et al., 1998; Iakymenko, 2014; Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006; Thomassen et al., 2014; Torkkeli & Tuominen, 2002).

Important elements a justification technique should consist of are presented in Table 7. The elements are categorised as 'ease of performance', 'covers the necessary areas' and 'type of approach'. Techniques covering several of these elements is considered highly supportive for a selection process. In addition, the table shows which reference supporting the importance of the elements. These elements are used to evaluate the justification techniques performed in the empirical study.

3.3 Chapter summary

The importance of automation technology and the necessity for justifying the acquisition of it was explained in this chapter. Further, the techniques covering the selection process in their approach is evaluated whether to including or excluding a guidance of the selection process. After the evaluation, the two justification techniques APROS and 'The technology selection framework' were evaluated to be explaining the selection process thoroughly. These techniques are therefore explained in depth. In addition, the justification techniques should include important elements to be supportive in a selection process, which are presented in a table for the evaluation of the techniques in the empirical study.

Table 7: Important elements in a justification technique

Important elements	References
Ease of performance	
Effective in execution	(Farooq & O'Brien, 2012; Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006; Thomassen et al., 2014; Torkkeli & Tuominen, 2002)
Applicable	(Baines, 2004; Durrani et al., 1998; Farooq & O'Brien, 2012; Thomassen et al., 2014)
Well explained	(Baines, 2004; Durrani et al., 1998; Farooq & O'Brien, 2012; Thomassen et al., 2014)
Covers the necessary areas	
Include the important areas	(Chan et al., 2001; Granlund & Jackson, 2013; Gregory, 1995; Suresh & Meredith, 1985)
Ability to evaluate distinctive areas for the process	(Baines, 2004; Durrani et al., 1998; Shehabuddeen et al., 2006; Säfsten et al., 2007; Torkkeli & Tuominen, 2002)
Guides the selection part of the acquisition process	(Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006)
Guides multiple parts of the acquisition process	(Baines, 2004; Durrani et al., 1998; Farooq & O'Brien, 2012; Thomassen et al., 2014)
Exclude the practitioner's gut feeling	(Chan et al., 2001; Granlund & Jackson, 2013; Gregory, 1995; Shehabuddeen et al., 2006; Suresh & Meredith, 1985)
Type of approach	
Combine strategic and economic approach	(Chan et al., 2001; Small & Chen, 1997)
Prioritise technology alternatives	(Baines, 2004; Durrani et al., 1998; Iakymenko, 2014; Sambasivarao & Deshmukh, 1997; Shehabuddeen et al., 2006; Thomassen et al., 2014; Torkkeli & Tuominen, 2002)
Evaluate with a visualising model	(Durrani et al., 1998; Granlund & Jackson, 2013; Thomassen et al., 2014)
Evaluate with a scoring model	(Granlund & Jackson, 2013; Iakymenko, 2014; Shehabuddeen et al., 2006; Suresh & Meredith, 1985)

4 Empirical study

This chapter presents the empirical study of the master's thesis. A case study is conducted through interviews, workshop and mail correspondence with a case company. This chapter will present the case company and the execution of the workshop. A summary concludes the chapter.

4.1 Case company

This thesis will include the manufacturing company Nammo Raufoss AS from the Norwegian industry as the case company to execute an empiric analysis. This company is a part of the NAP-project and fits the scope of this thesis.

The case company is headquartered at Raufoss in Norway with 650 employees. Nammo is a technology-driven aerospace and defence group founded in 1998, but the production of ammunition at Raufoss started already in 1896 (Nammo, 2014). Because of this, the company has a long experience and good knowledge within their field of production. The production in Nammo is managed by the order fulfilment Make-To-Order with incoming orders approximately 1 year before the delivery date. This type of order fulfilment uses a standard design for the products, but the production of the final product is linked to the final customer's specifications (Stevenson, 2014). An order can include between one and one hundred thousand pieces. The current production line to be addressed in this case description is supposed to cover multiple products similar to each other. This will entail the possibility to change the equipment with minimal changeover time and to suitable equipment for the different types of products.

The case company's anticipation in the NAP-project includes a desire for automating their manual processes to gain a fully automated production line. The specific production line is located in the department of Medium and Large Caliber Division of Ammunition where employees currently perform parts of the production processes manually. The aim is to fully automate this production line to ensure satisfactory flow, higher flexibility and quality, and reduced necessity for manual handling of components. Nammo has good knowledge and routines for safety in the production area and a fully automated production line can increase the safety of handling explosives even more.

4.1.1 Desiring automation technology in the production

Automation project of the whole medium caliber ammunition production line started with an idea of automating the assembly process to increase the efficiency and reduce costs. Automation technology usually implemented in the production has typically included one or two functions, which has led to a production with both automated and manually performed processes, so-called semi-automated processes. This combination is not optimal for the safety of the employees and the efficiency in the production, which has led to a desire of acquiring a fully automated production line. A fully automated production line can be accomplished by acquiring new technical and organisational production systems. A reduction of human involvement in handling explosives is a top priority, which would increase the overall safety. In addition, a fully automated production line will improve the handling system by locating all of the processes under the same roof. This will lead to an improvement of the production time and reduction of the production costs. A collection of the overall reasons for the case company to desire a fully automated production line is presented in Table 8.

Table 8: Case company reasons for acquiring automation technology

Improvement area	Reason
Economy	• Reducing the costs since there is a desire for a reduction of working years
Product	• Increase the product quality by making the process more accurate, i.e. having a more suitable environment of type of building and ventilation
Handling	• Reduce intern transport by collecting the whole production line in one building • Reduce the changeover time between the production of different products
Human	• Increase the overall safety for handling explosives • Reduce the existence of unchallenging assignments for the employees • Less handling of products by humans to reduce personal injure • Make Nammo to an attractive work place in the future, since Nammo believes that future employees would want to perform more challenging assignments
Market	• A desire to expand the distance to their competitions even more

4.1.2 Previous experience with automation technology

The current production line is semi-automated with custom made automation technology to suit the production of the products. The production processes need to be highly secure because of the danger in handling explosives. This gives the process of acquiring automation technology additional challenges as the production will need special technology to fulfil the requirements.

Previous experience with acquiring automation technology is with automation technologies performed in a smaller scale with fewer process steps. This has resulted in semi-automated processes, which is a classification of the LoA. Nammo usually request tenders from relevant suppliers to involve them in the development of a new automated process. The suppliers will then present their alternative suggestion for how to solve the tasks with automation technology. Guidelines for selecting a supplier does not currently exist and the supplier appearing to present the most promising solution is usually chosen. They do not follow any written guidelines or steps for these decisions. An important part for Nammo in the process is to obtain the suppliers' automation solutions before sharing their own opinions. This is to not limit the views on a possible solution before acquiring and investing in automation technology. Then, Nammo has usually close collaboration with the chosen supplier to be able to contribute with all of their knowledge to get an optimal solution in the end. The tender from the supplier is usually not the one they end up with and it is usually presented several tenders from the same supplier because of adjustments requested by Nammo. Nammo bases its opinions on previous experiences from other automation technologies or restrictions related to the type of products.

The project manager and process engineer in the automation project in Nammo have earlier experience acquiring automation technology. However, they have experienced that suppliers often believe it is easier to implement the technology than it is in the reality, so it is important to expect some start-up problems. In addition, they confirm that it is important to have proper tools and competent employees when acquiring automation technology since it is time consuming and entails large investments. Their experience indicates that neglecting some areas in the evaluation can lead to absence of valuable information.

4.1.3 Processes in focus

The planned production line to be transformed into fully automated production line consists of stamping tracer and explosives, assembly, marking and packing as shown in Figure 7. A mapping of the processes, executed by the case company, has shown how automated each process are and that the assembly process in the production line seems to be the most challenging to automate. However, the assembly process appears as a mature process for being automated since the process requires automation technology to apply fluent additives and controlling the process. Additionally, the technology must be able to claw the parts and assembly them. The desire for automating the assembly process is based on the same arguments as the rest of the production line, as well as the risk related to the employees handling the explosives in the process.

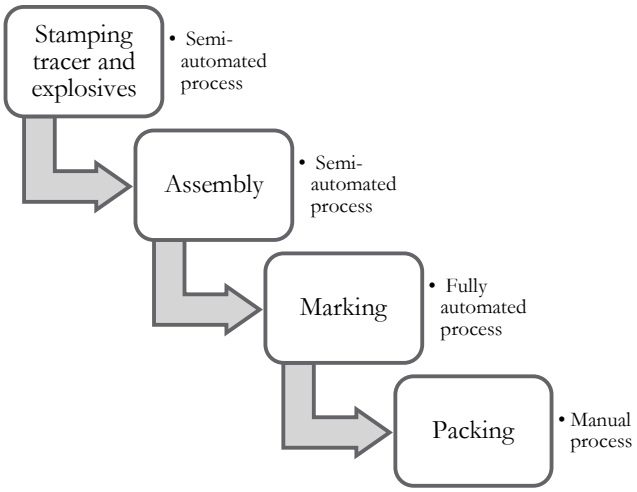


Figure 7: The processes in the current production line of medium caliber of ammunition

4.1.4 The biggest challenge of automating the processes

Since Nammo's production processes handle explosives, the employees' safety is the highest priority. Additionally, unstable processes are difficult to reveal which give varying product qualities. Such problems can be visible when the processes are transformed from manual to automated ones. The company's experience from previous acquisition of automation technology has shown that the problems in a production process appears when the automation technology is installed as the human brain no longer controls or adjust the process. In addition, the process applying fluent additives on the product will require a new type of automation technology than what Nammo is familiar with in the current production line. However, the acquisition of an automation technology

is not impossible to perform, but would benefit some guidance to ensure the decision maker that the most important aspects are taken into account in the selection of which automation technology to acquire.

4.1.5 Performed work prior to the master's thesis involvement

The desire of acquiring automation technology started with a strategy for improving the manufacturing systems in Medium and Large Caliber Division of Ammunition at Nammo Raufoss, as already explained in the beginning of this chapter. All of the processes intended for the new production line was analysed and well documented to establish a solid platform for further development. Nammo contacted three suppliers to receive tenders on potential automation technology to acquire for the assembly process. Some of the suppliers had a meeting with Nammo and some of them called frequently to collect the necessary information to give a proper automation technology tender. The suppliers did not receive any documentation of the processes due to process confidentiality, but this will be shared when the chosen supplier is clarified and the contract is signed. The milestones for the automation project of the assembly process are presented in Table 9. The assembly process is the first priority since the process is the most challenging and the equipment must be brand new to be able to manage the volume. Then the rest of the processes in the production line will go through the same procedure to accomplish a fully automated production line. The milestones listed are the ones concerning the assembly process.

Table 9: Milestones in the automation project for the assembly process in the case company

Date	Activity
12. 2015	Project start in the production department
01. 2016	Suppliers asked to send a tender with technology to the assembly process
02. 2016	Meetings held with potential suppliers for the assembly process
03. 2016	Tenders received from suppliers on the assembly process
04. 2016	Supplier selected for an automation technology in the assembly process
06. 2016	Order is placed for the selected automation technology on the assembly process
05. 2017	Automation technology for the assembly process is implemented
07.2019	The production line is fully automated in the manufacturing company

4.2 Case study

A case study is conducted in the case company to test the two justification techniques, APROS and 'The technology selection framework', addressed in Section 3.2.3. The case company had received tenders from three suppliers in advance of the workshop. The suppliers had both similar and different solutions to the automation of the processes, which gave the case company a good assortment in the evaluation to search for the best technology alternative. The documentation and explanation of the workshop will not focus on the content of these tenders, but on the outcomes of utilising the two techniques tested. The aim of this workshop is to evaluate the justification techniques' ability to support the selection of an automation technology in a manufacturing plant with challenging processes to automate. The acquisition and justification of automation technology can benefit from a thorough guidance of the process by following a justification technique, as earlier addressed in Chapter 3. A thorough guidance can give the decision maker necessary confidence during the selection process.

The case study has focused on the process of assembling the products since the case company already has chosen to fully automate it and received tenders from suppliers. These tenders contain multiple technologies to evaluate, and three parts of the assembly process is evaluated by the two justification techniques. The covered parts of the process are technology for intern transport, input, and glue application and control.

The two justification techniques carried out in the case company will further be explained and evaluated in two separate sections. The document guiding the workshop with the results are presented in Appendix D, which was followed during the case study.

4.2.1 Automation Project Selection

The first justification technique tested in the case company is the one explained in the research article 'A strategic approach for automation technology initiatives selection' by Thomassen et al. (2014). This technique guides the user from the establishment of the technology strategy to investment and implementation of the technology. The justification technique is divided into five steps, as seen in Section 3.2.3.1, where the first two steps explains the preparation for the selection

of automation technology, whilst the next three steps deal with the main selection of technology candidates.

4.2.1.1 Step 1 and 2 – Technology strategy and process analysis

The practitioner started to check that step one (1) and two (2) were fulfilled to continue the process of selecting an acquired automation technology. The steps seemed to be covered from the mapping of requirement and processes, already performed upon this stage, since the practitioner could answer all of the questions and perspectives in the technique. Nammo had also made strategic considerations by desiring to further expand the distance in the market to their competitions. The practitioner felt confident of perceiving to the next step in the justification technique, which was allowed since the two first step were not in focus during this case study.

4.2.1.2 Step 3 – Technology analysis

The practitioner followed the guidance in step three (3) and filled out the mapping of technology analysis in the two-dimension chart, as showed in Appendix E. Three alternatives were evaluated for each technology. Since it was three technologies, the two-dimension charts were filled out three times. The practitioner started to evaluate each technology alternative in relation to technology performance, technology maturity and required level of adaption. The practitioner had got to know the tenders from the suppliers in advance of the workshop and had experiences with automation technology from previous projects. After deciding where the technology should be placed in the chart, the technology was drawn in a size to visualise the volume of products the technology could process. A completed scheme from the workshop is given as an example of the execution in Figure 8, which is the input process. After executing the first chart, the next two concerning the other parts of the assembly process was performed more effectively. The practitioner experienced in some cases that the evaluation of the alternatives was quite different or very similar, as well as changing one's mind after evaluating them for a while. The results were varying and the technology alternatives were either included or reduced to two for the next step. The practitioner experienced the step to be lucid and easy to understand, and felt ready to go further to the next step after ensuring that all of the circles were placed correctly in the charts and with the right size relative to each other.

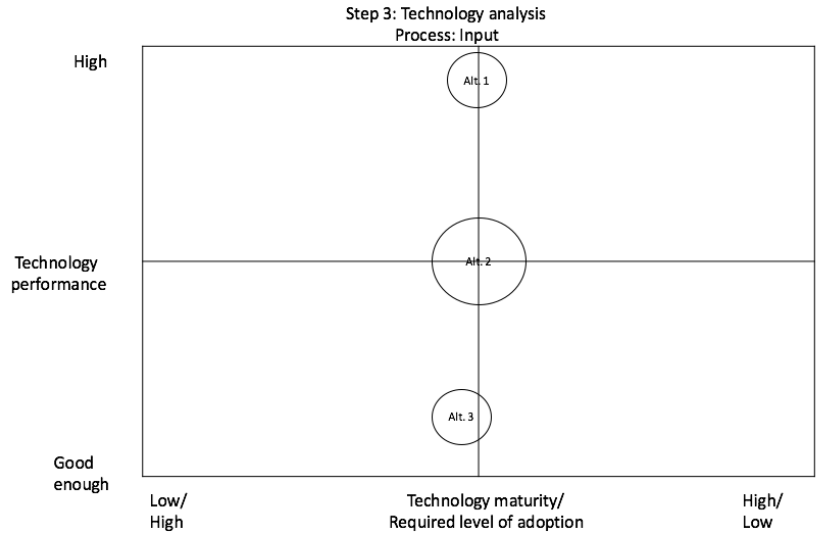


Figure 8: Step 3 in the APROS technique

4.2.1.3 Step 4 – Technology/process ranking

Step four (4) was executed quite similar to the previous step, but this time the evaluation of the technology alternatives was to the ease of implementation, strategic importance and the volume of products it could include. Two technologies had only two alternatives left from the previous step. The practitioner experienced a continuation of the differences between the alternatives, but also a total switch of the alternative's ranking from the previous step. This experience proved that both step three and four were important steps to consider, and that all of the evaluation areas were important to consider in the selection process. The size of the circles played a big part of the final decision, which indicated the volume of products possible to process with the technology. A completed scheme from the workshop is given as an example of the execution in Figure 9, which is the input process. Even though the practitioner had evaluated the alternatives and placed them relative to each other, the final choice was perceived quite open since the practitioner still could make the final decision by weighting size and position of the circles against each other.

