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School of Business

Improving manufacturing capability in an SME environment

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Visa Jaatinen
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AALTO UNIVERSITY SCHOOL OF BUSINESS ABSTRACT

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ABSTRACT

Objectives of the Study

The objective of the thesis was to assess how a manufacturing SME company should assess its current level of manufacturing capability and how to prioritize improvement of the capabilities. The primary motivation for the objective was case company's recent developments that had led the company to face the challenge of how to allocate scarce resources.

Academic background and methodology

This study used the findings of manufacturing capability research to form a solid foundation for empirical case testing of the proposed methodology. The breadth and depth of research made it possible to use multiple approaches. Primary approach is the theory of manufacturing capability dimensions.

The applied research methodology was a single case study. The main driver behind the choice of the methodology was the nature of the organizational issue, which required finding reasons for how the prioritization of capability improvement projects should be conducted and why such actions should be taken.

Findings and conclusions

The key finding of the study was the developed capability assessment methodology that enables a company to analyze and prioritize dimensions of manufacturing capability. In addition, it was found that dimensions of manufacturing capability are well applicable even for a SME company, which further fortifies the theory of manufacturing capability.

Keywords

Manufacturing capability, industrial engineering, SME, Sand cone mode, trade-off theory

AALTO-YLIOPISTON KAUPPAKORKEAKOULU TIIVISTELMÄ

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Visa Jaatinen

ABSTRAKTI

Tutkimuksen tavoitteet

Tutkimuksen tavoitteena on määrittää miten valmistavan teollisuuden pieni tai keskisuuri konepaja voi arvioida omaa tuotantokyvykkyyttään. Lisäksi tavoitteena on muodostaa ehdotus miten tunnistettuja kehitysalueita tulee priorisoida.

Tutkimuksen tärkeimmän lähtökohdan muodosti tutkimuskohdeyrityksessä tapahtuneet viimeaikaisen muutokset. Nykytilassa yrityksen avainkysymys on määrittää miten kohdentaa kehitystyöhön varatut resurssit tehokkaimmalla mahdollisella tavalla. Tutkimus on tehty kohdeyrityksen pyynnöstä.

Kirjallisuuskatsaus ja metodologia

Kirjallisuuskatsaus keskittyi pääsääntöisesti tuotantokyvykkyystutkimuksen löydöksiin. Aikaisemman tutkimuksen kattavuus ja syvällisyys muodosti rikkaan taustan analyysille. Niinpä tuotantokyvykkyys ja sen osa-alueet muodostivat pääasiallisen viitekehyksen itse tutkimukselle.

Ehdotetun metodologian validoimiseen sovellettu tutkimusmenetelmä oli yksittäinen tapaustutkimus. Tämä perustui siihen, että tutkimusongelmat liittyivät kysymykseen ”miten analysoida tuotavakyvykkyyden osa-alueita” ja ”miksi esitetyt toimenpiteet soveltuisivat tähän tarkoitukseen”.

Tulokset ja päätelmät

Merkittävin tulos oli tutkimuksessa kehitetty tuotantokyvykkyyden arviointimalli. Malli mahdollistaa osa-alueiden analysoinnin ja priorisoinnin. Lisäksi tulokset vahvistavat ennestään tuotantokyvykkyyden keskeisimpiä teorioita.

Avainsanat

Tuotantokyvykkyys, valmistava teollisuus, PK-yritykset, Sand cone model, trade-off theory

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In addition, I want to acknowledge my thesis-supervising professor Markku Kuula from Aalto University's Department of Information and Service Economy for his various and insightful comments that have guided this writing process from the formulation of the initial research objective to the publication of the final thesis.

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1. INTRODUCTION

“How to grasp the command of our future“, was the question that the management of a Finland-based small manufacturing company Ratesteel asked in the summer of 2013. The management had recently acquired the ownership of the company in a buyout. The company had grown steadily and profitably during the recent years and the management had been involved in its ups and downs for a better part of a decade. The ambition for growth was still strong but it was hold at bay because daily tasks and routines were consuming too much of the management’s time. They were being buried under fire fighting and the opportunities to guide the company toward the high-level vision were few and far between. The management saw that there was a need for tools and accelerators that would enable them to efficiently grasp the control of the company, clarify the strengths and weaknesses and especially prioritize how the move forward.

Unsurprisingly, similar issues are essentially driving the operations management focused academic literature, which breadth and depth is vast. The field deals with design and management of products, processes, services and supply chains and its topics focus on every level from strategy to operations (e.g. mitsloan.mit.edu). Questions such as how to continuously improve, how the operations should be conducted or the competition tackled are at the very heart of the on-going operations management focused academic research. The researchers from the field have been able to further develop ideas initiated by practitioners to further develop praised insight. For example, the famous concepts of Six Sigma and Lean both have the general goal of improving the business performance and are prime examples of issues that operation management focuses (e.g. Tennant 2001).

While there are various successful propositions of solutions in the literature, the tools to gain understanding what are the key issues to be solved to achieve performance improvement are inferior (e.g. Kumar et al 2011). When Ratesteel approached the author, they key problem was not what is the best way to improve the company, but rather where the improvements should be targeted to. After reviewing the literature, this seemed to be a general fallacy. Many articles propose methodologies, which do not offer sufficient guidance on this area, especially not for the SME companies. Therefore, the objective of the thesis is to propose a methodology that can be utilized for this purpose. The proposed methodology is built firmly on the previous research. Most importantly, the theory of manufacturing capabilities (e.g. Kumar and Butt 2010) forms the basis for this study, and it is further supported by the Trade-off theory (Skinner 1964) and Sand Cone model (Ferdow and De Meyer 1990). The proposed methodology is inspired by work of Merrifield *et al.* (2008) and phase-gate model (Cooper 2008) but it is also an attempt to add a piece of new theory by proposing insight how the dimension of manufacturing capabilities can be used to define the course of future actions. To do this the capabilities are combined with generally accepted dimensions of project feasibility. The decision-making is supported by a modifiable scoring scale making it possible for manufacturing SME managers to make scientifically justifiable decisions logically. The decisions are likely to results in a favorable course of action because they are based on scrutinized factors.

It must be acknowledged that the proposed methodology is a result of logical steps, taken from the point dictated by real-life circumstances. Thus, it is self-explanatory that the real-life circumstances, which led to this thesis, guided greatly the scoping of the objective and lines of research. Reality is also volatile and complex, thus enabling various interpretations of what would be the optimal scope given the situation that Ratesteel was in the summer of 2013. Equally, the literature is also broad and offers endless potential lines of research. The scope of the thesis was set on the manufacturing system in thoroughly discussions with the company. Therefore, the initial research question that this thesis attempts to answer is what are the key areas of the manufacturing system to be focused on in order for the company to be prepared for future requirements of new customers. Additional question is, how these issues should be analyzed in an SME environment in order to prioritize possible necessary development projects.

This formulation of research question led to scope out some aspects that could have been perceived as valuable to clarify what Ratesteel should do in order to achieve success. These aspects include mostly macro-level analysis of current situation and opportunities, i.e. analysis of the economic developments and the industry growth trends via SWOT or PESTLE analysis.

The structure of this paper is as follows: the first section after the introduction section presents the general background of the thesis consisting of the introduction of Ratesteel. A brief introduction of the industry in scope is included into this section. The industry introduction contains among other information relevant economic data, description of industry dynamics and description of the industry value chain. This section is the foundation for later research, most importantly for the literature review, which follows it. After an analysis of the literature review findings, the initial research question is revised and formulated to further specify the research effort. Then to ground the research to current circumstances of Ratesteel, a section that discusses literature review findings in the context of the economic environment of the manufacturing SMEs is presented. Then a step-by-step methodology is introduced. The methodology section presents the logic and use of it in a detailed manner. The next section describes a case study of the methodology. The purpose of the case was to gather empirical findings to evaluate the practicality of the methodology.

The last two sequential sections are findings and discussion followed by conclusions and recommendation for future research agenda. In the first section, the validity of proposed methodology is discussed and its contribution to existing theory assessed. The purpose of the latter section is to propose conclusions and evaluate the shortcomings of this study. The recommended future research agenda proposes actions to further improve the proposed methodology.

2. THESIS BACKGROUND AND SCOPE

A Finnish mechanical engineering company Ratesteel has assigned the topic for this thesis to the author. The collaboration with the company and the author has begun in the fall of 2012 in terms of market research and identification of existing opportunities from the market. From that project the company and the author has continued the collaboration in a form of this master's thesis project

Ratesteel was founded in Middle Finland in 1998, today it employs over 30 people, and its revenue is approximately five million euros. Throughout the company history, it has showed quite a steady growth. It has matched and beaten its main competitors and the industry growth trend.

The company has a typical mechanical engineering workshop background and its roots are deep in a particular industry in the sense that it was founded for a certain need of one of its current customers. This background can be seen influencing company's operations today as well. The company does not have own products but rather it serves its customer throughout the expertise it has gathered through its history by employing most of the common manufacturing technologies such as welding, drilling, molding and coating. The technologies are employed to produce high-tech products for its customers.

The manufactured products are mainly components, which are later assembled into heavy machinery at customers' site. As is obvious, the company does not have consumer customers but only business ones. As also is considered typical, but is noteworthy from researchers point of view, the industry is not a true limiting factor for the engineering workshop. The components manufactured by the company can quite easily be sold to customers in other industries as well. Take a bearing for example. The same product can be assembled to variety of products in different industries. This is an important assumption when the company starts to target new customers.

The most important recent development that has also sparked this research project is the management buyout completed in spring 2013. The current acting management is eager to set the company on the trajectory of growth. The company has also set a monetary revenue objective to be achieved within a certain period.

The first discussions related to the thesis were centered on this willingness to grow. The main purpose for the thesis assignment was to produce supporting information for the new management to ensure the focus on the key growth related issues.

2.1. Introduction to mechanical engineering workshops

The focus is on the supplying workshops of the Finnish mechanical engineering industry, i.e. the SME manufacturing companies. The mechanical engineering industry in Finland employs 125 000 people and generated over 28 billion euros worth of combined turnover in 2012 (teknologiateollisuus.fi). The number of people employed makes the branch the largest technology related industry in the nation.

It is characteristics of the industry to strongly correlate with the economic turbulence. The branch consists of companies that produce heavy equipment and lacks consumer customers. The acquisition of the manufactured end product (e.g. ships, forest machinery, pipelines) often requires long projects and large investments from the acquiring company. Therefore, the recent economic downturn has been especially challenging for the mechanical engineering industry, since the renewals of products and new investments by customers tend to cease or at least slow down when times get difficult. This creates a bullwhip effect on inbound orders at the suppliers end.