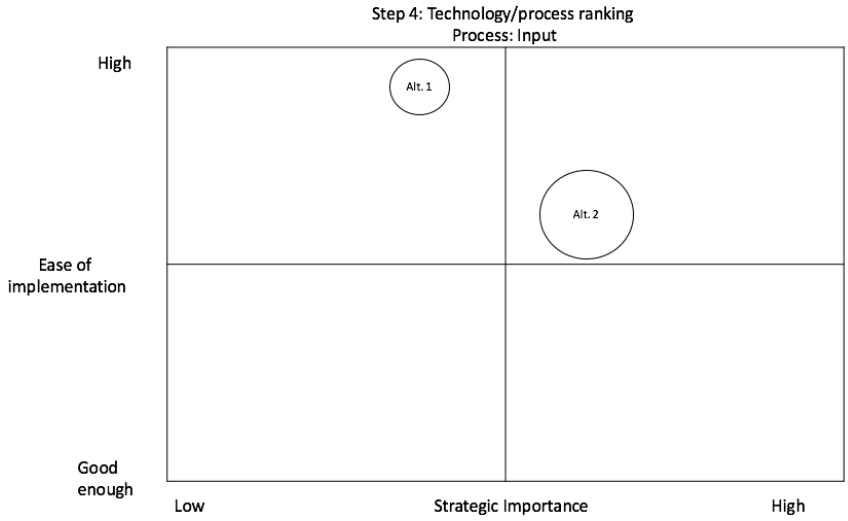


Figure 9: Step 4 in the APROS technique

4.2.1.4 Step 5 – Investment and implementation

The final step in the justification technique, step five (5), focused on the investment and implementation and was performed on the alternatives remaining after the previous step. The evaluation included all the practitioner's knowledge within the alternatives. The implementation of each alternative was evaluated to be almost similar to each other. This evaluation was based on the practitioner's previous experience with automation technology, and the understanding of how complicated and time-consuming any implementation of a technology in a production line can be. The investment perspective made the final decision for what technology alternative to implement in the production line. This applied to all of the processes evaluated with this justification technique, which proved that the economical perspective plays the most significant role in the end.

4.2.1.5 Evaluation of the justification technique performed in the case company

The practitioner experienced this justification technique as easy to understand and apply in the selection process of an acquired automation technology. The visualisation of the results made it easier to compare the results of each step, which made it even easier to evaluate them. The justification technique was efficient and feasible to manage. The practitioner experienced that the evaluation areas included multiple aspects, but missed an evaluation area including the experience and reputation of the suppliers offering the technologies. This aspect can influence the evaluation if the company has any experience with the supplier from earlier projects. The practitioner admitted to rating a technology lower if it was any uncertainty linked to the technology, which is

unfavourable since the technology could be a satisfactory candidate even if the supplier had presented it poorly. However, the technique was experienced to covered the specific challenge in the production process in the evaluation during the steps. It is important to cover the most challenging area for a specific production in a selection process, and the justification technique is evaluated to be a good support for the practitioner. The highest benefit was the visualisation of the results, which occasionally surprised the practitioner when comparing the technologies against each other.

4.2.2 The technology selection framework

The second justification technique tested in the case company was the one explained in the research article 'From theory to practice: challenges in operationalizing a technology selection framework' by Shehabuddeen et al. (2006). This technique focuses on the assignment of selecting an automation technology and consists of two filters with multiple sub-filters. The filters support the practitioner in evaluating each area according to its importance for the company, and the score of the technology alternatives in that category. The figure presenting 'The technology selection framework' seemed complicated and time consuming to the practitioner. However, the practitioner willingly tested the justification technique on the same technology alternatives evaluated with the first technique as explained in Section 4.2.1.

4.2.2.1 Requirements filter

As already shown in Section 3.2.3.2, this justification technique uses a scoring model, which can be filled out in the program Microsoft Excel as utilized in this case study, or similar programs. The first filter made the practitioner to weight the importance between the sub-filters Technology, Financial and Pressures. These sub-filters covered the areas; quality, reliability, flexibility, repeatability, volume, capital, sales, renewal, operation, environmental, regulatory and standards. This was the hardest evaluation for the practitioner since it also involved giving less priority to some of the evaluation areas. However, the aim was understandable and the practitioner performed the evaluation. Subsequently, each technology alternative was evaluated and it was given a score to each evaluation area connected to the technology alternatives. A filled requirement filter in the scoring model from the workshop is presented as an example in Figure 10, which is the input process. The technologies got a total score between one to ten on each evaluation area, where the

highest number indicated the best alternative. The practitioner experienced the alternatives to get a relative close score and chose to bring multiple alternatives to the next filter.

Filter consisting	Weighting %	Alternative 1	Alternative 2	Alternative 3
Technology				
Quality	20	8	8	8
Reliability	12	8	6	8
Flexibility	10	3	10	3
Repeatability	15	8	8	8
Volum	8	3	9	5
Financial				
Capital	8	3	5	7
Sales	5	8	8	8
Renewal	3	2	4	5
Operation	10	7	5	2
Pressures				
Environmental	3	5	5	5
Regulatory	3	5	5	5
Standards	3	5	5	5
Total score	100	6,15	7,11	6,22

Figure 10: Requirements filter in 'The technology selection framework'

4.2.2.2 Adoption filter

The second filter was further applied on the alternatives with the higher score in the previous filter. The second filter was decomposed into the sub-filters; integratability, usability, supplier suitability, strategy alignment and risk. These sub-filters were evaluated against each other on importance and the technology alternatives was evaluated within each sub-filter. A filled adoption filter in the scoring model from the workshop is presented as an example in Figure 11, which is the input process. The sub-filters had underlying areas as the previous filter to be guided even more. As mentioned in Section 3.2.3.2, the integratability sub-filter evaluates the compatibility and impact, the usability sub-filter evaluates usefulness and utilisation, the supplier sustainability sub-filter evaluates service, integrity and partnership, the strategy alignment sub-filter evaluates the support and compatibility, and the risk sub-filter evaluates the operational, technological and commercial areas. However, the evaluation areas are only mentioned in Figure 4 earlier presented in Section 3.2.3.2 and nowhere else in the scientific article. Therefore, it is possible to interpret the adoption filter in different ways since these areas are not thoroughly explained to be included in the scoring model. Since the justification technique appears as time-consuming due to a large number of evaluation areas, this filter was restricted to evaluating the superior sub-filters. In this way, the execution of the technique is more applicable for the practitioner in the case company.

The distribution of the hundred percentage of importance was given to the sub-filters, and not to the evaluation areas. The evaluation areas were instead explained verbally to the practitioner, as seen in Appendix D. The practitioner understood each sub-filter for the evaluation, but experienced to give the sub-filters connected to uncertainty or with a lack of information a mid-score. These parts could have been a limitation for the results if the score constituted the main excursion, but after looking closer at the impact of the uncertainty it became clear that the deviation was minimal on the final results. The explanation could be that the sub-filter seemed less important for the case company and that the suppliers had perceived this and given it less attention in their tenders. This could also mean that the weighting of the sub-filter with uncertainty was too low to have an impact compared to the others.

Filter consisting	Weighting %	Alternative 1	Alternative 2	Alternative 3
Integrability	35	8	7	8
Usability	30	7	6	5
Supplier sustainability	10	7	5	7
Strategy alignment	10	5	5	5
Risk	15	5	3	6
Total score	100	6,1	5,7	6,4

Figure 11: Adoption filter in 'The technology selection framework'

4.2.2.3 Internal and external business agents

The internal and external business agents were enlightened to be production function, finance function, human resource function, customers, technology suppliers, competitors and regulatory bodies. The practitioner did not understand how to include these agents, but acknowledged these agents in the evaluation of the areas in the filters.

4.2.2.4 Evaluation of the justification technique performed in the case company

This justification technique was easier to use than expected and the practitioner did not have any problems of giving the technology alternatives a score in each sub-filter. The practitioner believed this technique included the most important areas, made the process easier by following the approach and ensured the practitioner that the technology alternatives got thoroughly evaluated. The technique covered the specific challenge when acquiring automation technology in the case company with the evaluation of multiple sub-filters. The safety aspect was included when

evaluating reliability and standards in the first filter, the usability and risk in the second filter, as well as the product function and human resource function as business agents.

The practitioner experienced weighting the evaluation areas in the filters difficult since the hundred percentage had to be distributed between areas where all of them seemed to be important. The practitioner used some time on this part and ensured a solid foundation for the rest of the evaluation process. The second filter was shortened to performed the technique faster than performing the originally evaluation areas during the case study. The second filter was only listing the sub-filters and not their underlying areas, as in the first filter. However, the underlying areas connected to the sub-filters were verbally included in the evaluation before setting the score. The deviation is evaluated to have minimal influence on the results choosing the alternatives, but rather point to the possibility for interpretation of the scientific article.

The alternatives received close score in each filter, often not more than 1 point in difference. In addition, the meaning of the score was not enlightened in the technique description and the practitioner experienced insecurity of the evaluation of each alternative. The score only indicated the rating of the alternatives compare to each other and the score could be interpreted as the practitioner desired. However, this made it more challenging for the practitioner to decide which technology alternatives to bring to the next filter if the score only separated with 0.3 points. Additionally, the scoring model did not give the practitioner any possibilities to adjust the results or evaluate them to a result suitable for the practitioner's instinct. The weighting of importance of each sub-filter was time consuming and the practitioner found it difficult. However, this foundation made it easier for the selection process that followed. The justification technique made the practitioner more confident in the selection process.

4.3 Chapter summary

The empirical study describes the case company and highlights its processes and previous experience with automation technology. The company has an ongoing process of acquiring technology to accomplish a fully automated production line. Further, the workshop utilises justification techniques evaluated to guide the selection process, which was the outcome in the literature review chapter. The practitioner's experience with the techniques during the workshop is described and the findings will be discussed in the next chapter.

5 Empirical findings and discussion

The case study executed in the case company and explained in Section 4.2 brought important data for evaluation. Two justification techniques will be discussed upon each other and experiences from the performed workshop will be shared. The justification techniques will further be referred to as the first and second technique after which order they were performed in the workshop. A summary concludes the chapter.

5.1 Results from the performed justification techniques

Three automation technology tenders received from three different suppliers were evaluated with the two justification techniques in the case study. The first tender, technology alternative 1, consists of robots processing and transferring one product at time between the stations. The second tender, technology alternative 2, consists of transporting pallets with multiple products. In addition, the input is handled by a robot and navigated with a camera solution. The last tender evaluated, technology alternative 3, consists of an input with a blister and transports multiple products with pallets. The practitioner picked out three parts of the assembly process for evaluation, which were the three most important parts in the assembly process to be supported by the justification techniques. The final results are presented in Table 10 and will be further explained in the following text. In addition, these results can be studied in more detail in Appendix D, E and F.

Table 10: The results of the case study performing the justification techniques

Part of the process	Selected alternative in the first technique	Selected alternative in the second technique
Intern transport	Technology alternative 1	Technology alternative 3
Input	Technology alternative 2	Technology alternative 3
Glue application and control	Technology alternative 1	Technology alternative 3

The results from the executed justification techniques seem completely different by the first glance at the table. A closer look at the documentation makes the results less different and more understandable. It is important to be aware of that the three technology alternatives were very close

to each other in the ratings in both techniques. In addition to the following explanation, the schemes from the execution of the first technique can be found in Appendix E and the filled scoring model from execution of the second technique can be found in Appendix F. These results will be discussed further.

The first process evaluated was the handling of intern transport. In the first technique, all three alternatives were brought to the fourth step and the easiness of implementation gave alternative 2 and 3 a much higher score than alternative 1. This is presented in Figure 12 showing step 3 and 4 in the technique. Alternative 2 and 3 were given an equal score for this process. However, alternative 1 had a bigger circle and was preferable in step 5, as a result of the investment perspective. Alternative 1 was chosen even though the scheme could indicate that alternative 2 or 3 should be selected. The technique's scientific article does not give any rule for choosing in such situations, but allows for an evaluation by the practitioner.

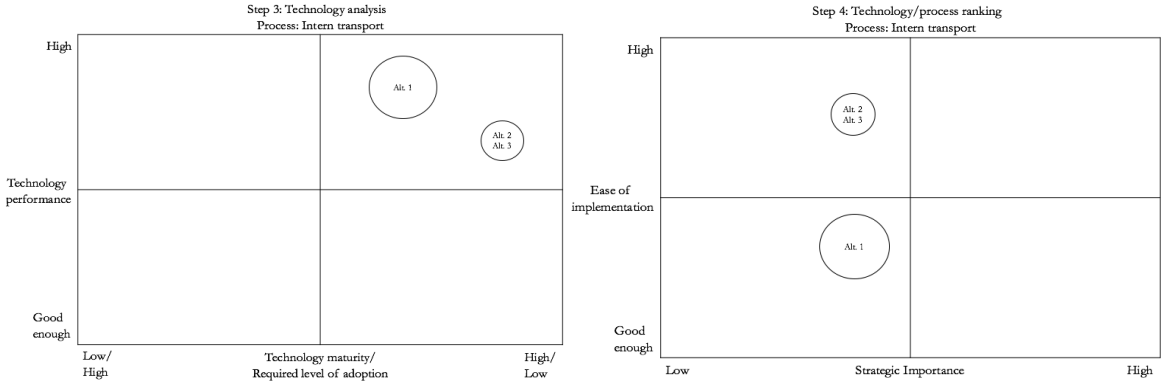


Figure 12: Results of the intern transport process by the first justification technique

In the second technique, alternative 1 and 3 separated with 1.1 points in the second filter, which made alternative 3 the best alternative. This is presented in Table 11. The practitioner could not see any other solution and decided that the difference by 1.1 point was self-explanatory.

Table 11: Results of the intern transport process by the second justification technique

Process: Intern transport					
First filter			**Second filter**		
Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
6.04	5.76	5.88	5.4	-	6.5

This means that both alternative 1 and 3 were the last two final alternatives remaining in both justification techniques, and that different focus on the weighting steered the final results in opposite directions. In addition, note that the first part of the second technique ranked alternative 1 as the best alternative, which is similar to the result in the first justification technique.

During the second practical evaluation of the techniques, the technology alternatives were evaluated to perform the process input. In the first technique, all of the alternatives were evaluated in the middle of the technology maturity axis in step 3. This is presented in Figure 13. However, alternative 3 was placed on 'good enough' on the technology performance axis since it required assistance of manual handling. Alternative 1 and 2 were therefore the only alternatives included in the next step, as shown in Figure 13. These technology alternatives were drawn over the mid line of the implementation axis and in the middle of the strategic importance axis in step 4. However, alternative 2 was drawn as a bigger circle than alternative 1 and got chosen, even though the alternative 1 was higher up on the implementation axis.

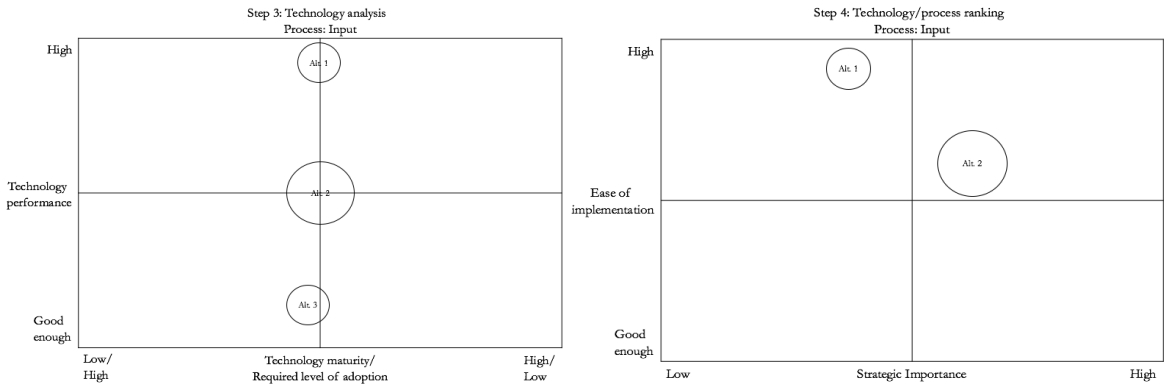


Figure 13: Results of the input process by the first justification technique

In the second technique, all alternatives were brought to the second filter since the alternatives only were separated with 1 point from the lowest to the highest score. This final score is presented in Table 12. The practitioner did not want to select alternative 2 based on one filter only. In the second filter, the alternatives separated the scores by 0.7 points and were at the same time very different from the previous filter. This was the alternatives with the highest and lowest score, while alternative 1 was in the middle in both filters. Alternative 3 had the highest score in the second filter which made the practitioner choose this alternative for the final decision.

Table 12: Results of the input process by the second justification technique

Process: Input					
First filter			**Second filter**		
Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
6.15	7.11	6.22	6.1	5.7	6.4

The two techniques conclude with different outcomes, which does not necessarily mean that the alternatives are completely different from each other. However, the lowest ranked alternative in the first technique was the highest ranked alternative in the second technique. It is important to highlight that the second technique only differed by 0.7 points from the lowest to the highest ranked alternative. The second justification technique did not explain the meaning of the different scores in the scoring model, which made the practitioner to follow the highest score even if the score difference was minimal. The first technique asks for technology performance which arrange alternative 3 on 'good enough' because it has a semi-automated solution. The second technique does not ask specific on the technology performance, but on the technology quality, reliability, flexibility, repeatability and volume. None of these evaluation areas points on the level of automation which is the decisive evaluation area for alternative 3 in the first technique. The evaluation areas differentiate the justification techniques.

The two justification techniques were also used on the last process named glue application and control. Alternative 1 and 3 were close in each scheme in the first technique and alternative 1 was placed higher than alternative 3 in step 3 and 4. Additionally, alternative 1 was rated better on the investment perspective and came out as the best alternative. Step 3 and 4 are presented in Figure 14.

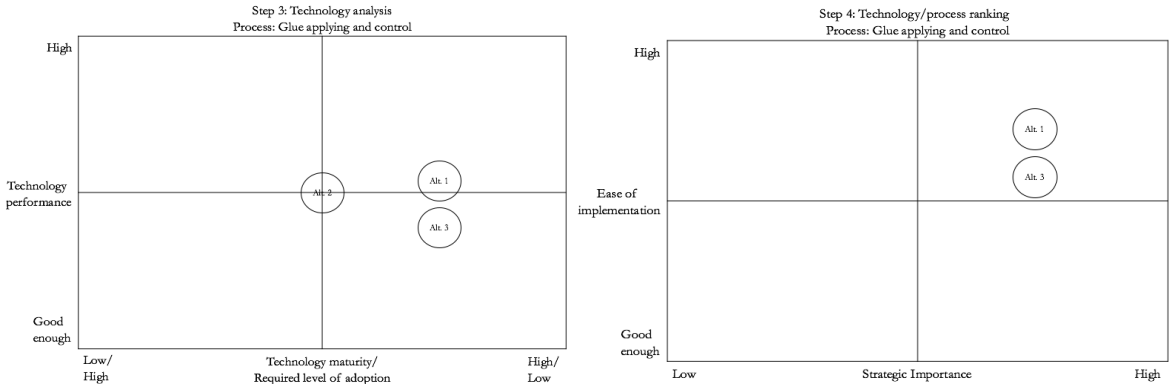


Figure 14: Results of the glue application and control process by the first justification technique

In the second technique, alternative 1 was 0.3 points higher than alternative 3 in the first filter, but it switched in the second filter and alternative 3 got 1.05 points higher score than alternative 1. The final scores is presented in Table 13. The switch in the second filter is because alternative 3 was evaluated higher than alternative 1 in the integratability and usability areas. This gave the practitioner confidence in selecting alternative 3 in the second technique.

Table 13: Results of the glue application and control process by the second justification technique

Process: Glue application and control					
First filter			**Second filter**		
Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
5.78	4.95	5.42	5.75	-	6.8

Alternative 1 and 3 were the last alternatives in both techniques evaluating the appropriate technology for the glue application and control process. The second filter in the scoring model separated the alternatives the most, but the alternatives were arranged similar up to this point. This proves that different focus in the approaches can evaluate the same alternatives to be close to each other, but their evaluation areas can tip the one alternative over the other.

As already explained, the alternatives had close scores in the evaluation with the two justification techniques tested in the workshop. There was a small gap between the alternatives that constituted the final decisions. A score difference of 1 point in the second technique was not considered by the practitioner as a large deviation, hence all of the alternatives were chosen based on the score in the second filter in the scoring model. The practitioner found all of the results reasonable based on their evaluation areas, even though they were different in their respective justification techniques. This is because all of the alternatives contains good solutions for the new and fully automated production line.

5.2 Experiences from the performed justification techniques

The first justification technique had fewer points to evaluate than the second, but managed to cover more of the same areas as the second technique because of the more superior areas listed in the steps. According to the practitioner, the second technique used a more listed approach with a

more specific explained mind set through the evaluation. The first technique did not cover the supplier references or their earlier experience as good as the second technique. The practitioner wanted this area to be included in the evaluation since it is a major investment for the company and all necessary areas should be included. The second technique covered the supplier aspect in the second filter, after making the most important evaluation in the first filter. This included the supplier aspects requested from the practitioner in addition to prevent the practitioner's possibilities of manipulating the results. The practitioner experienced the possibility of manipulating the results in the first technique because the selection of the most preferable technology could be chosen based on the biggest circle or the best position in the scheme if the alternatives were close.

The first justification technique was less time consuming than the second one, which make the technique suitable for a faster segregation. A faster segregation is preferable if there is a large number of options to start with. The practitioner suggested that the first technique can be used as a screening and first-step assignment, and that the second technique had a more thorough approach, suitable for a final decision. The scope of the acquisition process in step 1 and 2 in the first technique is very important, but the practitioner pointed out that the case company already have good routines for mapping the needs before processing the tenders from the suppliers. Their most interesting and challenging part of the acquisition of automation technology is the selection part. However, both of the techniques were considered to have a good utility and the lack of information in the tenders from the suppliers were made visible, which can be used in the further communication with the suppliers regarding their tenders. The two first steps in the first technique is seen as important and its present in the technique is a benefit for manufacturing companies finding this type of guidance necessary.

The practitioner found the second technique more flexible than the first one because one could add more sub-filters if desired. However, it did not seem to be necessary to add more filters during the workshop. The scoring model in the second technique was easy to manage and at the same time documented the decisions more detailed. This was due to the higher number of listed areas to examine in the tenders. As mentioned in Section 4.2.2.2, sub-filters in the adoption filter had no underlying areas listed in the scoring model during the case study. An interpretation of this filter constituted fewer evaluation areas. In this way, the technique took less time to execute and the sub-filters evaluated had more explanation than if it had been the underlying evaluation areas. However, the areas were verbally included in the evaluation before setting each score to the sub-filters during

the workshop. The ability of interpretation could also be seen as a weakness since valuable information can be lost. This also applies to the score's interpretation which is entrusted to the practitioner. The technique's scientific article fails to explain the meaning of the scoring scale more thorough than 1 as the lowest and 10 as the highest score to give. The practitioner would benefit an available definition of the possible differences between the scores and what these can indicate. An explanation of the difference of 1 point or 0.1 point could probably give the practitioner a better understanding of the technology alternatives.

The practitioner found it easier to understand the reasons for the results by looking at the scoring model in the second technique, than looking at the circles in the first technique. The weighting in the scoring model made the focus of the evaluation clear for the practitioner and the high number of sub-filters gave the filters more weight and meaning. An unexperienced practitioner could manage the second technique, but should expect to use more time than an experienced one because of the weighting and the high number of evaluation areas. The weighting of the evaluation areas is based on the company's prioritized areas.

The economy aspect in both of the justification techniques is present, but the degree of the focus is both diffuse and varied. The economic consideration is mentioned in the first technique in the last step as 'analyse investments', but with no further guiding in for example how to perform an analysis. The second technique focus on financial considerations in its first filter in form of capital, sales, renewal and operation. In addition to this, the finance function is mentioned as an internal factor. However, this technique mentions neither a formula nor an explanation of how it can be calculated. In this case study, the practitioner used its tenders together with experience to evaluate the economic aspects. It is important to remember that not every company has this competence.

The case company utilised the two techniques to experience their guidance in the technology selection process. The focus in the techniques was on the evaluation of the technology alternatives. The techniques were tested to evaluate the fulfilment of the important elements for being supportive justification techniques. Any manufacturing company in the industry could benefit such support in selecting technology for challenging processes to automate. The project manager was the main person in the acquisition project in the case company and experienced both of the techniques to be supportive. However, the practitioner gave the highest confidence in the second technique. Results from this technique are based on a higher number of evaluation points, which

make it impossible to choose alternatives based on instincts. The use of the second justification technique can ensure that the automation technologies are equally treated in a selection process.

5.3 The final decision for the case company

The justification techniques performed in the workshop had an impact on the further process in acquiring automation technology in the case company. The case company adopted the second technique, 'The technology selection framework', for the selection and executed this method once again with more participants than in the workshop. The participants were the project manager, process engineer and maintenance manager to be able to examine all areas and include important points of view to the tenders. The evaluation from this execution can be found in Appendix G and the final results in the scoring model are presented in Table 14. The case company evaluated alternative 1 and 3 since these two alternatives were the ones ranked the highest in both of the justification techniques during the case study. An evaluation of only two technology alternatives spared the practitioners for some time in the execution of the second justification technique.

Table 14: Results for the assembly process by the second justification technique

Process: Assembly			
First filter		**Second filter**	
Alternative 1	Alternative 3	Alternative 1	Alternative 3
6.65	5.55	6.4	6.5

Technology alternative 1 was selected for the acquired automation technology. The first technology alternative was selected two out of three times in the first technique in the workshop. The second method selected the third technology alternative each time, but this time, the first alternative was selected with the second technique. This result was for the whole tenders, and not just parts of the suppliers' tender as in the workshop. The practitioners performed the selection process on suppliers' tender as a whole because it felt more efficient and was evaluated to not exclude too much details anyway. The first alternative had 1.0 points higher score than the third alternative in the first filter, whilst the second filter evaluated the first alternative 0.1 point lower than the third alternative. Since the first filter had a clear division and the second filter had minimal differences, the first alternative was evaluated to be the best one for the case company. The ability of

interpretation of the technique made this conclusion possible. The results in the workshop had been more similar in the techniques if the same interpretation had been used at that time.

The second justification technique was chosen this time since it was more detailed than the first technique and was experienced to give a more documented result. In addition, it became clear that the results were easier to present for others since it was well documented and arranged after evaluation areas, and not a so-called gut feeling as the first technique appeared.

The idea of using the first technique to get a faster, but still thorough evaluation of many alternatives and the second technique for a more detailed evaluation, is seen as a possibility. However, both of the techniques give satisfactory results and are confirmed as helpful and with a good user interface.

5.4 Chapter summary

The justification techniques point out different solutions, but the differences between the results are actually not so far apart. The results are in close race in both of the techniques for each process, which make all results from the justification techniques valuable. The first technique was experienced to be easy to understand and included the important areas to evaluate. However, it was easy to manipulate by the practitioner which can impact the results. The second technique was experienced to be more focused on the facts and did not give the practitioner any possibility to choose the best alternative based on its own instincts. However, the technique opened for individual interpretation, which not necessarily is an advantage for the selection process. Nevertheless, the case company chose to apply the second justification technique in the final selection process of an acquired automation technology.

6 Justification techniques supporting a selection process

This chapter will present strengths and weaknesses of two justification techniques followed by their especially suited situations to support. The techniques are the 'Automation Project Selection' by Thomassen et al. (2014) and 'The technology selection framework' by Shehabuddeen et al. (2006).

The evaluation of the important elements in the justification techniques is presented in Table 15. The important elements were found in the literature review and earlier presented in Table 7 in Section 3.2.4. Table 15 points on the justification techniques' ability of being supportive in a selection process. The evaluation categorises the techniques' degree of fulfilling the important elements with strong support (***), medium support (**), weak support (*) or lack of support (-).

Table 15: Evaluation of the important elements in the justification techniques

Important elements	Automation Project Selection	The technology selection framework
Ease of performance		
Effective in execution	***	**
Applicable	***	**
Well explained	***	**
Covers the necessary areas		
Include the important areas	**	***
Ability to evaluate distinctive areas for the production	*	***
Guides the selection part of the acquisition process	***	***
Guides multiple parts of the acquisition process	**	-
Exclude the practitioner's gut feeling	*	***
Type of approach		
Combination of strategic and economic approach	**	**
Prioritise technology alternatives	***	***
Evaluate with a visualising model	***	-
Evaluate with a scoring model	-	***

The first part of Table 15, 'Ease of performance', had three elements and both of the techniques were evaluated to be effective in execution and also applicable. However, the APROS technique was experienced to be slightly easier to perform than 'The technology selection approach'. In addition, the APROS technique was experienced to be well explained in each step without any questions during the execution. 'The technology selection framework' presented the figure of the approach in an overwhelming way, which made it difficult to understand in the beginning. The scientific article explaining this technique opens for interpretation. It does not explain all of the evaluation areas underlying the sub-filters in the adoption filter. This led to an execution of the technique with less evaluation areas in the second filter. As a result, the technique was more efficient in the case study which could give a higher score than deserved in the 'effective in execution' element in the table. In addition, 'The technology selection framework' could benefit an explanation of the meaning of the scoring result. Lack of explanation of the score is seen as a weakness since the score can be interpreted differently each time utilising the technique. The technique should therefore signify the scores and how different scores are compared to each other. However, both of the techniques explain their approach well enough for practitioner willing to examine the technique before the execution.

The part 'Covers the necessary areas' in Table 15 distinguish the techniques even more. The APROS technique guides multiple parts of the acquisition process. It is possible to utilise the technique in different areas dependent on the practitioner's desire, as done in the case study by only testing the selection part of the justification technique. In addition, the technique includes important evaluation areas, but could benefit of including earlier experience with the suppliers and their reputation. It does not necessarily have to be included as a superior evaluation point, but give the practitioner some possibility to let it be considered in the process. 'The technology selection framework' includes all of the important areas to evaluate in a selection process and specifies its guidance to the selection process in the acquisition of an automation technology. In addition, this technique includes the possibility for adding more areas to be evaluated and makes it impossible for selecting an automation technology based on the practitioner's instinct.

The last part in Table 15, 'Type of approach', states that both of the techniques are a combination of a strategic and an economic approach. This combination in an approach is experienced to be thorough, simple to use and attains higher level of success in automation technology projects (Chan et al., 2001; Small & Chen, 1997). However, both of the techniques presented vague explanation of financial perspectives to the practitioner. The techniques could therefore benefit of a more

thorough clarification of how to get information about the economical perspectives of the alternatives. The techniques are different in their approach with either a visualisation model or a scoring model. Both of these models are evaluated to be supportive for a practitioner.

Overall, the justification techniques are evaluated to include the important elements to be supportive in the selection of an acquired automation technology. The APROS technique is evaluated to be highly effective and easy to understand with more superior areas to evaluate. "The technology selection framework" makes it possible to include more areas to evaluate in the technologies. After getting to know the approach, the technique is experienced to be reliable and preferred by the case company. The strengths and weaknesses of the two justification techniques are summarised in Table 16.

Table 16: Strengths and weaknesses of the justification techniques

Justification technique	Strengths	Weaknesses
Automation project selection (APROS)	Effective, applicable, easy to understand its steps, fulfil important criteria to be supportive, evaluate important areas of the technologies, and prioritise the alternatives.	Does not include previous experience with the suppliers and their reputation and does not calculate the cost.
The technology selection framework	Effective, applicable, fulfil important criteria to be supportive, evaluate important areas of the technologies, excludes the practitioners gut feeling, can add more areas for evaluation, and prioritise the alternatives.	Difficult to understand, can be interpreted differently, does not explain the meaning of the scores, and does not calculate the cost.

It is important to emphasise that the case company found both of the techniques applicable and that the techniques accomplished their aim with their approach. The required guidance in a selection of an appropriate automation technology is being covered by these techniques, which are available for practitioners in the industry. The justification techniques executed in the case study

and explained in Section 3.2.3 were, and will be useful in the future for the case company in the selection of an automation technology. The case company's previous process of acquiring automation technology had no documented approach or guidance, and decisions were based on earlier experiences from other processes or with respect to the process requirements. The case company experienced the justification techniques to perform the process more structural and give necessary guidance and support in the selection of an acquired automation technology. This will also apply to other companies in the industry.

The evaluation of the techniques during and after the case study pointed on their especially suited situations to support. A manufacturing company will especially benefit utilising one justification technique over another dependent of its situation. The following list presents these situations which were pointed on in Chapter 5:

The APROS technique is especially suited to support situations where:

- The practitioners require guidance in the acquisition process from establishing a strategy to the investment and implementation of an automation technology
- The practitioners prefer a visualisation model to select an automation technology
- The practitioners have to perform a fast segregation of several technology alternatives

'The technology selection approach' is especially suited to support situations where:

- The practitioners only require guidance for the selection of an acquired automation technology
- The practitioners prefer a scoring model to select an automation technology
- The practitioners require a thorough and trustable justification technique selecting an automation technology based on only facts.