The structure of the industry value chain is such that large exporting companies from the foreign markets generate most of the revenue at the very end of it. Many manufactured products, such as lifts, cruise ships, power plants and forestry machines have their end customers in the growing markets far away from the domestic one. The role of the Finnish mechanical engineering workshops is thereby to supply the larger counterparts (see e.g. VTT 2009, Tornikoski et al. 2011, typical also internationally see Grundowski and Waszczur 2011).

There are several small and medium size mechanical engineering workshops and it seems that many companies have formed around one of the larger exporters. It is quite usual that significantly large share of suppliers' turnover is generated through one key customer (Tornikoski et al. 2011). This forms great monolateral dependency between the supplier and the exporter.

The mechanical engineering industry has always relied on the efficiency of its SME suppliers to maintain and support the competitiveness of the entire industry (Subrahmanya 2011). The successful maintenance of competitiveness may be seen behind the fact that the Finnish mechanical engineering industry still employs more people in Finland than other countries (teknologiateollisuus.fi). This means that cost savings, innovation and overall efficiency of the industry have been good enough to enable such an outcome. However, this situation has been changing through recent years. Several recent studies have pointed out that the efficiency, adoption of new technologies and implementations of new business models have been poor. This in turn has contributed to the slow growth and lack of efficiency improvement among the supplying SMEs (Tekes 2013, Nordea and Elinkeinoelämän keskusliitto 2013, Tornikoski et al. 2011, VTT, 2009).

This means that there is a great need for the supplying SMEs to find new ways to reverse this development. Therefore, this thesis focuses to provide SME managers a holistic methodology that helps to find which of the company's capabilities are in the greatest need of development.

3. METHODOLOGY AND RESEARCH DESIGN

The purpose of this section is to describe and justify the chosen research methodology, which is a single case study. Case steady as a research strategy is one where theory or propositions are built from empirical evidence (Eisenhardt 2007). This is largely based on the nature of the research problem and that a company has assigned the research problem to the author. The fact that research problem has been assigned provides the author with valuable opportunity to test theoretical findings in a real-life context. Generally, such setting may set a challenge for research in a form of compromising the confidentiality agreement between the author and the company, while reporting factors driving the research or the findings of the research. Therefore, sometimes a multiple case study could be better choice of research because larger sample enables one to exclude confidential information from the analysis. Because the chosen methodology is a single case study, all the information is presented under the approval of the authoring company and no relevant information has not been left unreported.

The nature of the problem guides to choice of methodology towards a single case study. Yin (2009) suggests to use case studies when one attempts to find answers to how and why questions, the investigator has little control over the events or the focus is on phenomenon within a real-life context. The setting of this thesis is exactly as Yin describes. The research objective is to find answers how the SME companies should analyze the capabilities of their manufacturing system. The author is just able to observe the events rather than control or even monitor them. Finally, the real-life context is what has sparked the research and the case studies emphasize the real-world context, in which the phenomenon occurs (Eisenhardt 2007). What also guides the choice of methodology towards a case study is the identified research gap. As was explained in the introduction, the research question is crucial for the case company and the existing theory does not sufficiently address it. Usually, this kind of setting requires theory building and case studies are ideal for that (Eisenhardt 2007). Furthermore, single case study has strength when compared to a multiple case study: it enables the researcher to go deeper into the dynamics of the particular setting to truly understand it and gain more insight (Dyer and Wilkins 1991). Therefore, the choice of method is well in compliance the accepted theory. The next step is to design the research accordingly to the chosen method.

The concept of research design is defined by Yin (ibid) as “the logical sequence that connects the empirical data to study’s initial research question and, ultimately, to its conclusions”. Yin identifies five elements of research design that outline the line of research. Furthermore, Yin has also set guidelines how to ensure that case study is both valid and reliable. The rest of this section focuses on these requirements. First the five elements of research design are introduced, then reliability and validity of the research. The first element of research design is a research question. This part is relatively simple because the entire thesis is based on a real-life business issues that largely dictates the scope.

The second element is study question's propositions, which main purpose according to Yin (ibid) is directing attention to something that should be examined within the scope of the study. For this thesis, the proposition mainly refers that the answer is sought from the internal factors and external analysis is out of scope. The third element is the units of analysis, which is the major entity being analyzed. For this thesis, the units of analysis are manufacturing system and its components (i.e. activities that a company does to manufacture its products). Fourth element is the logic linking the data to the propositions. The applied technique is pattern matching. In pattern matching it is attempted to find generalizable patterns from the collected data. In this thesis, literature is reviewed to identify theoretical framework that would serve the need of a company that faces the challenges described but also to identify the research gap. In parallel, the theory is built into a methodology that is tested in a real-life context to validate it. The building of the theory is a part of the case in the sense that along with scientific findings, the practitioners' insight is a key input that supports the development. The validation is done through collection information in a form of inquiry to support the presented methodology.

Fifth element is finding criteria to interpret the collected information. According to Yin, in a case study analysis it is especially important to pay attention how the validation is done, because the lack of statistical data gives greater degree of freedom for interpretation. How this problem is solved will be described in more detail in the findings section alongside to the interpretation of findings. The key however, is to have established validation criteria before knowing, what the information at hand will be. The research design dictates the form of information, thus it is possible to formulate criteria prior to receiving the information.

The overall objective of designing the research is to ensure that the study is both valid and reliable. Both concepts are challenging for a real-life case study (e.g. Lee 1989). Therefore, one must find sufficient criteria to evaluate the concepts. To ensure validity of the study three criteria are proposed by Yin (ibid). They are constructed validity, internal validity and external validity. All of these are met. First, multiple sources of evidence are used and a logical chain is followed from the literature review to the final section of conclusions. In addition, key personnel of the case company review the material on multiple occasions to ensure that it truthfully describes the business issues. Second, multiple rival explanations are addressed to enable critical review of source information interpretation. Third, the criteria of external validity are met by applying the presented single-case study theory (ibid). In other words, the generalization of particular set of results to some broader theory will be completed.

Reliability of a case study is always a bit more challenging because the study cannot be replicated exactly (Fielding 2004). According to Yin, reliability of the researched comes from following case study protocol and collecting a case study database that is accessible for external reviewers. In this case, the separate case study protocol will not be included, as it would be unnecessary. Case study protocol is followed strictly.

The most essential components of the protocol in this case are the procedures applied for the information gathering, which are unstructured discussions with the case company's employees and formal questions. The unstructured discussions are perceived as valid because the process of answering the research question requires close collaboration with author and the company. More formal information gathering would endanger the quality of the proposed methodology. This is because without the discussions, it cannot be ensured that propositions answer the key issues.

The case study is supported by other research conducted in a following manner. The initial research objective is formulated into a research question. This was done already in the introduction section. The research question's purpose is to provide a starting point for information gathering. The information is gathering's purpose is finding sufficient grounding for the later arguments. Information gathering at this point refers solely to a literature review.

Literature review is conducted to find a framework, which could be used as an approach for the research question and to evaluate research gaps. The findings, i.e. the framework and a potential literature gap help one to revise the research question. The purpose of revision is to narrow down the research to scope to ensure that arguments are laid on a solid grounding and targeted firmly towards the initial issue that has sparked the research.

The next step in the research is the one that attempts to contribute a piece of new theory to deepen existing literature. The step consists of developing a methodology proposition that answers the research question. The proposed methodology will then be tested in a real life setting to gather insight and evidence. Before this though, a series of criteria will be developed. The criteria will define before findings are gathered how the proposed methodology will be validated.

Then the findings are analyzed against the validation criteria and other observations are discussed. These form the basis for conclusions. In addition to conclusions, a future research agenda is developed to suggest further research avenues.

4. LITERATURE REVIEW

The extensive literature review conducted serves the following purposes: Firstly, it must be understood what is the role of manufacturing SMEs in the economy, industry value chain and how significant the role is. Then, to understand the difficulties the case company is facing the key obstacles on the path to growth for SMEs must be identified. Equally important is to understand the opposite, i.e. what the key factors contributing to the success of manufacturing SMEs are. Once this is clarified, an understanding of the key capabilities driving the success and how the capabilities are developed must be established. After one knows how the improvement schemes are conducted, one must learn how to assess improvement schemes feasibility. Logical simultaneous question is to ask how to assess capability improvement projects' potentiality. The final step is to clarify how to combine improvement project's feasibility and potentiality. After all these steps are taken, one should possess a complete view of the current academic perception of the research objective.

4.1. SME companies, the economy and the industry

The manufacturing small and medium size enterprise holds a great importance to a nation's economy and to the competitiveness of the entire industry branch. Several authors (see e.g. Muhos et al. 2012, Farooquie and Khan 2010, Raymond et al. 2010, Poikkimäki, Valkokari and Anttila 2009) have recognized this. While their contribution to GDP is modest in monetary value when compared to the leading companies of the industry branch, they play a centric role for domestic economy as employment providers (e.g., Kumar and Antony 2008). According to studies conducted by to the foundation of Finnish technology industries there were tens of thousands of people employed by manufacturing SME, companies and it may be appointed that many of these companies are located in rural Finland where other employment opportunities are slim to none (www.teknologiateollisuus.fi). Studies conducted by European Union also show that this is cross-European phenomena. Besides, recent reports of ever-growing unemployment rates indicate that economies all over the EU are hoping for small entrepreneurs to boost their business in order to provide more employment (eurostat.ec.europa.eu).

The importance of SME is not limited just to the employing effect they create. An important additional reason is that SMEs have been and often are sources of innovation (Löfqvist 2010), but even more importantly they supply larger exporting companies. In fact, typical manufacturing company today is mainly the final assembling point in the supply chain rather than actual manufacturing point ((Poikkimäki and co. 2009, Joshi 2009). This means that companies seek improvement through better performing suppliers (Lewis 1995). Therefore, the competitiveness of the industry is dependable on their suppliers' ability to perform as required. Furthermore, the fact that companies are improving through their suppliers set pressure for them to come up with process innovations.

4.2. SME's obstacles for growth

The literature review clearly shows that that the superb performance, i.e. growth of the SMEs is economically important and results in improved overall competitiveness of the entire industry. However, an SME on the trajectory of growth is a rarity. A recent study conducted by "Elinkeinoelämän keskusliitto" (2013) has showed that only 4 to 6 percent of the Finnish SEs achieve annual labor force growth rate of 20%, which would be considered significant. The proportion of companies who achieve this may be considered low, since according to OECD in many competing nations of Finland, such as Estonia, the proportion of companies to achieve that growth rate is high as 13 percentages (www.ek.fi). Furthermore, another Finnish public organization TEKES pointed out in their growth study that it is the small companies in particular who not only fail to grow, but go bankrupt entirely (www.tekes.fi). This phenomenon seems to be quite common also internationally (Wheelen and Hunger, 1999).

The explanations for this tendency are vast in number and versatile in causes, some of them strongly contradict others. Some authors argue that a lot of the tendency could be explained by lack of skills, proper education and knowledge, which are a common struggles for SMEs (Subrahmanya 2011, Tornikoski et al. 2011, Raymond et al. 2010). It is noteworthy that in a recent survey conducted by the British Engineer magazine, which consisted of 700 English manufacturing SME companies, 45% of respondents pointed the lack of skills and knowledge as the main barrier to grow (Engineer Online Edition 2013).

Some academic authors put greater importance on business environmental factors (Taymaz and Ücdogk 2009). These researchers have found evidence that no lack of intangible assets conclusively proves to be causing the lack of growth. Instead, they emphasize more practical, observed reasons, such as insufficient capacity, lack of new products or means of productions and other similar factors.

Another interesting school of authors is the one that combines the two explanations. They argue that the failure of SMEs happens despite the fact that companies possess necessary intangible resources (see e.g. Lombardozzi 2013, Tuan and Yoshi 2009, Pfeffer and Sutton 2000). This is based on the observation that relatively high level of education and knowledge is observed in both successful and unsuccessful companies and therefore it cannot be the decisive factor in inability to grow. In addition, availability of physical resources is important but not sufficient. Sometimes SMEs have failed to grow regardless the physical resources they possessed (ibid). Therefore, it seems unlikely that literature will offer a conclusive explanation for the phenomena.To find an academic framework that will actually offer a solid platform for further analysis, the literature review is not focused on the observed day-to-day challenges that are common for SMEs to find a common nominator for various practical problems. It is well enough that there is plenty of strong evidence that many managers share the same type of issues and certain feeling of irresolute what to do in order to align the company for growth. Therefore, the reversed approach for framework construction is way that is clearly more fruitful. Therefore, instead of common challenges, it is worthwhile to focus on the common success factors.

4.3. Willingness and capability to grow are the key

A rather recent article written by Tornikoski, Saarakkala, Varamäki and Kohtamäki in 2011 studied the growth of the small Finnish metal works companies that all had the supplying role in the value chain as is considered typical in the industry. In their research, the authors set out to find what factors are usually essential for growth of the SMEs in the Finnish context. In their paper, they state that growth of a company bases mostly on the degree of willingness to grow, and how capable the company is to grow. Davidsson et al. (2006) have also verified their observation earlier in a global context. The concepts of growth willingness and growth capability have clear definitions.

Willingness to grow means that company seeks deliberately new ways to grow its business. For example, Tuan and Yoshi (2009) found evidence in their article that companies who introduce new products, are growing faster than those who do not (companies who compete with existing product/service portfolio). Introduction of new products is a manifestation of deliberate growth seeking. It may seem obvious but while reasons that resulted in growth may vary, be sudden and unexpected, the growth has to be welcomed and sought by the company in order to happen (Beaton 2010, Bennis 1999, Nelton 1991). From these observations, it should be derived that when researching why some companies fail to grow, the first question is to assess their willingness to grow. When there is none, it is enough to explain the lack of growth. This is an important control variable to bear in mind. From economic and operation research's perspective, the more important research objective is to examine the manufacturing SMEs who constantly and deliberately try to expand their business by acquiring more customers through marketing or innovations but still fail to grow. In other words, whose willingness to grow is high. For this, the growth capability is an essential concept; it is not only a good starting point for practitioners but it has also been in great interest of researchers for some time lately.

4.4. Capability and manufacturing capability

Generally, capability refers to company's ability to efficiently exploit their resources, to manufacture products or develop services to achieve business objectives (Kumar et al. 2010, Amit and Shoemaker 1993). Capabilities consist of skills and accumulated knowledge that allow organizations to deploy their assets and coordinate their activities through processes and organizations. Therefore, they cannot be built by imitation (Miller et al. 2002). From here it follows, that capabilities form the primary basis for competition between firms (Corbet and Claridge 2002). Therefore, growth capability is merely a different way to say that a particular company is more capable to execute its core business objectives than the rivals are. Being more capable results in growth or supports the growth. Therefore, growth capability it is theoretically and practically the same concept as the general capability.

Capability is also a problematic as a concept per se, due to the way it is commonly defined. The various definitions emphasize relative strength, efficiency and goodness in the business valuable areas. Therefore, what is practically meant with the term varies between industries. In addition, as the previous definitions have it, capability is more of a descriptive measure of the current outcome of managerial efficiency of the company, or to detach the managerial influence; the outcome of the evolutionary development of the company. Focusing on the capability in general is focusing on the status of the company's different abilities.

Therefore, it is necessary to further elaborate the concept of capability to find a more solid platform that guides analysis towards what builds a set of excellent capabilities. This is necessary for any practical examinations of capability, such as case analyses. To understand capability's connection to everyday business, first capability should be seen drawing as a concept from company life-cycle models. The idea of company life-cycle states that companies, such as manufacturing ones, are founded for a very specific need. In practice, this refers to a series of events: an opportunity arises when there is an unfulfilled need; a future entrepreneur sees an opportunity, seizes it by founding a company and from that point onward, develops the company to even better fulfil the need. Thus, a company is a vehicle to accomplish something specific (Terziovski 2010, Shirokova 2009). Therefore, as the companies compete in the markets in fulfilling the customer needs, the previous capability definitions are to be thought as companies' abilities to efficiently execute their initial purpose. The abilities companies have, are in place and have been developed for best possible execution of this initial purpose, i.e. fulfilling the need that created the opportunity. Thus, capability offers the desired platform for analysis when adjusted towards this initial purpose companies maybe thought having. This is parallel perspective with Prahland's and Hamel's famous observation of core competencies (1990).

Therefore, when discussing manufacturing SMEs, the focus should be on the manufacturing capability. This is because manufacturing is the initial purpose all SMEs share. This guides any attempts to analyze manufacturing companies to the direction of certain characteristics that have been proved essential for any successful manufacturing SMEs.

4.5. Defining manufacturing capability

Manufacturing capability is a useful amplification of general capability. It is defined as the ability of a production system to compete on basic dimensions such as cost, flexibility and time (Kumar and Butt 2010). The fact that authors connect the concept of capability to actual measureable variables is an important step for further analysis. Without this possibility to explicitly express how manufacturing capability is observed in the practical context, the concept could not be observed reliably and validly. Thus, the next important step is to find a strong consensus what is meant with manufacturing capability.

After reviewing literature, it seems most sensible that to evaluate manufacturing capability, using the five dimensions of manufacturing capability is wise. They have been scientifically proved to be sufficiently comprehensive to cover all critical dimensions of the concept and are relatively easily measurable and thus, comparable. (see e.g., Schroder et al. 2011, Kumar et al. 2010, Kumar et al.

2010, Zahra et al. 2006, Corbet and Claridge 2002, Boyer and Lewis 2002). What is more is that the most successful manufacturing companies systematically master some of the dimensions of manufacturing capability. Equally important is the observation by Raymond et al. (2010) that rarely even the most successful companies excel all the dimensions.

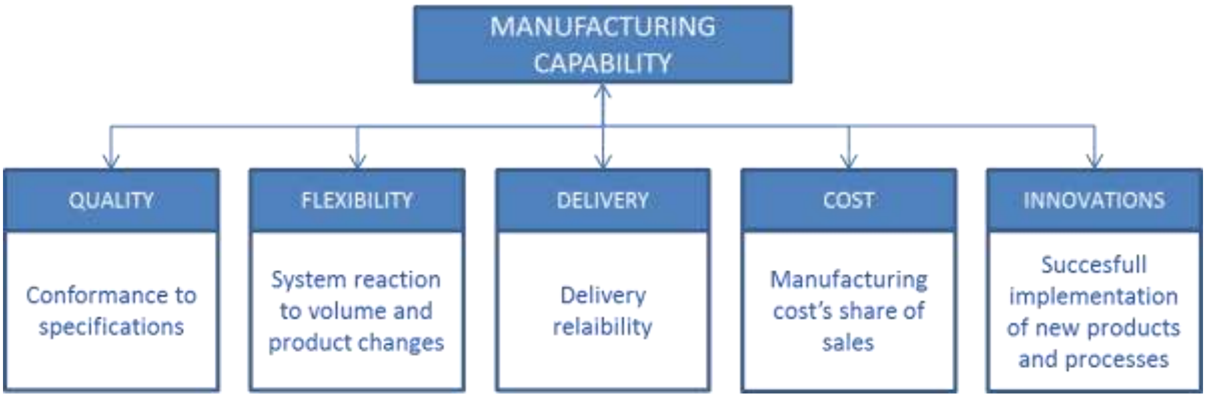

Figure 1 Dimensions of manufacturing capability

The figure above shows the consensus what manufacturing capability means. These five dimensions are a simple, yet a comprehensive way to break down what builds excellent manufacturing capability. A company aiming to be capable manufacturer should consider what they are doing in order to perform well in these dimensions. Once one understands what is driving the performance on each of these dimensions, it is easier to assess how well the manufacturing system will respond to new business requirements. This is why capability could be used as a measure to predict future performance. The table below contains detailed definitions for dimensions. For further examination for the dimensions, see e.g. Corbett and Claridge's (2002) or Ferdow and De Meyer's (1990) publications.

Table 1Manufacturing capability dimensions definitions

Quality	Conformance quality i.e. degree to which a specific product conforms to a design or specification
Flexibility	Ability to instigate rapid design changes and rapid volume changes, when measured as a total lead-time to introduce new products or process changes.
Delivery	Ability to deliver products on time to customer. Alternative perspective is the lead-time of deliveries, i.e. speed. However, on time is seen better because promised speed (lead time) is usually an order qualifier while delivering on time relative to the promised speed is an order winner (Corbett and Claridge 2002).

Cost	Level of manufacturing costs measured as a percentage of sales. Famous sand-cone model (Ferdow and De Meyer 1990) emphasize that capability to achieve desirable rate of manufacturing costs usually follows achieving sufficient quality and delivery capabilities.
Innovation	Ability to develop and implement new product or processes successfully. Innovation is not considered as a "classic manufacturing capability" as the others. Still, several authors emphasize this capability as a key one (Corbet and Claridge 2002).