The manufacturing companies in the Norwegian industry acquiring automation technology should give the suppliers a good basis of information to receive satisfactory tenders to be evaluated with the use of justification techniques. A good groundwork would make the selection process of an acquired automation technology much more beneficial.

7 Conclusion

An acquisition of automation technology will entail large investments with a necessity of justification. Justification techniques can support an acquisition process and provide guidance to give confidence in the selection of an automation technology. Acquisition of new technical and organisational production systems with autonomy will benefit this support.

The theoretical part obtained justification techniques including the selection process of an acquired automation technology. These techniques had to include guidance for how to perform the selection process and include strategic importance and economic considerations. Two justification techniques fulfilled these criteria. Further, important elements for a supportive justification technique were elaborated from the literature review. A technique has to be efficient, applicable and well explained. In addition, it should include the most important areas to be evaluated and consist of guidance for one or multiple parts of the acquisition process. The ability of including areas in the evaluation will be beneficial to suit processes with specific challenges. In addition, a technique should exclude the practitioner's gut feeling to get an objective evaluation of alternatives. Different approaches, utilising a visualising or scoring model, were highlighted to be supportive with a combination of strategic and economic approaches. These important elements were presented to determine a supportive justification technique for a manufacturing company acquiring automation technology. The techniques were evaluated upon these elements in the empirical part.

The justification techniques, APROS and 'The technology selection framework', were in the empirical part performed in a case study. The case study contributed to cover a more practical evaluation of the techniques expressed to be of importance by their scientific articles. The techniques were well documented and evaluated continuously during the execution. However, data collection and analysis dependent on human understanding can present the results poorly if parts are overlooked or by mistake not documented. This is seen as a possible error connected to this thesis and closely followed up during the study.

The results in the findings and discussion were summarised in a table listing the important elements to be included in a supportive justification technique. The table showed that the techniques were efficient, applicable and covered the most important areas to evaluate for prioritising the technology alternatives. However, the study also compared the techniques and confirmed that one

technique was more difficult to understand and that the other technique made it possible to manipulate the results. Further, the justification techniques were summarised in a table highlighting their strengths and weaknesses followed by a list of situations the techniques are evaluated to especially support. These findings came from the case study, mainly from the practitioner in the case company.

Further work should be done to perform the two justification techniques with case companies having other challenges connected to their production processes. This is to substantiate the findings presented in this study. Additionally, practitioners in other positions than the project manager could experience the support in a different way dependent on its expertise and understanding of the techniques. Hence, it might be interesting to further examine a broader mapping of the justification techniques.

The study found two justification techniques supportive in the selection process of an acquired automation technology. These techniques were evaluated to suit different areas of application, either a fast segregation conceivably with several alternatives or a more thorough evaluation with fewer alternatives. Further research should be done to propose suitable justification techniques to additional areas of application, and at the same time include other justification techniques. A connection between justification techniques and company situations could be constituted in a maturity model available to manufacturing companies. In addition, a study of companies' necessity of combining techniques, adjusting existing ones or just following the original guidance might be of relevance.

References

Abdel-Kader, M. G., & Dugdale, D. (2001). Evaluating investments in advanced manufacturing technology: A fuzzy set theory approach. *The British Accounting Review, 33*(4), 455-489.

Accola, W. L. (1994). Assessing risk and uncertainty in new technology investments. *Accounting Horizons, 8*(3), 19.

Baines, T. (2004). An integrated process for forming manufacturing technology acquisition decisions. *International Journal of Operations & Production Management, 24*(5), 447-467.

Baldwin, J., & Lin, Z. (2002). Impediments to advanced technology adoption for Canadian manufacturers. *Research policy, 31*(1), 1-18.

Beckman, S. L., & Rosenfield, D. B. (2008). *Operations strategy: competing in the 21st century*: McGraw-Hill/Irwin.

Boothby, D., Dufour, A., & Tang, J. (2010). Technology adoption, training and productivity performance. *Research policy, 39*(5), 650-661.

Bostad, M. (2015). *Guidelines for the early steps in the acquisition of automation technology*. Retrieved from Norwegian University of Science and Technology:

Bryman, A. (2015). *Social research methods*: Oxford university press.

Bryman, A., & Bell, E. (2015). *Business research methods*: Oxford University Press, USA.

Chan, F. T. S., Chan, M. H., Lau, H., & Ip, R. W. L. (2001). Investment appraisal techniques for advanced manufacturing technology (AMT): a literature review. *Integrated Manufacturing Systems, 12*(1), 35-47.

Charmaz, K., & McMullen, L. M. (2011). *Five ways of doing qualitative analysis: Phenomenological psychology, grounded theory, discourse analysis, narrative research, and intuitive inquiry*: Guilford Press.

Christensen, C. (2013). *The innovator's dilemma: when new technologies cause great firms to fail*: Harvard Business Review Press.

Chuang, M., Yang, Y. S., & Lin, C. T. (2009). Production technology selection: Deploying market requirements, competitive and operational strategies, and manufacturing attributes. *International Journal of Computer Integrated Manufacturing, 22*(4), 345-355.

Chung, C. A. (1996). Human issues influencing the successful implementation of advanced manufacturing technology. *Journal of engineering and technology management, 13*(3), 283-299.

Duncheon, C. (2002). Product miniaturization requires automation-but with a strategy. *Assembly Automation, 22*(1), 16-20.

Durrani, T. S., Forbes, S. M., Broadfoot, C., & Carrie, A. S. (1998). Managing the technology acquisition process. *Technovation, 18*(8), 523-587.

Efstathiades, A., Tassou, S., & Antoniou, A. (2002). Strategic planning, transfer and implementation of Advanced Manufacturing Technologies (AMT). Development of an integrated process plan. *Technovation, 22*(4), 201-212.

Farooq, S., & O'Brien, C. (2012). A technology selection framework for integrating manufacturing within a supply chain. *International Journal of Production Research, 50*(11), 2987-3010.

Ford, D. (1988). Develop your technology strategy. *Long range planning, 21*(5), 85-95.

Frohm, J. (2008). *Levels of Automation in production systems*: Chalmers University of Technology Gothenburg.

Frohm, J., Granell, V., Winroth, M., & Stahre, J. (2006). *The industry's view on automation in manufacturing.* Paper presented at the Proceedings of the 9th symposium IFAC on Automated Systems Based on Human Skills and Knowledge, France.

Gellatly, G. (1999). Differences in innovator and non-innovator profiles: Small establishments in business services. *Statistics Cananda Working Paper*(143).

Granlund, A., & Jackson, M. (2013). Managing automation development projects: a comparison of industrial needs and existing theoretical support *Advances in Sustainable and Competitive Manufacturing Systems* (pp. 761-774): Springer.

Gregory, M. (1995). Technology management: a process approach. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 209*(5), 347-356.

Groover, M. P. (2007). *Automation, production systems, and computer-integrated manufacturing*: Prentice Hall Press.

Gupta, Y. P., & Somers, T. M. (1993). Factory automation and integration of business functions. *Journal of Manufacturing Systems, 12*(1), 15-23.

Iakymenko, N. (2014). *An approach for evaluating the appropriateness of automation in manufacturing processes with increasing product mix.* (Master thesis), Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Production and Quality Engineering.

Jiménez, C. H. O., Garrido-Vega, P., & González, S. G. (2011). Manufacturing strategy–technology relationship among auto suppliers. *International Journal of Production Economics, 133*(2), 508-517.

Jovane, F., Koren, Y., & Boer, C. R. (2003). Present and future of flexible automation: towards new paradigms. *CIRP Annals-Manufacturing Technology, 52*(2), 543-560.

Karsak, E. E., & Tolga, E. (2001). Fuzzy multi-criteria decision-making procedure for evaluating advanced manufacturing system investments. *International Journal of Production Economics, 69*(1), 49-64.

Kerr, C., Farrukh, C., Phaal, R., & Probert, D. (2013). Key principles for developing industrially relevant strategic technology management toolkits. *Technological Forecasting and Social Change, 80*(6), 1050-1070.

Lindström, V., & Winroth, M. (2010). Aligning manufacturing strategy and levels of automation: A case study. *Journal of engineering and technology management, 27*(3), 148-159.

Lowe, A., Ridgway, K., & Atkinson, H. (2000). QFD in new production technology evaluation. *International Journal of Production Economics, 67*(2), 103-112.

Martin, T., Kivinen, J., Rijnsdorp, J. E., Rodd, M. G., & Rouse, W. B. (1991). Appropriate automation—integrating technical, human, organizational, economic and cultural factors. *Automatica, 27*(6), 901-917.

Meredith, J. R. (1987a). Implementing the automated factory. *Journal of Manufacturing Systems, 6*(1), 1-13.

Meredith, J. R. (1987b). Managing factory automation projects. *Journal of Manufacturing Systems, 6*(2), 75-91.

Morgan, L. O., & Daniels, R. L. (2001). Integrating product mix and technology adoption decisions: a portfolio approach for evaluating advanced technologies in the automobile industry. *Journal of Operations management, 19*(2), 219-238.

Nammo. (2014). Nammo AS homepage. Retrieved from https://www.nammo.com/

Noor, K. B. M. (2008). Case study: A strategic research methodology. *American journal of applied sciences, 5*(11), 1602-1604.

Noori, H. (1997). Implementing advanced manufacturing technology: The perspective of a newly industrialized country (Malaysia). *The Journal of High Technology Management Research, 8*(1), 1-20.

Noy, C. (2008). Sampling knowledge: The hermeneutics of snowball sampling in qualitative research. *International Journal of social research methodology, 11*(4), 327-344.

Nyen, P. A. (2015). NAP. Retrieved from http://www.sintef.no/prosjekter/nap/

Ordoobadi, S. M., & Mulvaney, N. J. (2001). Development of a justification tool for advanced manufacturing technologies: system-wide benefits value analysis. *Journal of engineering and technology management, 18*(2), 157-184.

Parasuraman, R. (2000). Designing automation for human use: empirical studies and quantitative models. *Ergonomics, 43*(7), 931-951.

Parsaei, H. R., & Wilhelm, M. R. (1989). A justification methodology for automated manufacturing technologies. *Computers & industrial engineering, 16*(3), 363-373.

Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2006). Technology management tools: concept, development and application. *Technovation, 26*(3), 336-344.

Rajasekar, S., Philominathan, P., & Chinnathambi, V. (2006). Research methodology. *arXiv preprint physics/0601009*.

Raafat, F. (2002). A comprehensive bibliography on justification of advanced manufacturing systems. *International Journal of Production Economics, 79*(3), 197-208.

Samad, T., McLaughlin, P., & Lu, J. (2007). System architecture for process automation: Review and trends. *Journal of Process Control, 17*(3), 191-201.

Sambasivarao, K. V., & Deshmukh, S. G. (1997). A decision support system for selection and justification of advanced manufacturing technologies. *Production Planning & Control, 8*(3), 270-284.

Schlechtendahl, J., Keinert, M., Kretschmer, F., Lechler, A., & Verl, A. (2015). Making existing production systems Industry 4.0-ready. *Production Engineering, 9*(1), 143-148.

Shehabuddeen, N., Probert, D., & Phaal, R. (2006). From theory to practice: challenges in operationalising a technology selection framework. *Technovation, 26*(3), 324-335.

Small, M. H., & Chen, I. J. (1997). Economic and strategic justification of AMT inferences from industrial practices. *International Journal of Production Economics, 49*(1), 65-75.

Small, M. H., & Yasin, M. M. (1997). Advanced manufacturing technology: implementation policy and performance. *Journal of Operations management, 15*(4), 349-370.

Stevenson, W. J. (2014). *Operations Management* (12th ed.): McGraw-Hill Education.

Suresh, N. C., & Meredith, J. R. (1985). Justifying multimachine systems: an integrated strategic approach. *Journal of Manufacturing Systems, 4*(2), 117-134.

Säfsten, K., Winroth, M., & Stahre, J. (2007). The content and process of automation strategies. *International Journal of Production Economics, 110*(1), 25-38.

Thomassen, M. K., Sjøbakk, B., & Alfnes, E. (2014). A Strategic Approach for Automation Technology Initiatives Selection *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World* (pp. 288-295): Springer.

Torkkeli, M., & Tuominen, M. (2002). The contribution of technology selection to core competencies. *International Journal of Production Economics, 77*(3), 271-284.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management, 22*(2), 195-219.

West, J. (2000). Module Overview: Sustaining Growth through Operations: Harvard Business School.

Wilson, C. (2013). *Interview techniques for UX practitioners: A user-centered design method*: Newnes.

Yin, R. K. (2013). *Case study research: Design and methods*: Sage publications.

Appendix A: Overview of the communication with the case company

Participant	Participants position in the company	Date	Length
Øystein Pellegård (Phone interview 1)	Project manager for the production of Large Caliber Division	02.02.2016	30min
Kristian Haug Iversen (Phone interview 2)	Process engineer for the production line for Medium and Large Caliber Division	15.02.2016	35min
Øystein Pellegård (Phone interview 2)	Project manager for the production of Large Caliber Division	15.02.2016	35min
Øystein Pellegård (Workshop)	Project manager for the production of Large Caliber Division	29.03.2016	6 hours
Øystein Pellegård (Mail correspondence)	Project manager for the production of Large Caliber Division	14.04.2016 03.05.2016 04.05.2016 19.05.2016 20.05.2016	4 mails 2 mails 2 mails 2 mails 2 mails

Appendix B: Interview guide for the first interview (In Norwegian)

Introduksjon

1. Takk for at du tok deg til til å snakke med meg
2. Stillingen din ?
3. Fortell om mitt studieprogram og at jeg nå skal skrive masteroppgave

Navn på intervjuobjekt:

Øystein Pellegård

Hoveddel – Informere om oppgaven og avklaring

1. Masteroppgaven skal omhandle analysemetoder for å støtte utvelgelse av automasjonsteknologi
    a. Trenger case bedrift for å utføre et case studie
    b. Case studie vil teste ut 1-3 metoder

2. Hva dere vil få ut av det
    a. Få tilgang på metoder som vil forbedre deres prosess
    b. Bli omtalt i masteroppgaven min
    c. Et bidrag til NAP-prosjektet dere er involvert i
    d. Jeg kan sende Prosjektoppgaven min som er grunnlaget for masteroppgaven slik at dere kan se på det

3. Hva det innebærer
    a. Vil ha en fordel for kan bygge på kartleggingen som ble gjort i sommer ifm automatiseringsprosjektet
    b. Vil holde et intervju for å kartlegge litt mer
    c. Vil holde en workshop da jeg kommer til dere en dag eller to, det blir litt senere i semesteret
    d. Vil spørre spørsmål inne i mellom ved behov

4. Er Nammo villig til å være min case bedrift?

Til slutt

1. Har intervjuobjektet noen spørsmål?
2. Takk for at du tok deg tid til å snakke med meg.

Appendix C: Interview guide for the second interview (In Norwegian)

Introduksjon

1. Takk for at jeg kan intervjue
2. Kan intervjuet bli tatt opp?
3. Anonymitet?
4. Stillingen deres
5. Fortell om temaet og målet med oppgaven.

Navn på intervjuobjekt:

Øystein Pellegård og Kristian Haug Iversen

Hoveddel – bli kjent med utfordringene i dagens situasjon

1. Hvor langt har Nammo kommet i prosessen av å automatisere sin produksjonslinje?
    a. Ut i fra NAP-prosjektet har prosessene blitt kartlagt ved bruk av IDEF0-dokumentasjonsformat. Hvor langt i prosessen har Nammo kommet nå?
2. Har Nammo hatt lignende prosesser for automatisering av produksjonen før NAP-prosjektet?
    a. Hva var det?
    b. Når var det?
    c. Hvordan gikk dette?
3. Har Nammo noen analytisk metode de vanligvis benytter?
    a. Hvordan er denne?
    b. Hvem har brukt denne, og når?
4. Har dere noen form for dokumentasjon av tidligere automatiserings prosesser som det er mulig å kunne se på?
    a. For å sammenligne og se hvilke utfordringer dere da hadde, og om jeg vil kunne bruke det for å finne en bedre metode for Nammo.
5. Hva ser Nammo på som den største utfordringen i prosessen av å anskaffe seg automasjonsteknologi for den nye produksjonslinjen?
6. Hvilke tanker har dere rundt montasjedelen i den nye produksjonslinjen?
    a. Hva blir utfordringen med denne oppgaven?
    b. Hvilke faktorer må tas hensyn til?

Til slutt

1. Har intervjuobjektet noe å tilføye?
2. Takk for at jeg kunne intervjue dere.

Appendix D: Guidance to the workshop in the case study with results (In Norwegian)

Gjennomføring av case-studie i bedriften Nammo Raufoss AS

I forbindelse med masteroppgave ved NTNU av Marthe Bostad

Målet for denne gjennomføringen av case-studiet er å kunne finne riktig form for utvelgelse av automasjonsteknologi en bedrift vil anskaffe.