In order to connect manufacturing capability to actual business performance, literature must be reviewed to assess how reliable and valid this perception of capability is. For this purpose, several studies were examined. Most studies were conducted in the light of two dominant capability models: the sand cone model and the trade-off model. These two models will both be introduced later in more detail. At this point, it is relevant to know that both models examine the mentioned dimensions of capabilities. They contradict on the domain of explaining whether capabilities develop in a particular sequence or do companies make trade-offs to achieve certain capabilities. Both theories and the studies where they are examined agree that the introduced dimensions of capabilities are the key ones for success.

Most of the studies reviewed were mathematical in nature and they were conducted as regression analysis where certain correlations were the deciding factors of accepting or rejecting hypothesis. To summarize some findings; according to study conducted by Corbet and Claridge (ibid) most commonly companies possess one or two capabilities. Out of their sample of over 500 companies, only one possessed all five capabilities. However, companies with high performance level of possessed capabilities seem to do better as opposed to rivals, even when the companies have just a few capabilities. Some other similar studies conducted by Avella et al. 2011 and Sarmiento et al. 2010 published supporting findings. From the reviewed capability studies, it is reliable to draw the conclusion that capabilities are at the very heart of success in the manufacturing industry.

Therefore, the essential concept to understand is how capabilities are achieved or how they are thought to develop. There seem to be two dominating theories, which both have variations. They are the previously mentioned sand cone model and trade off model. These both will be introduced next. As a foreword, it is useful to know that the key difference between the theories is the approach towards capabilities, which can be compacted as follows: Trade-offs see capabilities as independent, deciding and significant factors of growth and success. Therefore, the choice has to be made which of them to target. Sand cone model sees capabilities as connected to each other and obtained through specific sequence. This is because one capability supports or is necessary for achieving the one that is seen to follow it.

4.6. Trade off theory

The Trade-Off model has far more distant roots than Sand Cone Model, the concept was introduced by Wickham Skinner in 1969. He emphasized that successful manufacturing strategy requires making trade-offs between different variables like cost and quality. Hayes and Wheelwright (1984) took this idea further. They emphasized that the trade-offs are not only necessary, but also a wise choice for a business practice. Trying to compete on all of the capability dimensions would never result in a desired all-around solid performance. Instead, this would result in an unfocused effort, where resources would be hastily allocated. The created circumstances would lag the rate of capability development. Instead the authors recommend a focused effort, which makes trade-offs are vital.

It seems that the supporters of Trade off Theory do not always advocate that tradeoffs are a desirable state of business (Boyer and Lewis, 2002). The tradeoffs are more approached as given state of business and therefore the research focuses on optimal choice of capabilities and minimizing the tradeoffs. The tradeoffs themselves are seen to cause strategic inflexibility (Shahbazpour and Seidel 2007).

4.7. Sand cone model

Sand cone model is a cumulative model that emphasize that capabilities are achieved one after another and in a particular order. This was based on the previously mentioned logic: The initial theory had it that quality precedes delivery, and both precede flexibility. All three are required to achieve cost (Ferdow and De Meyer 1990). The sand cone model, the accumulation in particular, has a lot of support but the proposed sequence has many variations in the literature (Scudder 2001).

Whether there actually is, any sequence or accumulation at all has been in center of a lot of debate ever since the concept was published. The evidence for the proposed original sequence has not been conclusive. Instead, there have been more findings to support that capabilities are achieved in various different sequences (Schroeder et al. 2011). Furthermore, no particular sequence seems to be better than another is. In addition, which capability is the most important and should be first achieved depends on the industry (Corbett and Claridge 2002). There is still a lot off academics who firmly believe that achieving one capability in order to achieve another is the way companies develop and acquire capabilities.

4.8. Need for practical and holistic methodology

While the review of the two most significant theories clearly shows that they contradict one and another on the certain key issues, the both still support the role of capabilities as the key for the growth of manufacturing companies. Therefore, in terms of the study's objectives the literature findings seem very recommendable when one wants to determine how to break down the concept of capability into dimensions. Dimensions are more specific and thus, relatable for an SME. The debate of the two models is thus secondary to the primary findings of the importance of capability dimensions. This leads the research of SME growth towards the following question: if there is neither clear developing sequence nor necessary tradeoff decision to be made, how are the capabilities actually developed or assessed?

As the review of literature clearly shows, the academics cannot agree whether capabilities must be traded for one another or achieved in a particular order or not (e.g. Boyer and Lewis 2002). In practice, this means that it is quite difficult to reliably say what the capability level is if you cannot rule out the need for sequential development or individual development. Therefore, these two famous frameworks are only a little help when assessing the following key question from practitioners' point of view: how to assess and develop capabilities, and how to distinguish which capabilities to develop first. As the objective is to give a solid, practically usable recommendation for a manufacturing SME, this is a challenge for this study. To find a solution, it is important to understand why this failure to provide solutions happens.

Many theories exists, which explains the difficulties that relate to developing of an exhaustive framework. One of them is the variations among perceptions of the key capabilities between the industries (da Silveira, 2005). Industries may be inherently different enough that different set of capabilities are required in different industries. However, no causation has been found between successful performance in a particular industry and a precise set of capabilities. Other offered potential explanation is the dynamic and unpredictable nature of business environment (Brown and Blackmon 2005). The reality is too complex and unpredictable that a particular set of capabilities would prevail as the repeatable key factor to ensure success. In parallel, capabilities are even when broken down to dimensions a broad concept and it is not obvious how they should vary in relation to the industry dynamics. Finally, entirely confusing approach to capabilities has been proposed as explanation for the researchers' inability to find a consensus between the sand-cone model and trade-off theory. According to Kumar et al. (2010), the capabilities are sometimes treated as outcomes and sometimes as the means of growth. It appears that there is no clear line of research whether capabilities are what you need for growth or result of pursuing success through different improvement initiatives. Therefore, the two theories are impractical per se, but they do offer a very solid platform for further research.

Nevertheless, if the previous claims are true, then the general approach to study capabilities is thoroughly problematic. If researchers see the lack of strong evidence as result from theories' inability to take into account industry specific factors, left alone company specific factors, it seems that deductive reasoning is not very fruitful study strategy. Instead, better approach could be using the theories as a platform to forge methodologies that enables gathering observations how the practitioners view their capabilities from the theoretical point of view of the two dominant theories. I.e. what seem to be the key capabilities in different situations?

Working iteratively, over time a solid theory could be built inductively from collective findings. The only requirement would be that observations would be collected in a similar manner, relying on the dimensions of manufacturing capability. In this kind of approach, the key is to take into account the realities of manufacturing SMEs. The observations could be collected only if the forged methodology is usable for the SMEs. SMEs have very specific needs and the frameworks have to be tailored for these needs. Yet many researchers have failed to do this as the following findings show.

Researchers have followed the kind of strategy where observations are collected via methodologies and the incorporated into theories on relating research domains. For example, widely researched Business Process Redesign, Lean Six sigma and other similar holistic methodologies can be seen relating to the outcomes (capabilities) as potentially improving them and indeed from a single company's perspective. It is however questionable that is it a realistic assumption that SMEs could implement such heavy models as Lean Six Sigma. Even though there have been some attempts to tailor these methods for SMEs, the researchers seem unconfident that there exist sufficient models that help execution of these methodologies which were initially aimed for larger enterprises.

For example, Golicic and Medland (2007) reviewed Lean Six Sigma implementation articles and concluded that not only are the needs of SMEs overlooked but also the general recommendations and poorly applicable for SME companies.

Kumar et al. (2011) evaluated 17 existing methodologies' weaknesses and limitations from this domain. They summarized their findings into seven key ones. The most relevant ones were:

- Many models are built on unrealistic assumptions of data availability (larger companies possess sufficient resources to gather data more rapidly)
- 6 out of 17 had step-by-step structure (makes application easier)
- Most of the models ignore the lack of necessary resources (prioritization is inevitable)
- Too much focus on operational levels and not enough on strategic alignment (must ensure that actions support desired strategic outcome)

The authors go on to explain how in their view the Six Sigma project should be adjusted to be applicable for an SME. However, the first step in their methodology is "recognizing the need for change". To recognize the need, the authors identify five internal and external factors that should be focused upon to identify the need. They also recommend conducting further analysis to identify the exact need; however, no guidance is given how this exactly is accomplished in the SME environment.

This is rather major common shortcoming because results obtained in a study conducted by Kumar and Antony (2008) clearly showed that one of the critical lacking factors for SMEs not to implement quality initiatives is the lack of knowledge of how to gather sufficient momentum for initiatives to efficiently kick off. In other words, because SMEs have scarce resources, they cannot venture into Six Sigma-like projects just to explore the suitability. Instead, they should find the justification to make use of different quality initiatives through better understanding of their current capability level on each dimension and related desired levels.

Even though Six Sigma is one of the most famous quality improvement tool sets, and thus a good example how current literature fails to provide information, it still one tool among the many. However, similar findings have been provided by other authors as well (Ates and Bitici, 2011) from other methodologies. Regardless the focus of the studied quality tools, similar problems reoccur. This gap is discussed in the following section in more detail.

When the findings from literature review are compared to the initial research problem:

1. *What are the key areas of the SME's manufacturing system to be focused on in order for company to be prepared for possible future acquisition of new customers?*
2. *In addition, how these issues should be analyzed in a manufacturing SME environment in order to prioritize possible necessary development projects?*

It must be concluded that current research does not provide satisfactory answers for the latter of these problems. This conclusion is in line with Tornkikoski et al. (2012) who stated that current models that are aimed to develop understanding of growth in manufacturing SME context fail to provide answers on how growth is achieved. It has to be acknowledged though that regardless the same objective, in their approach they reviewed growth in a more general manner. However, in another research conducted by Zahra et al. (2006) the authors also made a supportive conclusion after reviewing the literature by stating that "most research and theory building has focused on established companies thus ignoring new ventures and SMEs". Based on the literature review, it is valid to state that growth and success in the manufacturing SME context base on several factors. From a company point of view, manufacturing capabilities is certainly one of the key scientifically valid issues. In addition, there is a good established consensus what the dimensions of manufacturing capability are.