Gjennomføringen vil foregå i form av workshop lokalisert i case bedriftens lokale. Det vil først bli utført metode 1, deretter metode 2. Det er viktig at hver metode blir grundig evaluert etter gjennomføringen.

Dato: 29.03.2016

Til stede: Marthe Bostad (Masterstudent, NTNU), Øystein Pellegård (Prosjektleder, Nammo)

Analysemetoder for case studie i Nammo, norsk versjon

Gjennom et litteraturstudie har det kommet frem ti (10) analysemetoder som omhandler utvelgelsen av en automasjonsteknologi for en produksjonsbedrift. Videre har disse blitt analysert nærmere og det er valgt ut to analysemetoder som vil kunne passe til case-studie som skal teste disse metodene for en spesifikk type produksjon. Produksjonstypen er:

- Make-To-Order
- Mass customisation (produserer i hovedsak standardiserte produkter, men det inngår også en form for tilpasning)
- Norsk bedrift med norsk kultur
- Høyt fokus på sikkerhet
- Har et mål om å høy-automatisere produksjonen
- Har prosesser som trenger spesialtilpasset teknologi

Nammo Raufoss er en passende produksjonsbedrift for case-studie. En av deres avdelinger skal oppgraderes til høyautomatisert produksjon. I tillegg kan de produsere mellom 100 til 100.000 produkter avhengig av ordre som blir mottatt cirka ett år i forveien av leveransedato. Nammo Raufoss er en norsk bedrift med norsk kultur i sine arbeidsmetoder for forbedringsarbeid. Mer informasjon finnes i case beskrivelsen.

Nammo Raufoss har allerede utført analyse av behov for automatiseringsteknologi i sin produksjonslinje. På dette tidspunkt anser de montasjeprosessen som mest krevende og har fokuset på denne oppgaven. De er derfor midt i en prosess for å anskaffe automasjonsteknologi, som vil si at leverandører av teknologien er kontaktet og tilbud er mottatt. Utvelgelsen av ønsket automasjonsteknologi er derfor neste steg i prosessen, og det vil være hensiktsmessig å benytte denne oppgaven i case-studie.

Det vil derfor bli forklart hvilke analysemetoder som er funnet hensiktsmessige slik at det skal være lettere å benytte disse under case-studiet.

Rød skrift viser resultater fra case-studiet i tillegg til de resultatene i appendiks E og F.

Første analysemetode

Navn: Automation Project Selection

Forfatter: Thomassen, M. K., Sjøbakk, B., & Alfnes, E. (2014). A strategic Approach for Automation Technology Initiatives Selection *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World (pp. 288-295): Springer.*

Steg	**Steg-navn**	**Input**	**Vurdering og avgjørelse**	**Output**
1	Teknologi strategi	Firmaets strategi, CSR strategi, Teknologitrender og kompetanse	Definere produksjons konkurranse prioriteter og ansvars mål, Definere innovasjonsposisjon for hoved teknologi	Teknologi strategi, Område for interesse for automasjon
2	Prosess analyse	Produksjonsytelse og ansvarlighets krav, Produkt prosesserings krav, Oversikt over produksjonsprosessene	Kartlegg prosessene, Velg arbeidskrafts intensive prosesser, Tilfør kandidater basert på tillagte krav	Produksjons prosess kandidater
3	**Teknologi analyse**	**Litteratur og patenter, Konferanser, Ekspertkunnskap, Interne dokumenter og workshops**	**Identifiser alternative teknologier, Vurder teknologi modenhet og ytelse, Velg teknologier for hver prosesskandidat**	**Teknologi/ prosess kandidater**
4	**Teknologi/ prosess rangering**	**Samlet input av steg 1-3**	**Vurder strategisk viktighet, Vurder vanskelighetsgrad på implementering,**	**Rangert teknologi prosjekter**

			Velg prosjektkandidater basert på strategisk viktighet og vanskelighet på implementering	
5	**Investering og implementering**	**Salgs prognoser, Anskaffelseskostnad, Betjeningskostnad, Leverandør uttalelse**	**Analyser investering, Vurder leverandør, Vurder kompetansekrav, Velg prosjekt og plan implementasjon**	**Tidslinje av implementasjons plan av teknologi**

Steg med fet skrift anses som relevant for utvelgelsen, men gå igjennom at alle tidligere steg er tilgjengelig som grunnlag.

Målet med metoden:

At den er selv-forklarende, lett å benytte og muliggjør hurtig prioritering av automasjons utspill. Metoden er basert på at produksjonsbedrifter ønsker å beholde sin produksjon i et høykostnadsland som Norge. Metoden hevder å være meget gjentagende i praksis selv om den består av fem steg, og gjentagelse som kan oppstå vil være naturlig i prosessen og heller føre til revurdering av tidligere valg.

Steg 1: Allerede gjennomført og OK.

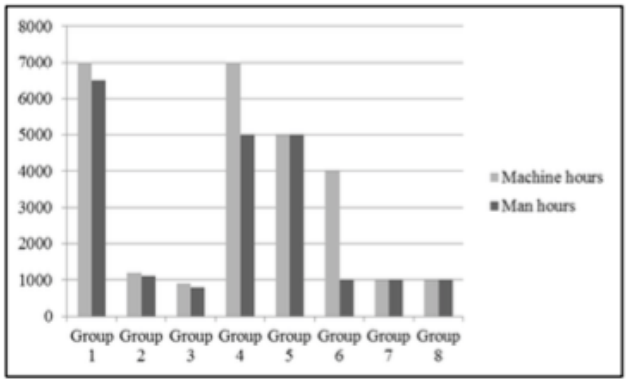
1. *Hvordan kan produksjonen støtte bedrift strategien i form av ulike resultattall?*
    a. *Større nøyaktighet og billigere. Godt salgsargument.*
2. *Benytt terminologier som helse, sikkerhetspraksis og miljøforvaltning til å beskrive hovedprinsippene for ansvarlig produksjon.*
    a. *Høyt prioritert i Nammo. Helse og sikkerhet. Får for eksempel vekk manuelle lime prosesser. Mindre manuell håndtering av satser og eksplosiver.*
3. *Bestem om bedriften skal være en innovatør eller følger når det kommer til bruk av teknologi. Skal bedriften være den første til å bruke en teknologi, eller adoptere teknologi som er allerede godt utprøvd?*
    a. *Innovatør innen sin bransje. Har kontakt med andre i bransjen. Opprettholde og øke konkurransefortrinnet.*
4. *Skal teknologien bli utviklet innad i bedriften, eller vil det være en betalt tjeneste?*
    a. *Teknologien skal bli betalt, alt utstyr blir kjøpt inn og satt sammen av andre. Nammo er bare produktspesialister..*

Steg 2: Allerede gjennomført og OK.

1. *Forstå produksjonen ved å kartlegge:*

- *Ytelseskrav i form av volum, batch størrelse, kapasitet og utnyttelse*
- *Hovedprodukter og deres prosesskrav, i form av geometri og material spesifikasjoner*
- *Prosessaktivitetene utført av produksjonssystemene*

2. *Kan deretter kalkulere nåværende og fremtidig tidsbruk i maskintimer og arbeidskrafttimer. Kan deretter velge ut kandidater basert på hva som tar flest arbeidstimer og se hvor "skoen trykker".*

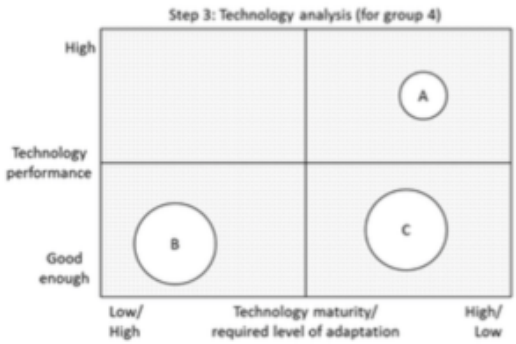


Figur 1: Eksempel på kartlegging av maskin- og arbeidstimer (fra artikkelen)

- *Ut fra eksempelbildet blir 1, 4 og 5 valgt videre i prosessen. 6 blir ikke valgt på grunn av at den allerede er høyautomatisert, som også vises ut i fra bildet.*

Steg 3:

1. Potensielle teknologier burde bli identifisert for hver prosess, altså sett teknologikandidatene til en prosess inn i skjemaet nedenfor.
2. For hver teknologi burde modenheten vurderes sammen med nivået for å tilpasse denne teknologien til å utføre prosessen som kreves.
3. Evaluer hver teknologi opp mot hvilken ytelse det kan gi prosessen.
4. Valgte teknologier burde være passende til hver prosess og sett opp mot kort- og langsiktig perspektiv for bedriften.
5. Baser valgene på interne søk og ekstern ekspertise.



Figur 2: Eksempel på kartleggingen i steg 3 med visualisering

- Ut fra eksempelbildet ser vi at teknologiene blir kartlagt ved hjelp av to dimensjoner. Se eget vedlegg for slikt skjema.
- Hver sirkel er en teknologi, og størrelsen på sirkelen indikerer andelen av produkter som teknologien kan produsere.
- De teknologiene som oppfyller kravene, altså er plassert godt nok i skjemaet, blir tatt med videre til neste steg.

Innmating

- Alternativ 1: Modenhet er høy, ikke særlig fleksibel og teknologi ytelse er høy. Midt øverst. Middels størrelse.
- Alternativ 2: Ikke så høy ytelse eller modenhet, men den er ekstremt fleksibel. Plasseres i krysset. Denne er stor.
- Alternativ 3: Manuell innmating. Middels størrelse.

Limpåføring og kontroll

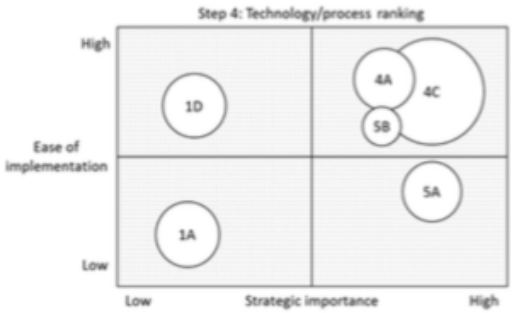
- Alternativ 1: Modenhet er bra for er brukt før og ytelse har han tro på. Middel størrelse.
- Alternativ 2: Teknologi er ikke så moden og ytelse er god nok. Middel størrelse.
- Alternativ 3: Likt som alternativ 1, men ytelse litt dårligere. Middel størrelse.

Intern transport i celle/ produktbærer

- Alternativ 1: Ikke fullt så moden, men ytelsen er høy. Tar alt av produkter, så er større størrelse. Trenger heller ikke kjøre samme løype.
- Alternativ 2 og 3: Paletter hvor modenheten er høy og ytelsen er høy. Bra størrelse.

Steg 4:

1. Rangering av prosess/teknologi kombinasjon hvor kandidatene blir vurdert opp mot strategisk viktighet og hvor enkelt det vil være å implementere det. Alternativer med størst påvirkning på strategi og lettest å implementere burde gis høyest prioritering.



Figur 3: Eksempel på kartleggingen i steg 4 med visualisering

- Ut i fra eksempelbildet ser vi at teknologiene blir kartlagt ved hjelp av to dimensjoner. Se eget vedlegg for slikt skjema.

- Hver sirkel er en teknologi, og størrelsen på sirkelen indikerer andelen av produkter som teknologien kan håndtere.
- De teknologiene som oppfyller kravene, altså er plassert godt nok i skjemaet, blir tatt med videre til neste steg.

Innmating:

- Alternativ 1: Enklere å implementere, og ok å implementere.
- Alternativ 2: drar med seg en ny teknologi som kan være viktigere å få med seg. Men ikke like lett å implementere. Fortsatt størst størrelse.
- Alternativ 3 blir ikke med videre.

Limpåføring og kontroll:

- Alternativ 1: Enklere å implementere og viktig å få en god løsning der så det er strategisk viktig
- Alternativ 3: Ikke like lett å implementere (bare en følelse), men lik på strategisk viktighet.
- Går videre med Alternativ 1 og 3 for de er mer modne, for er usikker på alternativ 2.

Intern transport i celle/ produktbærer

- Alternativ 1: Vanskeligere å implementere. Ok strategisk viktig.
- Alternativ 2 og 3 er enklere å implementere og like strategisk viktig.
- Velger å fortsette med alle, for det er vanskelig å skille ut noen.
- Hvis man klarer alle de store sirklene, så har man et godt utgangspunkt.
- Økonomispørsmålet blir kommentert til å være en påvirkende faktor for videre valg ettersom sirklenes plassering og størrelse ikke har stor forskjell.

Steg 5:

1. Økonomiaspektet skal bli gjennomgått med hver gjenstående teknologi.
    a. Selv om alternativ 2 er billigere så mangler de noe. Alternativ 1 sitt tilbud er dyrest, men tror de har tenkt noen kontroller vi ikke trenger, underveis og i etterkant (kontrollmålinger som står i tegninger som egentlig ikke er nødvendig å sjekke, har ikke vært feil på evigheter så er egentlig ikke nødvendig.)
    b. Innmating: Alternativ 2 er billigere og mer fleksibel enn alternativ 1. Alternativ 2 vinner derfor innmating runden.
    c. Limpåføring og kontroll: Alternativ 1 er mer komplett og lik kjøpe pris som Alternativ 3. Får derfor mer for pengene med Alternativ 1. som derfor blir best alternativ.
    d. Intern transport/ produktbærer: Alternativ 1 er definitivt billigst. De andre kan pådra seg mye mer kostnader dersom omfanget og geometri endrer seg. Alternativ 1 vant denne runden.
2. Utfør de beregninger som er spesifisert fra investering og økonomi avdeling, prosjektledere etc.
3. Utvikle tidslinje for implementering av teknologien og hvem som har diverse ansvar som følger med en implementering.
    a. Lik på alle.

Utfør denne metoden og gå igjennom alle steg før utvelgelsen for å sikre at forarbeidet er gjort, dette er en del av metoden. Etter utførelsen skal metoden evalueres ut i fra spørsmålene nedenfor.

Bedøm denne metoden ut i fra:

- Er endelig avgjørelse tilfredsstillende?
  - Nei. Det som manglet på denne metoden er erfaring og omdømme til bedrifter på tilsvarende oppdrag. Liker mye av det alternativ 2 har skisset opp mot, men har erfaring fra hva alternativ 1 får til og sett hva alternativ 3 har gjort – og det er veldig god teknologi. Erfaringen er ikke med. Ble ikke skuffet over resultatet og tror at det kan være riktig teknologisk sett ut i fra det Nammo kan vurdere.

- Hva var lett å forstå med denne metoden?
  - Var enkelt å vurdere, klarte å plassere sirkler og lett å sammenligne dem. Å få det grafisk er alltid fint.

- Hva var vanskelig å forstå med denne metoden?
  - Ikke noe. To ting på den nedre aksen som motarbeidet hverandre litt på en teknologi. (Teknologi/modenhet og krav til grad av adopsjon)

- Hva var lett å utføre med denne metoden?
  - Vurderingen var enkel og det gikk ganske fort. Det er mye å tenke igjennom selv om resultatet er veldig enkelt.

- Hva var vanskelig å utføre med denne metoden?
  - Se ovenfor.

- Har du inntrykk av at alle nødvendige områder å etterforske er dekket med denne metoden?

  - Erfaringen til leverandøren falt ut litt. Men alle leverandører er sikkert like gode på papiret. Tidligere erfaring kan spille inn dersom man for eksempel ikke har vært fornøyd før.

- Tok metoden for lang tid?
  - Gikk fort nok, får ikke gått fortere. Må ha stegene.

- Var visualiseringen enkel å benytte?
  - Ja.

- Var metoden praktisk nok? Var det bra at den var praktisk?
  - Praktisk nok. Var veldig bra.

- Var det nødvendig å legge til flere kriterier? Hvordan fungerte dette i så fall?
    - Det gjorde vi ikke, fordi vi ikke klarte det helt. Kan hende man kunne gjort det med mer informasjon.

- Ble alternativer som var utydelige pga manglende informasjon rangert lavere enn nødvendig, slik at alternativer som muligens kunne være bra heller ble luket bort?
    - Det kan være en mulighet for det. Det er vel alltid en risiko. For eksempel på limpåføring, så ble det rangert lavere pga mangel på informasjon.