The quality leadership literature, i.e. the methodologies focuses on different dimensions of the manufacturing capability. Therefore, the findings from this area are important for capability research as well but not holistically applicable. There are some efficient tools in quality research, which also support capability development. Especially if one thinks "quality" in a broad sense constituting from more capability like dimensions, rather than just "conformance to specifications as it often is defined. Whether the quality tools actually work o in the SME environment or develop understanding of capabilities is questionable. Even though there have been attempts to tailor them for the manufacturing SME environment, more often than not these attempts seem to be unsuccessful. Reasons are various but it seems that this is mainly because SME managers do not perceive them suitable due to the lack of resources and arguably lack of knowledge. This has resulted in lack of practical and holistic methodologies.

Therefore, it seems that there exists a gap in the literature between suitable methods that assist the evaluation of current capabilities, identification of necessary areas to improve and developing understanding for why exactly a particular capability project is initiated. In practice, this means that practitioners probably find it difficult to define focus, gain momentum and sponsorship for capability improvement projects.

Therefore, when considering the scope of this study it seems that the task is plain and simple. From the literature review what is left over for further analysis is the second part of the initial question:

1. *How should the dimensions of manufacturing capability be analyzed in a manufacturing SME environment in order to prioritize possible necessary development projects?*

To answer this specific question and to cover the issues from this section a capability assessment methodology is developed and introduced in the section after next. The methodology aims to be practical and holistic. To ensure practicality, the next chapter discusses how capability dimensions relate to the realities of manufacturing industry. The reason for this is not only to ensure that methodology is tightly knitted to the dynamics of reality, but also to provide additional insight that supports the basing the methodology on capabilities.

5. FOCUS ON THE MANUFACTURING CAPABILITY ENSURES FOCUS ON THE KEY ISSUES

After reviewing the literature, it is clear that from scientific perspective focus on the manufacturing capabilities is beneficial, when the target is to determine how well a company's manufacturing system is prepared for different customer requirements. Before introducing the developed model that answers the research questions, it shall be evaluated if manufacturing capability is also important from more practical point of view. The goal is to assess the need for this research finding from a more intuitive point of view to ensure that the research has besides academic value, also practical value. However, if the connection of capabilities and the practical issues of the industry can be connected the research findings will also be more valuable from both, academic and practitioners' point of view.

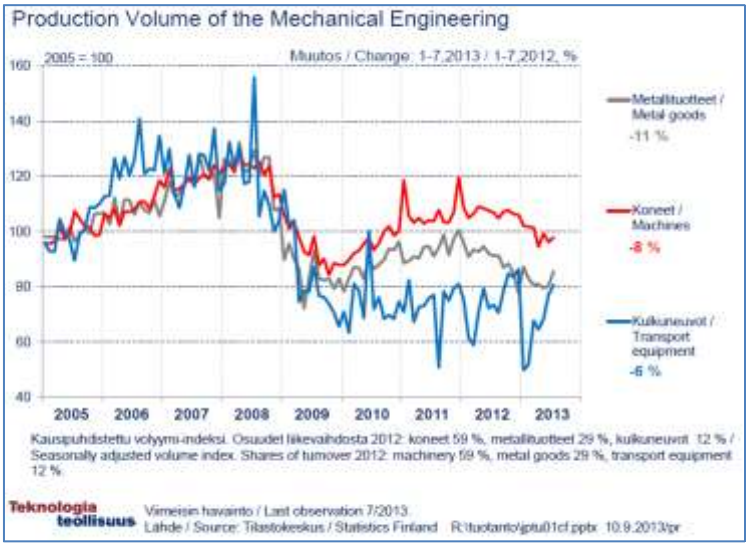

Figure 3 Production volume (Technology industries)

Figure 2 Volume of Industrial output (Technology industries)

To start this discussion, it is useful to know that the mechanical engineering industry is a mature branch and general growth has slowed down and even turned to negative as the adjacent table figure shows. Besides, as emphasized before, mechanical engineering industry consists of suppliers for heavy industry. The heavy industry has been set back by overall economic downturn. The downturn has also resulted in difficult times for the suppliers as well. The lack of growth means that the suppliers cannot entirely trust on their current customers to recover and provide them with more business opportunities.

Therefore, the supplying companies, such as the case company, have to start to look for growth opportunities outside of their current customers. This leaves the companies with an important choice that affects the way the business should be adjusted in the future. That is how new customer can be found. Generally, two different approaches are possible: Push-based sales and pull-based sales.

Push means that company applies its current product portfolio to find new customers and pull refers to a process where company first identifies the market needs and adjusts itself to serve those needs. The choice is based on the company's core competence. If the company has strong demand for its existing, products it has the privilege to apply push strategy, which usually requires less flexibility from the company. However, a supplying company in this industry seems rarely to have this opportunity.

Instead, for the manufacturing SMEs it is probably more necessary to apply the pull strategy. This means that first through steps that are not in the scope of this thesis; a company identifies growth opportunities from the market, i.e. potential new customers. In the mechanical engineering industry, the negotiations seem to follow quite typical path: Preliminary discussions with potential customers to assess collaboration possibilities, customer audits the suppliers premises, price negotiations, test series (Jaatinen et al. 2013). During this process, the customers evaluate supplier's flexibility, deliveries, price and quality.

In addition, because manufacturing SMEs don't usually have own products other than the components which features may vary from one customer to another, the push based demand is practically irrelevant. Once the company enters the preliminary discussions, the company cannot even qualify the offer unless it can assure the potential customer of the company's capability to perform on the four assessed dimensions. This means that all revenue increases are probably achieved through pull-strategies. The pull strategy that is assumed the industry norm is illustrated in the figure 2 on the following page. From the figure, it is seen that once a company identifies the opportunities (customers) from the market, it enables predicting what the future revenue could be.

As is displayed, along with revenue comes the new customers' requirements that company must be able to cope with in order to generate the revenue. As mentioned before, alongside the company life cycle modes, this boils down to company's goodness to execute its initial purpose. The initial purpose is delivered to customer through two systems in a form of products and services: supporting system and manufacturing system. The manufacturing system refers here to the functions, processes, tasks and responsibilities that are accomplished to deliver the customer order. Supporting system refers to the functions, processes, tasks and responsibilities that are accomplished to support the smooth accomplishment of manufacturing system. This definition is deliberately vague because it is important that manufacturing role be assigned also to activities, which are not always though as having that role. Another important observation is that the relation between objectives and the systems is bilater: on one hand, the customer requirements define what these systems must be able to accomplish and on the other hand, the current state of the system dictates what the requirements that the company could currently handle are. In the figure, an arrow that points both ways indicates these relations.

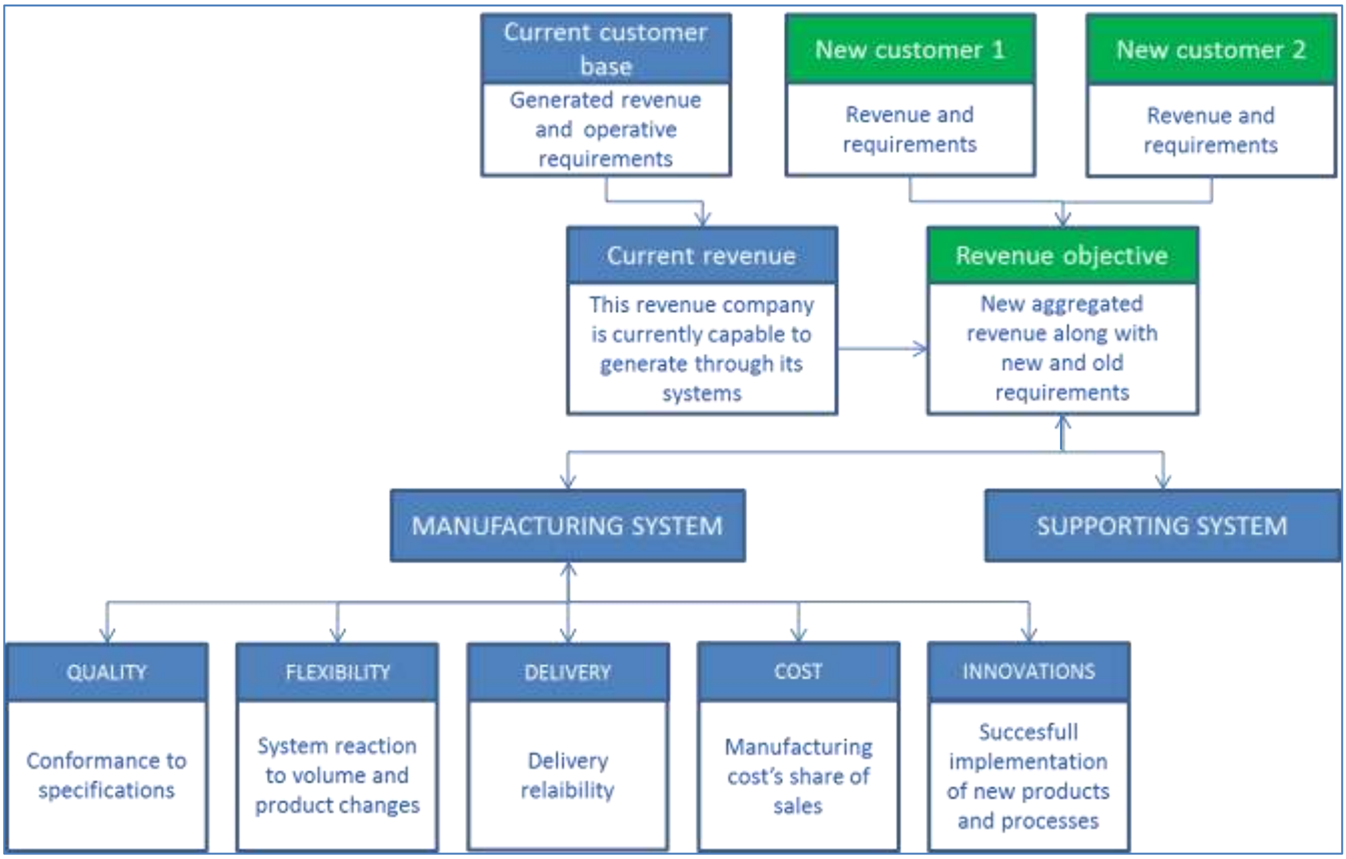

Figure 4 Connection between capability dimensions and growth, illustration by author

As was explained along with the typical industry negotiation process, when entering the preliminary discussions with customers, a company must possess clear perception of their own capabilities regarding the two systems, manufacturing and supporting. In this scope if the study is the manufacturing system. Even though supporting system is not in the scope, it is not overlooked. However, the logical sequence is that as the supporting system supports manufacturing system, it will be adjusted based on the needs of manufacturing system. Therefore, it is necessary to develop understanding of the manufacturing system's capability to understand the capabilities needed from the supporting system.