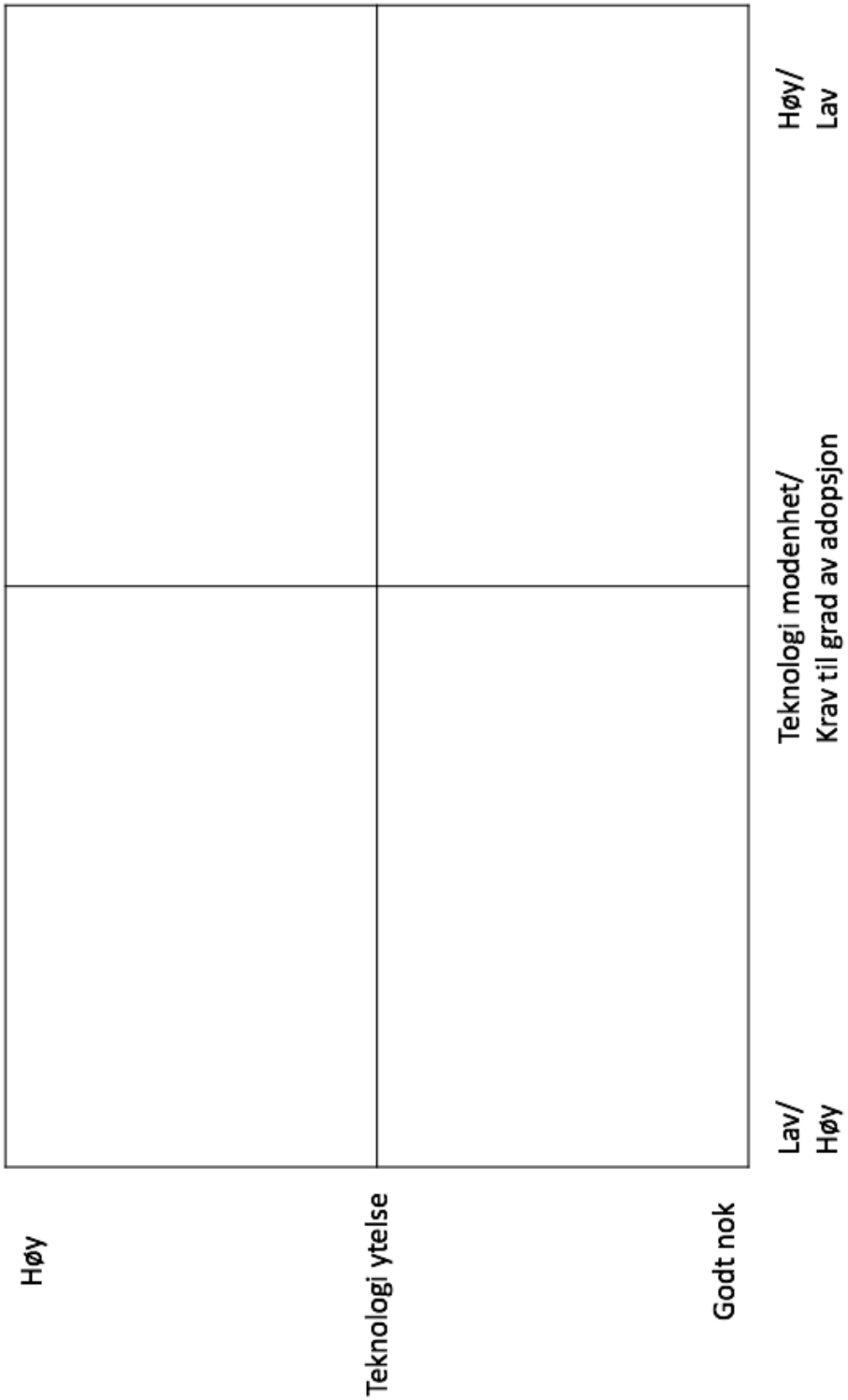
- Ble mangel på informasjon om alternativene et hinder?
    - Egentlig ikke, klarte å jobbe seg rundt det.

- Gikk prosessen fortere enn antatt?
    - Nei, trodde det skulle gå fort.

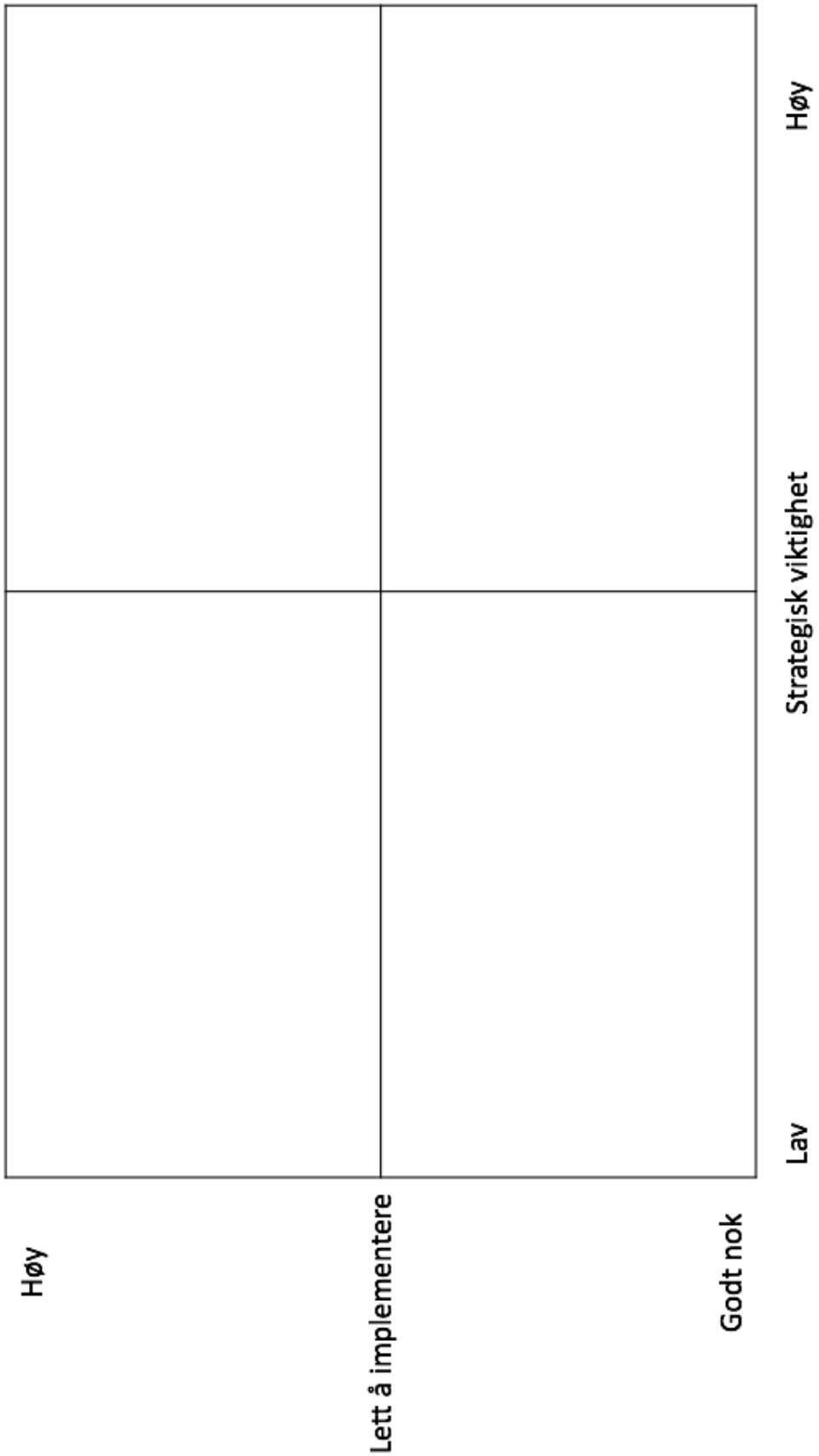
- Er en slik metode nyttig for bedriften i utvelgelsen av automasjonsteknologi?
    - Ja, det tror han. Denne prosessen blir gjort uansett, men tror det kan være lurt. Når man først får konkretisert det mer for å ta et valg så var det til hjelp. Ble litt overasket til tider, når det ble satt opp mot hverandre.

- Hvordan vil du oppsummere denne metoden?
    - Begynte med å se på ytelse og modenhet, og størrelsen var produktene den klarte å ta. Metoden tar med seg mange aspekter, og setter teknologiene opp mot hverandre. Det gjør utvalget enklere. Samtidig må man tenke igjennom alt like grundig enn om man ville gjort det på en annen måte (eks excel ark). Det er ikke like lett med teknologivalg her fordi det er så forskjellig.

Skjema for steg 3:



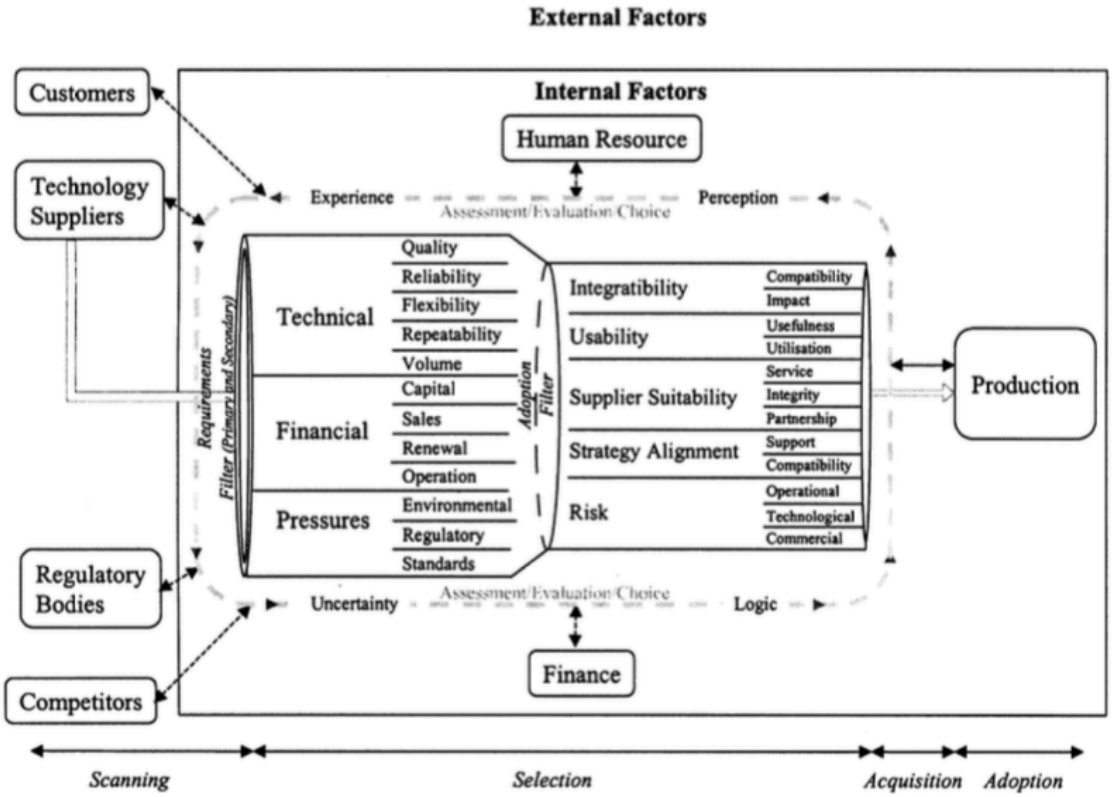
Skjema for steg 4:



Andre analysemetode

Navn: The technology selection framework

Forfatter: Shehabuddeen, N., Probert, D., & Phaal, R. (2006). From theory to practice: challenges in operationalising a technology selection framework. *Technovation, 26(3), 324-335*.



Figur 4: Teknologiutvelgelse rammeverk, fra artikkel

Et mer omfattende rammeverk ved første øyekast, men det skal videre bli forklart.

Målet med metoden:

Metoden er utviklet på grunn av mangel på veiledning av anskaffelse av automasjonsteknologi i industrien. De fleste metodene i litteraturen viser seg å være mest teoretisk og lite testet ut i praksis. Denne metoden har mål om å velge ut den beste teknologien ut i fra et utvalg potensielle teknologier å anskaffe, altså kun utvelgelsen.

Første filter:

Krav-filteret er dekomponert i under-filtrene 'teknologi', 'økonomi' og 'Ytre påvirkning'. Disse under-filtrene har viktige punkter som skal bli vurdert, og er:

- Teknologi
  - Kvalitet (av produkter som er levert av teknologien, er det mulig å levere riktige produkter med denne teknologien)
  - Pålitelighet (av teknologien, er det redusering av nedetider)
  - Fleksibilitet (redusert tid av omstillinger mellom oppetid og endring til produksjon av et nytt produkt)
  - Repeterbare (er konsekvent produksjon mulig)
  - Volum (av produkter som kan bli produsert av teknologien, hva er den maksimale produksjonen som er mulig)
- Økonomi
  - Kapital (kostnaden av kapitalen til teknologien)
  - Salg (inntekten teknologien kan gi)
  - Fornyelse (Hva vil det koste å fornye deler av denne teknologien)
  - Drift (kostnaden av å drive teknologien)
- Ytre påvirkning
  - Miljømessige (som teknologien kan tilpasses til eller hjelpe å løse)
  - Regulatoriske (som teknologien kan tilpasses til eller hjelpe å løse)
  - Standarder (oppfyller den disse)

Etter å ha fylt ut scoringmodellen vil det være tydelig hvilke alternativer som burde forkastes, og hvilke som burde være med videre i evalueringen som teknologikandidater.

Andre filter:

Det andre filteret er knyttet til innføringen av teknologien for å finne ut om det er egnet for adopsjon i organisasjonen. Filteret er delt inn i fem underfilter:

- Integrer barhet (om det kan bli integrert i organisasjonen og dens kompatibilitet og påvirkning)
- Brukervennlighet (kan det brukes til det tiltenkte formålet, om dens nytte og utnyttelse)
- Leverandør bærekraft (hvis leverandøren er akseptabel for organisasjonen, om dens service, integritet og samarbeid)
- Strategi justering (er det på linje med strategiske mål av firmaet, om støtten den gir og dens kompatibilitet)
- Risiko (usikkerhet tilknyttet teknologi, i tilknytning operasjonell, teknologisk og kommersiell)

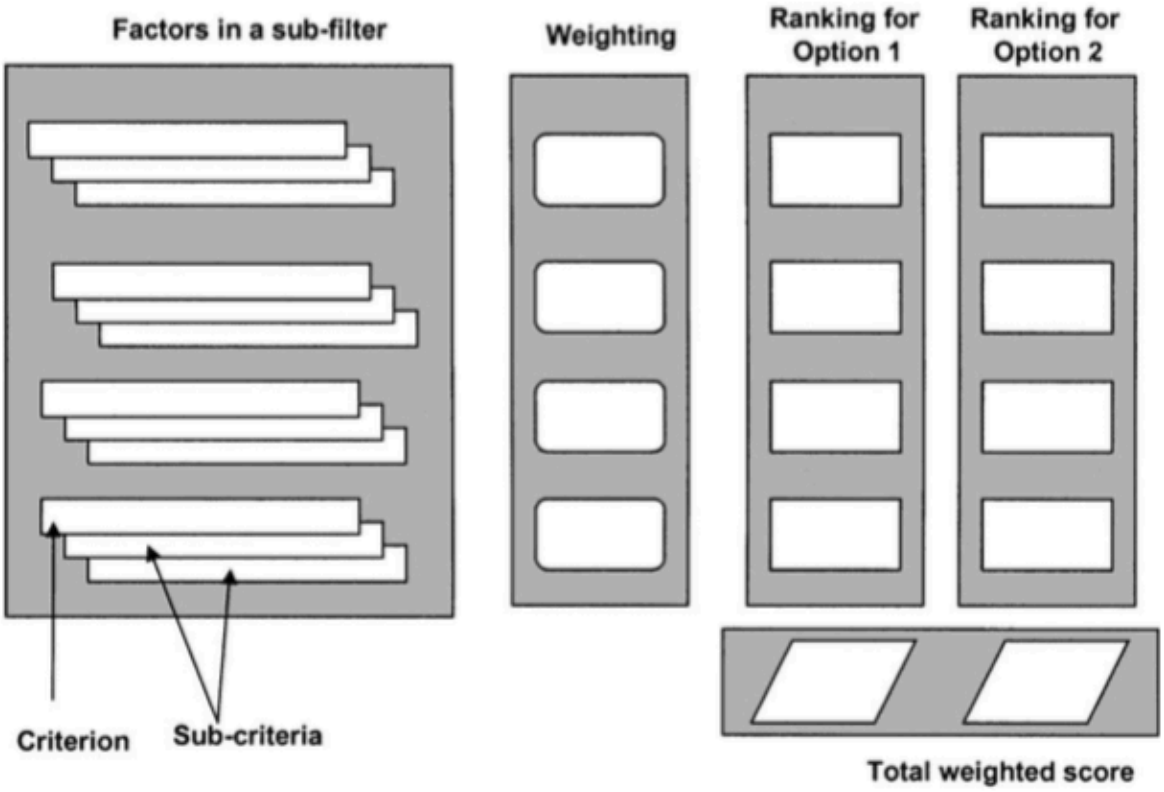
Etter å ha fylt ut scoringmodellen vil det være tydelig hvilke alternativer som burde forkastes, og hvilke som burde være med videre i evalueringen som teknologikandidater.

Interne og eksterne forretnings agenter vil også ha en påvirkning:

- Interne agenter er:
  - Produktfunksjonen
  - Finansfunksjonen
  - Personalfunksjonen
- Eksterne agenter er:
  - Kunder
  - Teknologileverandører
  - Konkurrenter
  - Myndigheter

- Det kan også være tilfelle at under-filteret eksterne agenter blir brukt som mer en sjekkliste enn å sammenligne score.

Følg metoden ved at de alternativene som kommer dårligst ut av filtrene blir eliminert og man vil sitte igjen med de best egnede alternativene. Som følge av disse filtrene vil det til slutt gjenstå en avgjørelse basert på hvilke svar som kommer ut av å ha fulgt rammeverket. Dette rammeverket skal utføres ved hjelp av en scoringsmodell som kan summere alle alternativenes vurdering opp mot hverandre. Det er derfor viktig at utførelsen blir lik på hvert alternativ. Modellen skal utføres i et Excel program ettersom bedriften ikke har tilgang på programmet Microsoft Visual Basic 6.0 som forskningsartikkelens forfatter har tatt i bruk.



Figur 5: Et eksempelbilde på hvordan scoringmodellen vil se ut, tatt fra artikkel

Første filter

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	Alternativ 4
Teknologi					
Kvalitet					
Pålitelighet					
Fleksibilitet					
Repeterbar					
Volum					
Økonomi					
Kapital					
Salg					
Fornyelse					
Drift					
Ytre påvirkning					
Miljømessige					
Regulatoriske					
Standarder					
Total score	100 %	0	0	0	0

Grå felter fylles ikke ut
Husk at summen av vekttall skal være 100%

Figur 6: Første filter fra Excel

Andre filter

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	Alternativ 4
Integrer barhet					
Brukervennlighet					
Leverandør bærekraftighet					
Strategi justering					
Risiko					
Total score	100 %	0	0	0	0

Husk at summen av vekttall skal være 100%

Figur 7: Andre filter fra Excel

Kommentarer til skjemaet:

- Det er viktig å påpeke at dersom bruker ønsker å legge til faktorer som burde bli vurdert, er dette fullt mulig.
- Når kolonnen for vektingen av viktigheten til kriteriene som skal vurderes skal fylles ut, er den totale summen å fordele lik 100. Dette skal symbolisere 100% og skal vekte viktigheten av hvert kriteria når man skal sette det opp mot hverandre.
- Ranger hvor bra alternativet er med en skala fra 1-10 der 1 er lavest og 10 er høyest. Altså om det er i positiv eller negativ forstand.
    - Det er viktig å være klar over dette i for eksempel bedømming av risiko. Da vil en høy risiko bli assosiert med mindre score pga at det er en negativitet. Vær obs på dette. Dette vil også gjelde for økonomiområdet også.
- Noen kriterier kan selvfølgelig være vanskelig å bedømme (eks pålitelighet), men prøv å bruke forestilling og erfaring etter beste evne. Om tidligere erfaring ikke finnes, prøv å oppsøke områder hvor en slik teknologi er i bruk eller hør med eksperter.

(På grunn av forskjellig bruk av program, vil det ikke være mulig å sette en begrensning for fordeling av poeng på 5 om gangen. Dette er likevel ikke sett på som noe problem, da artikkelen kritiserer metoden selv for å ha denne begrensningen.)

Utfør denne metoden og gå igjennom alle steg i utvelgelsen. Etter utførelsen skal metoden evalueres ut i fra spørsmålene nedenfor.

Resultat:

Intern transport: Vant Alternativ 3 (Alternativ 1 nr. 2 og Alternativ 2 nr. 3)

Limpåføring og kontroll: Alternativ 3 vant, (Alternativ 1 nr. 2 og Alternativ 2 nr. 3)

Innmating: Alternativ 3 vant (Alternativ 1 ble nr. 2 og Alternativ 2 ble nr. 3)

- Alternativ 1 og 3 har levert til Nammo før, det kan være en fordel. Alternativ 1 har blitt brukt mye før, da vet man hvordan man kan kommunisere med dem. Alternativ 3 virker veldig profesjonelle. Dersom Alternativ 1 hadde levert like bra tilbud som Alternativ 3 så hadde det ikke vært tvil om de hadde fått den.

Se Excel arkene i appendix X for å se rangeringen.

Bedøm denne metoden ut i fra:

- Er endelig avgjørelse tilfredsstillende?
  - Interntransport var tilfredsstillende.
  - Limpåføring og kontroll var greit tilfredsstillende (Alternativ 1 eller 3)
  - Innmating vant Alternativ 3, var som han trodde.

- Hva var lett å forstå med denne metoden?
  - Var litt mer innviklet enn den andre. Men samtidig går det mer i dybden. Tenker at den første metoden er god på en veldig fort utskilling om man har mange alternativer. Mens metode to var mer nøye og kan være grei å bruke. Hadde mer sansen for denne. Noen spørsmål var likevel litt vanskelig å forstå. Siste filter spesielt, at man burde beskrevet litt mer hva man mener. Ellers var det meste selvforklarende.
  - Enkelte ganger fikk alle fem, dette kan være på grunn av at det ikke er nok spesifisert i tilbudene. Har sett hvilke punk alterntativene er sterke eller svake på, og kan bruke dette i en dialog med dem for å få det mer spesifisert eller bedre.

- Hva var vanskelig å forstå med denne metoden?
  - Var mer spørsmål i denne metoden. At man kuttet ut en etter første filter, men så ville man ha den med videre fordi man visste at det kunne endret seg på neste filter. Men skjønner nå at det er riktig, for det er den viktigste utskillingen i starten. Men kunne vært at man ville hatt med brukervennligheten og risiko opp i filter 1. Fornyelse og drift kunne godt vært i filter to også. Her er det siste poenget med, om leverandøren, som man manglet på den forrige metoden. Men leverandørens erfaringer er for så vidt ikke med, men leverandør bærekraft veier litt opp. Erfaring med leverandøren er ganske relevant.

- Hva var lett å utføre med denne metoden?
  - Greit å følge igjennom dette. Ble fort kjent med skalaen.

- Hva var vanskelig å utføre med denne metoden?
  - Vektingen i starten var vanskelig. Og det er den mest tidkrevende delen. Endret litt på den i første runde.

- Har du inntrykk av at alle nødvendige områder å etterforske er dekket med denne metoden?
  - Besvart.

- Tok metoden for lang tid?
  - Nei. Det må ta såpass tid for å få med alt. Men man kunne også ha kutta ut noen spørsmål, men det vil variere fra prosess til prosess.

- Gjorde den det lettere å gå frem og tilbake i tankegangen underveis ved at dokumentasjonen var enkel å finne frem i?
  - Lettere å finne frem i Excel tabell enn i den med sirkler i den første metoden.

- Var metoden praktisk nok? Var det bra at den var praktisk?
  - Ja.

- Var det nødvendig å legge til flere kriterier? Hvordan fungerte dette i så fall?
  - Vanskelig å legge inn et kriterie med magefølelse. Men kunne lagt inn en som heter referamseprosjekter, det ville vært en fordel for leverandøren. Er som regel det første de spør leverandørerene om.

- Ble alternativer som var utydelige pga manglende informasjon rangert lavere enn nødvendig, slik at alternativer som muligens kunne være bra heller ble luket bort?
  - Det ble ikke gjort, lot tvilen komme de til gode. Men det var et lite hinder, hvis ikke hadde man fått slike 5,5,5.

- Ble mangel på informasjon om alternativene et hinder?
  - Besvart.

- Gikk prosessen fortere enn antatt?

  - Gikk fortere enn antatt. Så først ut som om det skulle ta lenger tid når man så figuren.

- Er en slik metode nyttig for bedriften i utvelgelsen av automasjonsteknologi?
  - Kommer hvertfall til å bruke den videre i prosjektet, og få støpt den litt til å passe. Litt av det samme som FMEA, kvalitetssikrer valget som er tatt. Er en trygghet.

- Hvordan vil du oppsummere denne metoden?
  - Oversiktlig og nær nok nedbrytet, sånn passe slik at det ikke er for mye. Den er ganske enkel å justere selv, det er fint. Slik at Nammo kan få inn det de synes er viktig. Fleksibel metode, mer fleksibel enn den andre. Den anne kunne bli brukt til sjapp screening. Mens denne her kunne bli brukt til å evaluere et ordentlig tilbud.

Opplevde å endre vekttall underveis.

Hvordan var de to metodene i forhold til hverandre?

1ern var mer subjektiv og det var lettere å manipulere den, mens den andre var mer faktabasert.

Hvilken metode gav ønsket resultat?

Limpåføring: 1 – Alterntativ 1, 2 – Alternativ 3

Innmating: 1 – Alternativ 2, 2 – Alternativ 3

Intern transport: 1 – Alternativ 1, 2 – Alternativ 3

Det var kun ett tall som var forskjell mellom alternativene i metode 2. Alternativene er også ganske like.
På metode 2 er det brutt ned mye mer, så man kan se vektingen klarere.
Tenkte i metode 1 at kvalitet, pålitelighet osv. lå inne i teknologimodenhet. Begrepet dekket ganske mye.
Liker best metode 2. Den er såpass liten og spesifikk. De første stegene i metode 1 bør nok være på plass uansett, det er der det begynner og det blir ikke noe start på prosjekt uten dette. Metode 2 gir flere aspekter.

Kunne påvirke metode 1 mer, for det gikk mer på synsing av hvem som gikk videre.

Hvorfor?
Besvart.

Forslag til eventuelle justeringer av noen av metodene?
Besvart.

Ønsker du å benytte noen av, eller deler av, metodene?
Besvart.

Første filter

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	Alternativ 4
Teknologi					
Kvalitet					
Pålitelighet					
Fleksibilitet					
Repeterbar					
Volum					
Økonomi					
Kapital					
Salg					
Fornyelse					
Drift					
Ytre påvirkning					
Miljømessige					
Regulatoriske					
Standarder					
Total score	100 %	0	0	0	0

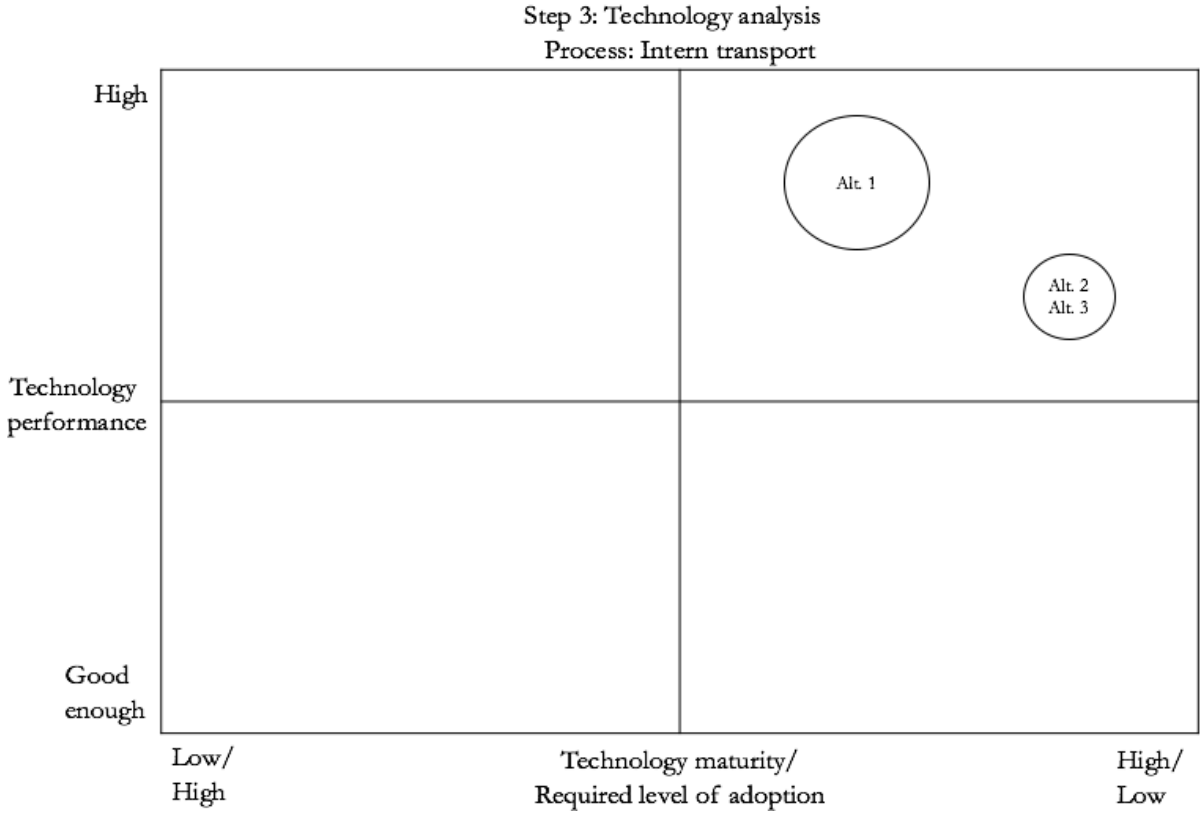
Grå felter fylles ikke ut
Husk at summen av vekttall skal være 100%

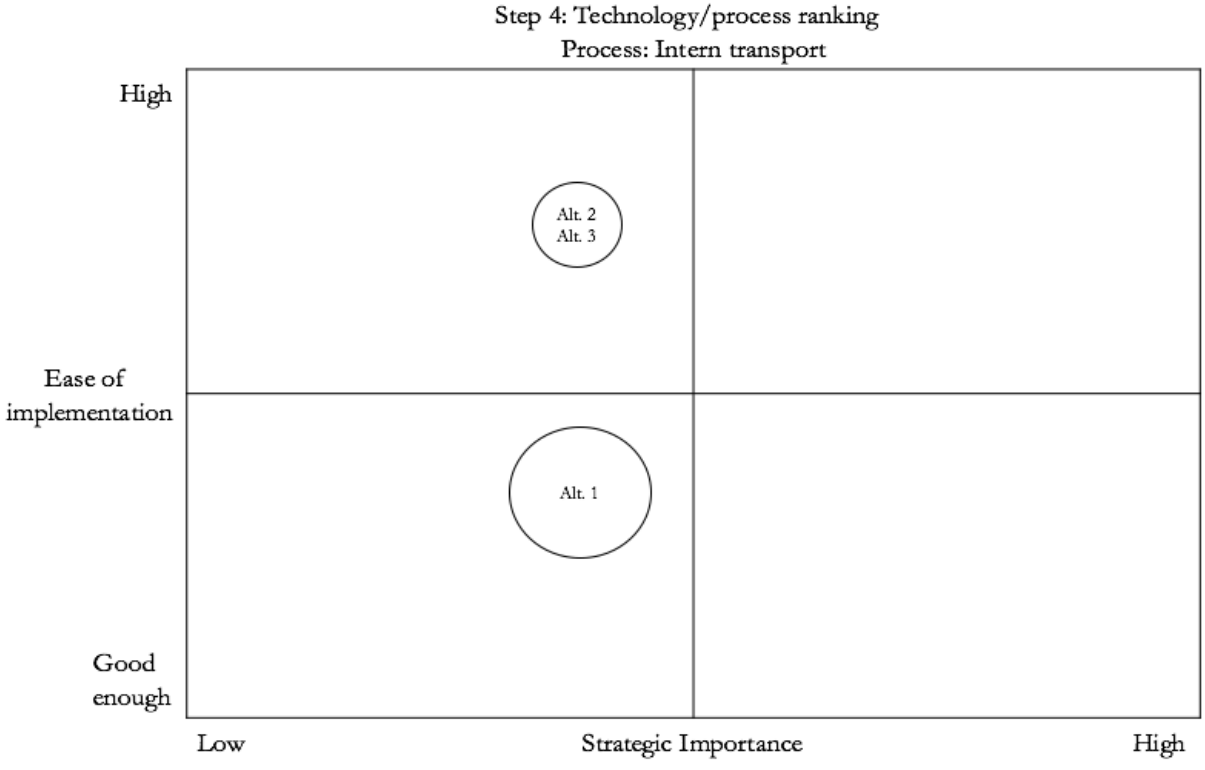
Andre filter

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	Alternativ 4
Integrer barhet					
Brukervennlighet					
Leverandør bærekraftighet					
Strategi justering					
Risiko					
Total score	100 %	0	0	0	0