To summarize, the mechanical engineering industry has faced tough times in the recent years. Competition is intense and often the companies have to assure their potential customers that they possess sufficient level of skills and capabilities. One way to scientifically approach the development of the capabilities is to base the analysis on the findings of the capability research. Capability dimensions seem to fit well with the described dynamics of the industry as they are also in the interest of customers during supplier reviews. To further develop capability research and especially to provide practical help and insight to Ratesteel, the next section introduces a capability assessment methodology.

6. THE CAPABILITY ASSESSMENT METHODOLOGY

This section introduces the developed methodology. Because the literature review did not produce a sufficient model, the overall goal of the developed methodology is to solve the research problem; *how should the dimensions of manufacturing capability be analyzed in a manufacturing SME environment in order to prioritize possible necessary development projects?* In addition, the methodology aims also to be a way to collect observations from practitioners for additional insight to support the on-going capability research.

Therefore, this methodology offers a bridge over the existing research gap between manufacturing capabilities and improvement tools by offering step-by-step guidance for ensuring the initiation of feasible and efficient development projects. Below in the, figure 3 a general sequence of the objectives that will be completed in the methodology is presented.

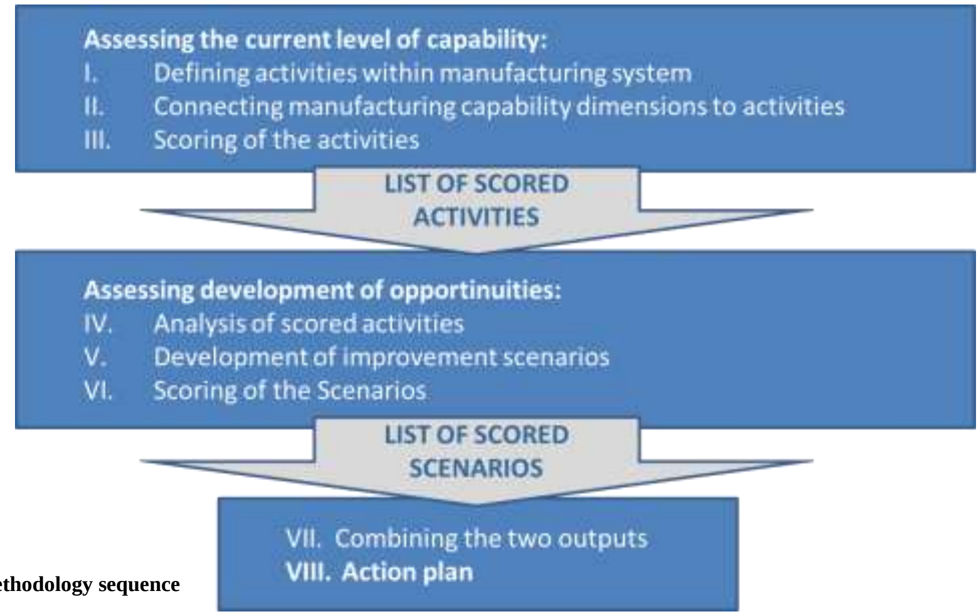

Figure 5 The methodology sequence

As is understood from the figure, the methodology consists of three major phases. The overall goal is that after working through each sub phase within the methodology a comprehensive action plan has been built that ensures that managers will have the correct overall direction of actions over time. Correct means that as a company will initiate various development projects during its path to growth with different objectives, the general objective will remain as improvement of the strategic key capabilities defined in the project that this methodology guides.

For the phases i-iii the of capability analysis, the main idea of scoring capabilities is based on the article written by Ric Merrifield, Jack Calhoun and Dennis Stevens, published by Harvard Business Review in 2008. In the article, the authors argue that when analyzing a company, the key is to assess each functions value to business. The authors emphasize the focus on primary purpose and outcome in business instead of how business is done is the new necessary business imperative. The author’s idea is general, but very powerful and adjustable to level that is more detailed.

In terms of capabilities, the activities a company does are valued based on how much they contribute to the dimensions of capability, i.e. what is the primary purpose or the outcome of the activities. When an activity is performed to the excellence, but the outcome of it is unnecessary there is no sufficient rationale to pursue the activity. In a similar manner, two seemingly different activities may both result in a similar outcome in terms of outcomes. This makes one of the two a redundant. This is why the authors emphasize to focus an approach on the outcomes. Identifying duplicates and improvement priorities is very efficient when completed in this manner. This is the governing thought of Merrfield et al. (ibid). However, their article was quite general. For this methodology, their governing thought is taken to the more specific level.

6.1. Defining manufacturing system

The first step of the methodology is to define the manufacturing system. This is the most important step in the whole methodology. The criticality of this step will be clear later on but at this stage it shall be emphasized that offhanded execution might result in not only useless but also deleterious results. The starting point for this definition of the system is the previously presented definitions: manufacturing system refers to activities (i.e. functions, processes, tasks etc.) accomplished to deliver the customer order. Therefore, in this phase all of the activities have to be evaluated from this perspective. One of the strengths of SMEs is that this phase is actually possible to carry out in a relatively short period.

To carry this phase out in practice, a company can utilize organizational charts, process maps, process flow charts, internal reports and even intuition. However, the documentation level is not a decisive factor because there are multiple ways to gather the activities. Worst come to worst, management can interview employed individuals and gather information of their routines and responsibilities. This however, is unfavorable choice of action due to the lengthening effect on time required. It is expected that most activities have a quite clear purpose, and are thus quickly assigned to the manufacturing system. The entire value of this phase is however, to include activities into manufacturing system that might normally not be treated as part of it. The idea is that to assess capability, one must be able to define all the activities that affect its dimensions. This takes us to the second phase of the methodology.

Table 2 Methodology phase i

#	Activity	Dimension	Value to capability	Current performance	Controllability	Predictability
1	Painting					
2	Ordering					
3	Assembling					

6.2. Assigning activities to capability dimensions

As the list of manufacturing system's activities is being collected, the activities are simultaneously assigned to capability dimensions (quality, flexibility, delivery, cost and innovations). The goal is to identify the primary purpose of each activity, which is often broader than the practical purpose of them. E.g., painting is just making the products to look nice and last longer, but capability wise it is important for the quality dimension. In the table 3 you can see an example if this phase where the used tool is simply an Excel spreadsheet.

Table 3 Methodology phase ii

#	Activity	Dimension	Value to capability	Current performance	Controllability	Predictability
1	Painting	Quality				
2	Ordering	Flexibility				
3	Assembling	Delivery				

It is preferable that an activity is assigned to just one of the dimensions to simplify later stages of the methodology. This is not required for one to use the methodology, but rather to make sure that development of improvement scenarios will be efficient as well. It might be challenging to assign the activities to just one dimension. There are some approaches one can try to quickly make the task clearer. It is may be necessary to break the activity into sub activities. For example when discussing design process, it might be difficult to distinguish whether the primary purpose is to ensure quality or cost. Clearly, the whole process of design contributes to quality, but also determines the cost of production. Therefore, the design process can be broken down to sub activities such as design of specifications and design of materials and to as many as one finds necessary. The design of specifications would be assignable strictly to quality. The design of materials would be strictly assignable to cost. Another good approach is reversed one; if the activity is poorly accomplished or not at all, what dimension of capability it will affect firstly or mostly? When there are many candidates, it is likely that the activity should be broken down to sub activities.

After completing the first two phases of the methodology, one has produced a list of activities and their dimensions. The list is the key input for one to create understanding of a company's capabilities. The next step is to process that input, i.e. score the activities.

6.3. Scoring the collected and assigned activities

Once a complete list of the activities is completed, it is time to evaluate and assign them to one of the given capability dimensions. Merrifield with his co-authors (ibid) recommends the following trimetric perception of necessary variables with their respective definitions:

Table 4 Initial assessment variables

Business value	Does the activity differentiate your company from competitors, greatly influence whether customers buy from you and remain loyal, or drive a key performance measure such as cost of manufacturing, product quality, or time to market with new products?
Current performance	Is the performance of an activity's underlying capabilities excellent, inconsistent, or poor in terms of your company's needs and relative to competitors? How much investment is necessary to raise performance to the required level? Would the higher performance justify the investment?
Predictability	Are the outcomes that an activity delivers (in terms of cost, time, quality, and so on) inherently predictable or not? The answer to that question is important because if the outcomes are highly unpredictable, the activity (or at least its user interface) will be difficult to automate.

For capability assessment methodology, the definitions above are not suitable per se. They are broad and not tailored to take into account the manufacturing capability dimensions. The definitions above have been slightly modified to be better suited for manufacturing capability evaluations and to be fit for SME environment in the table 5.

Table 5 Modified assessment variables

Value to capability	Instead of business, value in the consideration is the assigned dimension of activity. An activity in the manufacturing system should hold at least some value to one of the dimension. If it does, it will contribute to the business value of your manufacturing capability.
Current performance	This variable fits as long as managers can find truly meaningful data to back up the evaluation. When the data is unavailable, the following aspect will act as a substitute. However, if you have true means of measuring current performance, ask is the performance of an activity's underlying capabilities excellent, inconsistent, or poor in terms of your company's needs and relative to competitors.
Controllability	Current performance is better suited for larger, more resourceful companies who have holistic and robust measurement systems already in place. In SMEs not every element of manufacturing system is measured or has a clear benchmarking value. Controllability offers a more intuitive approach resulting in similar perception. To measure ask how well does the management know how a given activity is conducted, how quickly could you adjust or how easily have you adjusted the particular activity? If you would like to change the purpose or the outcome of the activity, do you know exactly how you would adjust it? When you have a positive answer for this type of questions, then this particular activity is probably performing up to expectations.
Predictability	While predictability might seem same as controllability, in the analysis they are anything but. Predictability refers to the activities outcome regardless of its controllability. For example even if you have very strict sales process in place, the outcome will never be predictable to the same degree as for example basic technical welding process. This measure’s main purpose is to act as a control variable for further actions as will be explained later.

6.4. Scoring the activities

To evaluate how well an activity is currently doing on each variable they must be scored. However, instead of three steps qualitative (low - medium – high) scale that Merrifield et al. used (ibid), it is recommended to use five step scales and simple number basis. This may seem like a minor adjustment, but it is an important one in fact. The reason is that three does not produce sufficient variance and there is a risk that it is difficult to distinguish the priorities in the later phase. Besides, qualitative low – medium – high scale is more difficult to enter into basic office tools.