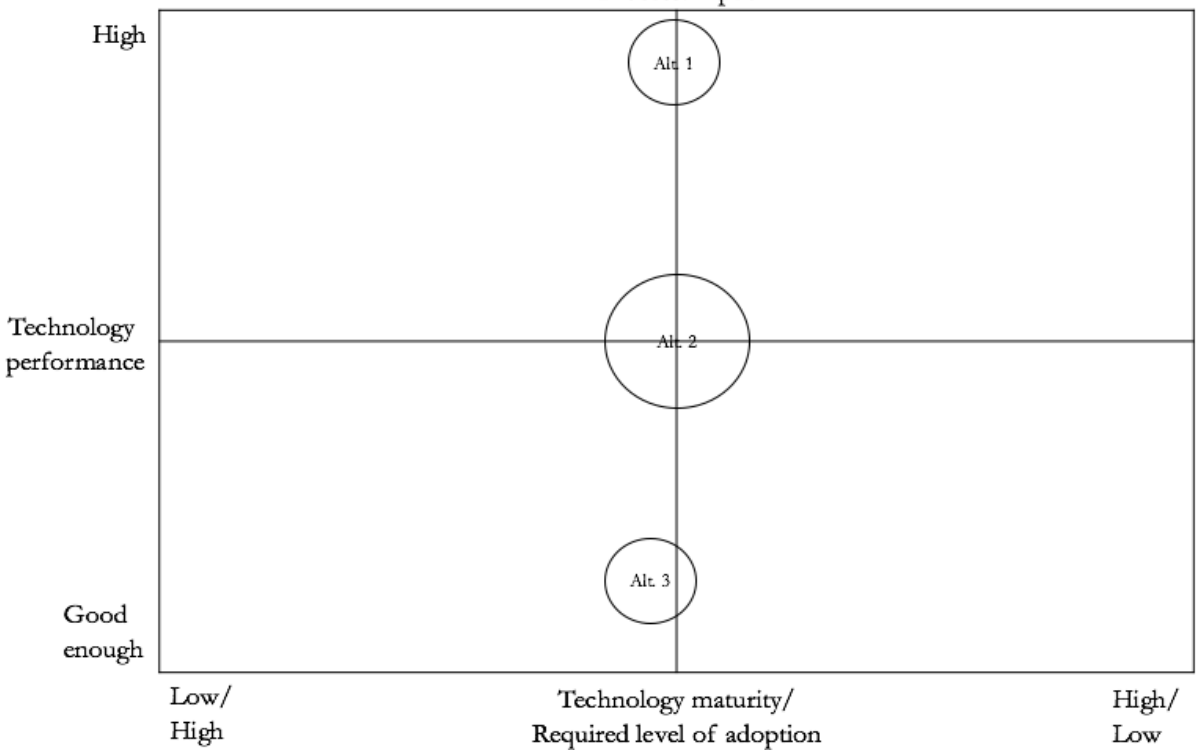
Husk at summen av vekttall skal være 100%

Appendix E: Results of the 'Automation Project Selection'

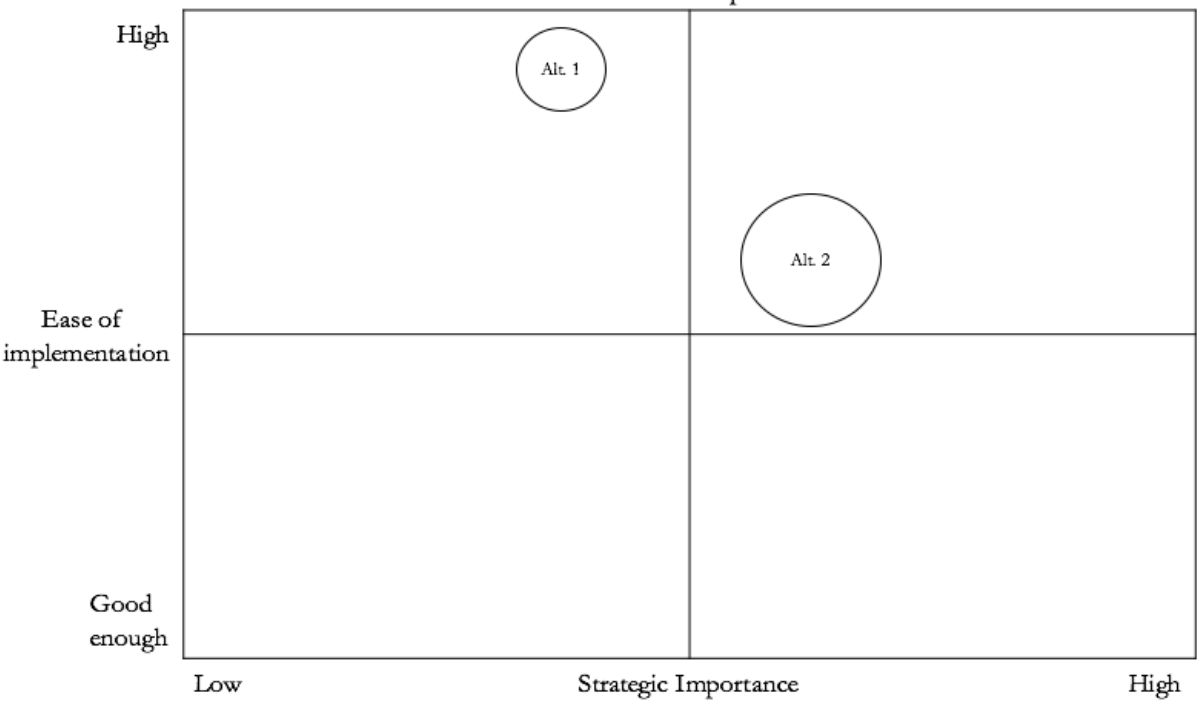




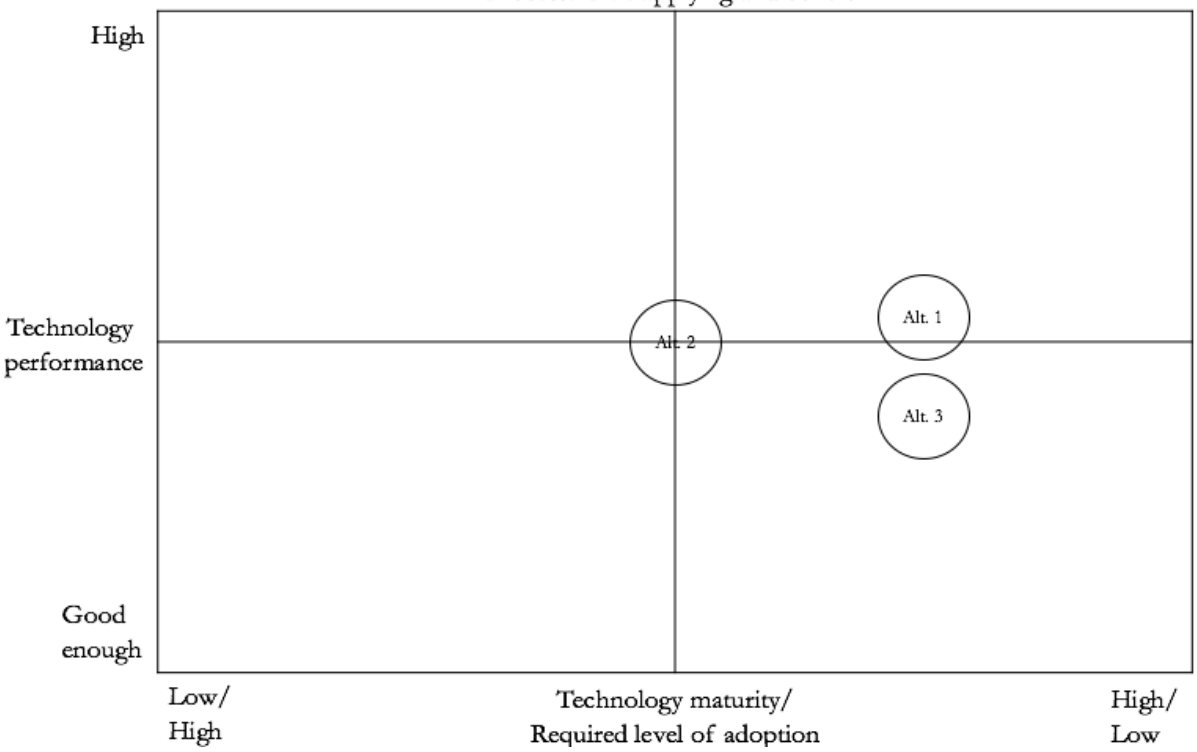
Step 3: Technology analysis
Process: Input



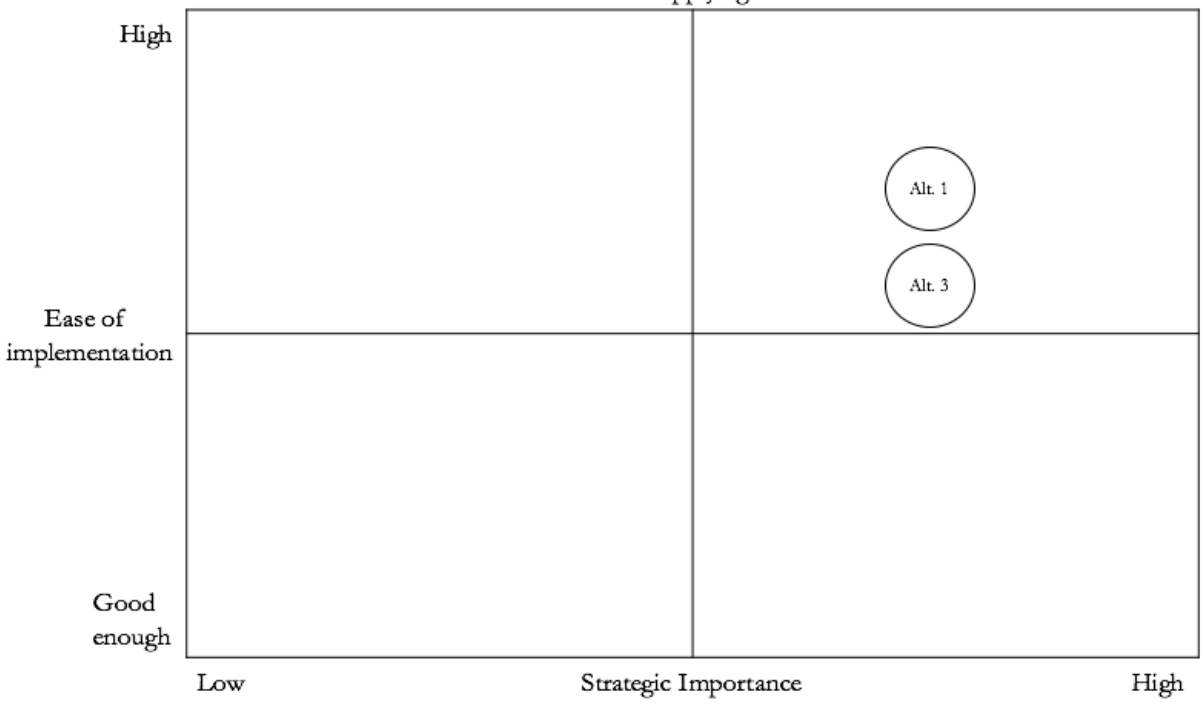
Step 4: Technology/process ranking
Process: Input



Step 3: Technology analysis
Process: Glue applying and control



Step 4: Technology/process ranking
Process: Glue applying and control



Appendix F: Results of 'The technology selection framework' (In Norwegian)

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Første filter

Prosess: Innmating

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	
Teknologi					
Kvalitet	20	8	8	8	
Pålitelighet	12	8	6	8	
Fleksibilitet	10	3	10	3	
Repeterbar	15	8	8	8	
Volum	8	3	9	5	
Økonomi					
Kapital	8	3	5	7	
Salg	5	8	8	8	
Fornyelse	3	2	4	5	
Drift	10	7	5	2	
Ytre påvirkning					
Miljømessige	3	5	5	5	
Regulatoriske	3	5	5	5	
Standarder	3	5	5	5	
Total score	100	6,15	7,11	6,22	0

Alle tre går videre

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Andre filter

Prosess: Innmating

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	
Integrerbarhet	35	8	7	8	
Brukervennlighet	30	7	6	5	
Leverandør bærekraftighet	10	7	5	7	
Strategi justering	10	5	5	5	
Risiko	15	5	3	6	
Total score	100	6,1	5,7	6,4	0

Husk at summen av vekttall skal være 100%

Alternativ 3 velges pga høyest score

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Første filter

Prosess: Limpåføring og kontroll

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	
Teknologi					
Kvalitet	20	6	5	6	
Pålitelighet	12	7	5	6	
Fleksibilitet	10	5	5	5	
Repeterbar	15	5	4	5	
Volum	8	5	5	5	
Økonomi					
Kapital	8	6	5	5	
Salg	5	5	5	5	
Fornyelse	3	7	5	5	
Drift	10	7	6	6	
Ytre påvirkning					
Miljømessige	3	5	5	5	
Regulatoriske	3	5	5	5	
Standarder	3	5	5	5	
Total score	100	5,78	4,95	5,42	0

Grå felter fylles ikke ut

Husk at summen av vekttall skal være 100%

Går videre med Alternativ 1 og 3

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Andre filter

Prosess: Limpåføring og kontroll

Filter består av	Vekttall %	Alternativ 1	Alternativ 3	
Integrerbarhet	35	7	7	
Brukervennlighet	30	7	8	
Leverandør bærekraftighet	10	7	7	
Strategi justering	10	5	5	
Risiko	15	4	5	
Total score	100	5,75	6,8	0

Husk at summen av vekttall skal være 100%

Alternativ 3 kommer best ut på limpåføring og kontroll. Alternativ 1 ble vektet lavt pga usikkerhet ved tilbudet

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Første filter

Prosess: Intern transport i celle

Filter består av	Vekttall %	Alternativ 1	Alternativ 2	Alternativ 3	
Teknologi					
Kvalitet	20	6	6	6	
Pålitelighet	12	6	6	7	
Fleksibilitet	10	9	7	7	
Repeterbar	15	5	5	5	
Volum	8	8	7	7	
Økonomi					
Kapital	8	4	6	6	
Salg	5	5	5	5	
Fornyelse	3	7	5	5	
Drift	10	6	5	5	
Ytre påvirkning					
Miljømessige	3	5	5	5	
Regulatoriske	3	5	5	5	
Standarder	3	5	5	5	
Total score	100	6,04	5,76	5,88	0

Tar med Alternativ 1 og 3 videre

Analysemetode for valg av automasjonsteknologi som skal anskaffes i bedriften.

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Dette dokumentet er tilknyttet forklaringen av metoden.

Andre filter

Prosess: Intern transport i celle

Filter består av	Vekttall %	Alternativ 1	Alternativ 3	
Integrerbarhet	35	6	7	
Brukervennlighet	30	5	7	
Leverandør bærekraftighet	10	7	7	
Strategi justering	10	5	5	
Risiko	15	4	5	
Total score	100	5,4	6,5	0

Husk at summen av vekttall skal være 100%

Alternativ 3 vinner over Alternativ 1

Appendix G: The final decision in the case company with 'The technology selection framework' (In Norwegian)

Navn på artikkel: From theory to practice: challenges in operationalising a technology selection framework

Forfatter: Shehabuddeen et al.

Process: Monteringscelle

Første filter

Filter: Krav

Filter består av	Vekttall %	1	3
Teknologi			
Kvalitet	13	6	5
Pålitelighet	12	7	6
Fleksibilitet	11	9	6
Repeterbar	10	6	5
Volum	7	7	6
Økonomi			
Kapital	5	6	7
Salg	6	6	5
Fornyelse	4	7	5
Drift	11	6	5
Ytre påvirkning			
Miljømessige	3	5	5
Regulatoriske	3	5	5
Sikerhet	15	7	6
Total score	100	6,65	5,55

Alternativ 1 tilfredsstiller kravene best	

Andre filter

Filter: Egnet for adopsjon	

Filter består av	Vekttall %	1	3
Integrerbarhet	35	7	7
Brukervennlighet	30	6	7
Leverandør bærekraftighet	10	7	7
Strategijustering	10	7	5
Risiko	15	5	5
Total score	100	6,4	6,5

Husk at summen av vekttall skal være 100%

Begge er egnet for adopsjon	

Alt. 1 blir valgt