For example if for sake of simplicity the scoring is limited to integer numbers and current performance and controllability are used as substitutes, a scale from one to three would produce only 3^3=27 possible combinations. Chances are that a manufacturing system consists of more activities than just 27. For further use of the methodology such, a limitation would make distinguishing of priorities difficult since many activities are likely to get exactly the same score.

When the chosen three variables of the possible four ones are scored on a scale from one to five, scoring would result in exactly, 3^5=125, one hundred and twenty five different combinations when then scoring is limited to integer numbers. That is a significant increase of variance and therefore better for later phases of methodology. However, the scale may be divided into as many categories as managers feel necessary to produce meaningful distinguishing. What comes to the chosen variables, they are expected to be independent and don not correlate ex-ante, i.e. they describe activities from different perspectives and an activity may have any combination of values.

As for predictability, its purpose as a variable in the methodology is mainly to act as control variable in the later steps. As one may understand from its definition, it separates activities that are inherently easier to improve from the more difficult ones. The inherent predictability cannot easily be changed.

Below a combined figure is presented as an example of scored activities presented as histograms.

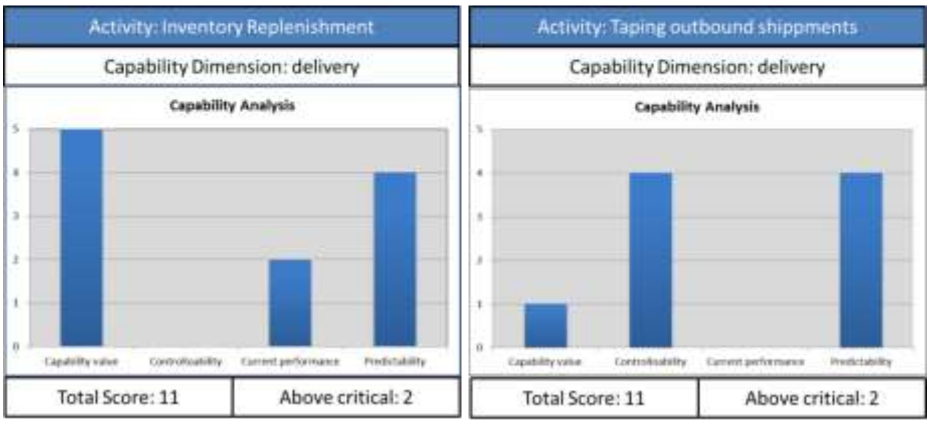

Figure 6 Example of methodology phase iii

As is seen, the activity on the left hand side is scored on current performance indicating that there has been collected data to utilize while other is scored on controllability. The functions of "total score" and "above critical" will be explained later. At this point is important to note the rather self-evident fact total score is the sum of all given scores on the three variables.

Once every activity that was assigned to the manufacturing system has been connected with its respective capability and scored on these three variables, one has created a holistic perception of the current capability level of the manufacturing capability. This completes the first phase of the methodology. Now this data will be analyzed which is at the core of the second phase.

6.5. Analysis tools for scored activity

The key to utilize the scoring work is considering the three out of four aspects simultaneously and understand the relations that varying scoring combinations result in. The scoring is used to rank activities and the rank forms basis for prioritization. However, this is slightly more complicated than just picking the activity with highest total score for development. Additional clustering is needed as well. It is important to be able to effectively cluster the scored activities somehow to fasten the deployment of improvement projects.

For clustering, a special kind of heat map is necessary. A heat map is mainly a visual illustration of the relations that the considered variables formulize. Because this methodology has four aspects, three of them used for one evaluation and controllability and current performance being substitutes, the visual interpretation is inherently three-dimensional. This is showed in the picture on the left hand side as an empty cube. The previously used scales and aspects are attached. The origin is considered to be in the front low left corner. It is important to note that predictability increases towards origin, while other attributes increase away from origin. It is easy to see, that all the scored activities will find a place inside the cube depending on the assigned scores. The position the activity gets inside the cube describes its relevance for the company's overall manufacturing capability and thus the potential benefit when improved.

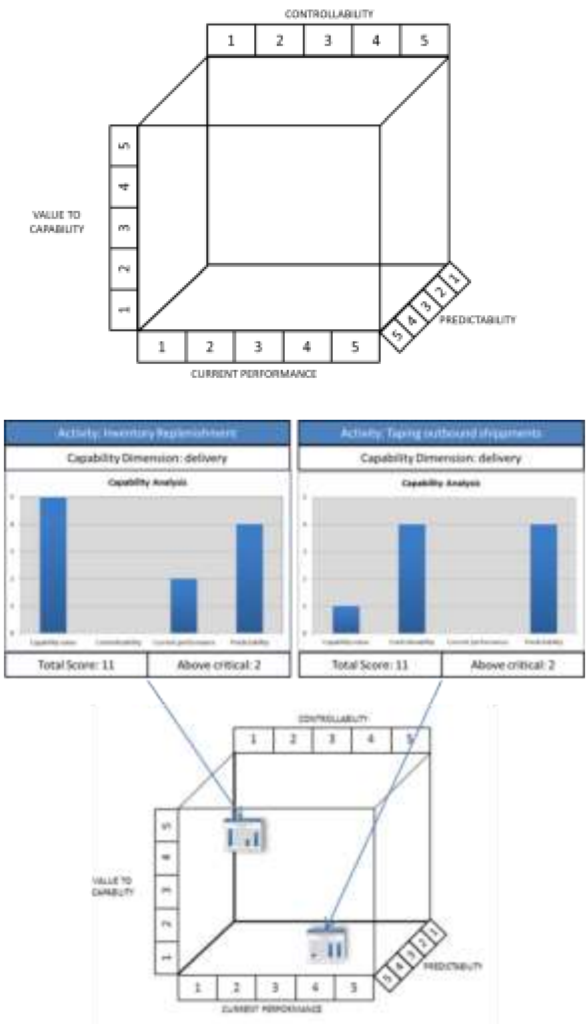

Figure 7 Scored heat map and the activities

As is seen the activity on the left hand side has gotten five on value to capability, two on current performance and four on predictability. The combination these scores form have the activity located in the top left front corner in the box. In a similar manner, the next activity finds its place on the top right front corner. Theoretically, each of the scored activities will find a phase within the cube, based on the score an activity was assigned in the previous phase.

It shall be noted that it is not expected that a company actually use the cube for clustering. For the actual clustering there is a different, better tool set for available. The purpose of this example is to illustrate the logic that is used in the actual clustering to better make sense of the interactions that the four variables have.

6.6. The variable scores and clustering the activities

To approach the analysis of the interaction of the three used variables will be examined on the following assumptions of scoring: three is medium and less than three is considered low. Likewise, three or more is considered high. This assumption is mainly for discussion purposes but it is believed to be a useful simplification for practical analysis as well. From this basis, it is simple to exhibit the variable interaction with the previous cubical illustration.

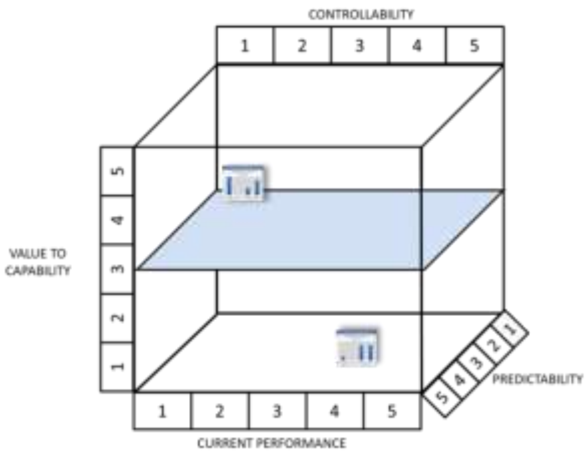

Figure 8 Clustering the activities

The primary purpose of the methodology is to ensure that the company will focus on the most important issues within the manufacturing system. As Merrifield et al. (ibid) state in their business capability improvement article, the key is to find and focus on the activities that contribute most to overall business capability. This conclusion forms base for manufacturing capability improvement methodology as well: The Company should concentrate its efforts on those activities that were scored high on the value to capability variable. What is considered high depends on the actual distribution of activities within the cube but a general rule of thumb is that activities scored three or higher hold more intrinsic capability value. The blue layer illustrates this. The activities located below the blue layer hold less to medium intrinsic value for the given manufacturing capability dimension and thus, for the overall manufacturing capability. The practical assumption is that improving activities below this layer would never significantly improve the company's manufacturing capability when compared to the potential of the activities located above. The purpose of this assumption is to ensure that SMEs limited resources are concentrated on potentially more beneficial improvements. Value to capability is however not the decisive factor alone. The other two variables enable making of valuable conclusions from activities and thus, play crucial roles on how the activities are finally ranked. Next, every possible cluster of three variables is examined to demonstrate the conclusions.

Activities scored low on value to capability, predictability and controllability

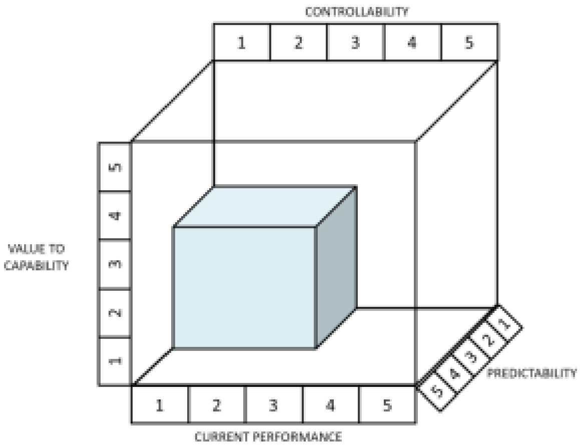

Figure 9 Activities scored low on value to capability, predictability and controllability

The first possible combination of scoring to be discussed is those activities scored low in every aspect (current performance or controllability, predictability and value to capability). Clearly, these kinds of activities hold the least value for the manufacturing capability because of the low intrinsic capability value, poor performance or difficulties to control the activity and unpredictable outcome of the activity even when it is in control. Therefore, attempts to improve capability should be aimed anywhere but to the activities in this area. Instead, managers should evaluate, whether it is possible to get rid of these activities entirely.

Activities scored low on value to capability, predictability and controllability

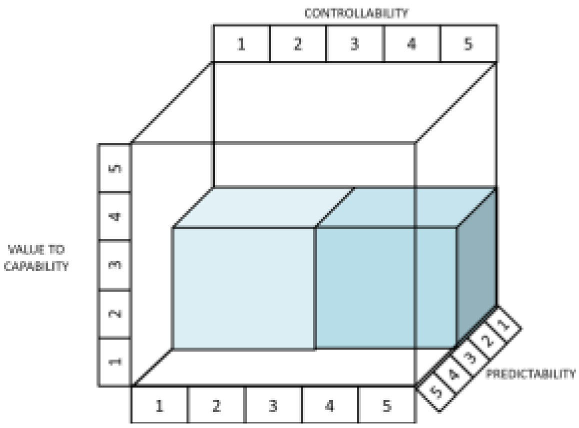

Figure 10 Activities scored low on value to capability, predictability and controllability

The second area considers those activities that are also scored low in terms of predictability and value to capability but high in current performance. Such an activity may also be overlooked since the low intrinsic capability value, low predictability why it may perform well or managers feel that it is in control. However, due good performance or controllability, these activities might be worth to exam in order to learn what is being done right here or could some other activities be combined to these.

Activities scored low on value to capability, high on predictability and controllability

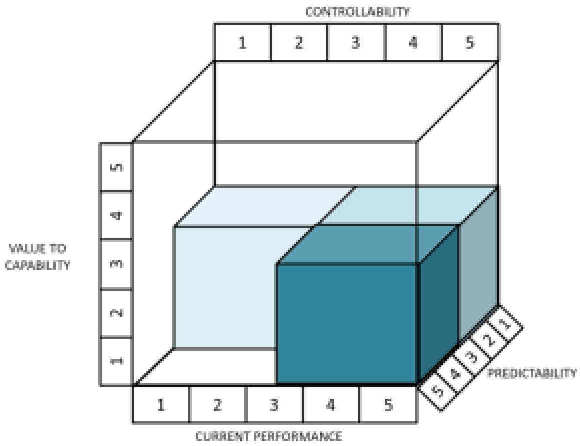

Figure 11 Activities scored low on value to capability, high on predictability and controllability

The third area consists of activities scored high in performance and predictability but they do not contribute much to manufacturing capability. Therefore, there is not that much to gain from improving these activities. Once again, examination of the activities that fall into this area might be a thing to consider if it seems like there is practices applicable elsewhere. In addition, comparing this and the previous category will improve understanding what effect unpredictability has for managing the activity.

Activities scored low on value to capability and controllability, high on predictability

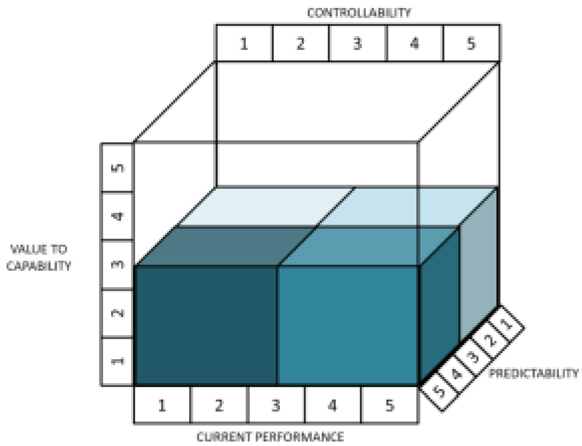

Figure 12 Activities scored low on value to capability and controllability, high on predictability

The last fourth of the bottom layer consists of activities that perform poorly, but could be inherently predictable. While they still hold low value capability-wise, there is a need of an improvement. In addition, because the activity is also predictable, it would be somewhat beneficial to improve these activities so that the scores would improve them into the previous category. One should not engage to this before all the activities those contribute significantly more to the manufacturing capability have been improved.

Summary of relations below the layer

At this point, it is clear that activities, which are not seen contributing to manufacturing capability, will not be improved unless there are no activities in the following four categories that are located above the middle layer. As explained before, these activities contribute significantly to the manufacturing capability and are thus the ones resources should be concentrated on. At this point, the focus will be turned to the interactions above the layer. Once again, each possible combination will be examined.

Activities scored high on value to capability, low on controllability and predictability

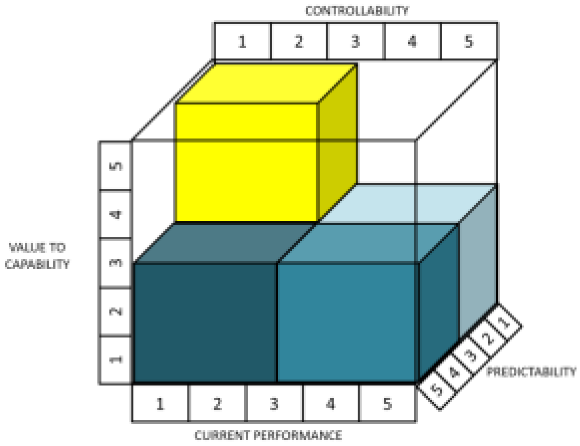

Figure 13 Activities scored high on value to capability, low on controllability and predictability

The first relations to be analyzed are those activities that regardless the high value to capability, are still uncontrollable or performing poorly and are inherently unpredictable. Hence, even though there are clear opportunities for capability improvement effects, the improvements should not be started from these activities. That is due to the low predictability score. It means that the capability improvement is uncertain even if the performance was improved or control attained because the activity's outcome is never certain. On contrary, projects that focus on these activities possess high probability to fail.

Activities scored high on value to capability and on controllability, low on predictability

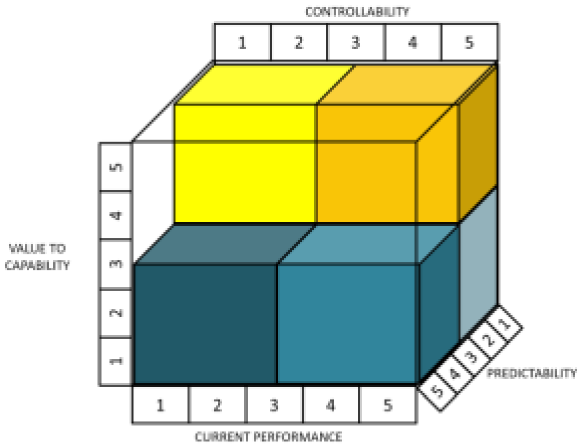

Figure 14 Activities scored high on value to capability and on controllability, low on predictability

The second examined relations is those activities that contribute significantly to the capability value, perform well or are well in control, but are unpredictable by nature. Depending on the exact performance score of the activity, there is a chance for performance improvement, but once again, the unpredictability of the activity makes these attempts all but easy. The fact that these activities are controllable or performing well makes them fruitful sources of best practices in the sense how you retain control of unpredictable activities.

Activities scored high on value to capability, controllability and predictability

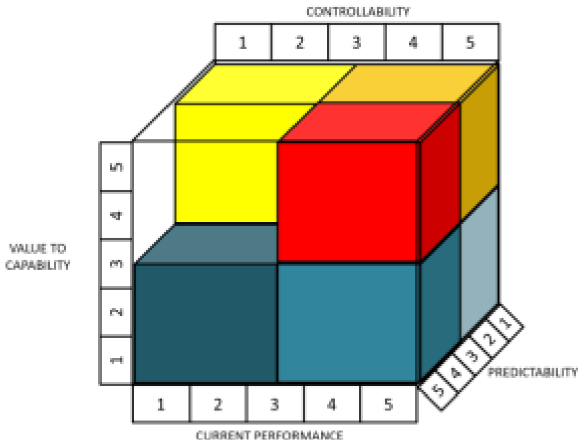

Figure 15 Activities scored high on value to capability, controllability and predictability

In the third eight in the hot floor are located the true star activities. They perform well or are in control, they are predictable and most importantly, contribute well to the manufacturing capability. That is not to say that there is no room for improvement. Only if the activity scored maximum in all three aspects, then there is no need for that. When that is not the case, it might be easier for managers to improve those activities that are already performing well or in control, rather than trying to improve the ones that are not (Blaxill and Thomas, 1991).

Activities scored high on value to capability and predictability, but low on controllability

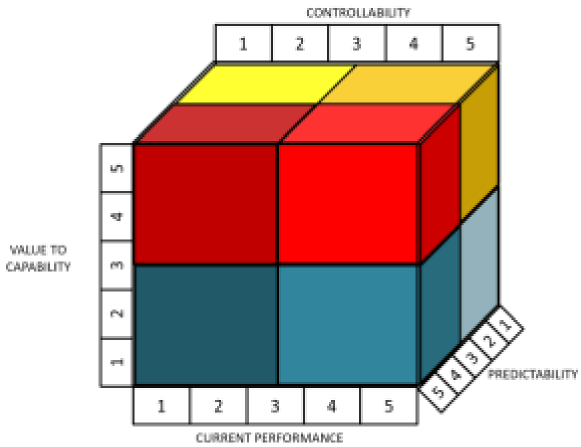

Figure 16 Activities scored high on value to capability and predictability, but low on controllability

The final relation consists of the activities with most potential when they are successfully improved. The activities contribute highly to manufacturing capability but are currently performing poorly or difficult to control. Because of the high predictability score, these activities are more interesting improvement wise than the ones with similar performance or capability value score. In practice, predictability means that improvement attempts will produce clear results because the outcome is based on the goodness of the activity and not luck.

This completes the clustering phase of the activities. Based on this reasoning, the improvements should be started from the activities those fall in one of the read eights. Thus, through the methodology one has gained hindsight where the efforts should be concentrated.

In the table six below, there are demonstrated a sample of scored activities. In reality, this list is of course significantly longer. It is still efficiently manageable with simple spreadsheet tools. The list however is the key input that will be taken to the next phase. The list a complete snapshot of the current capability level of the company's manufacturing system.

Table 6 Methodology phase iii

#	**Activity**	**Dimension**	**Value to capability**	**Current performance**	**Controllability**	**Predictability**
1	Painting	Quality	4	2	NA	4
2	Ordering	Flexibility	4	NA	2	2
3	Assembling	Delivery	5	4	NA	5

The next question is to evaluate which ones of the identified activities to improve first. That is the final part of the methodology and it will be discussed next.

6.7. From activity improvements to more capable manufacturing system

The purpose of the first three phases of the methodology was to form a complete view of the current level of the manufacturing capability. It is likely that while working through the phases i-iii one gets a hunch where to target the operational improvements to improve overall capability. The next phases focus to deepen this hunch and turn it into list of executable improvement projects. To determine the projects, in the next phases, the focus is turned towards the scored activities, root causes that are affecting the performance and to what kinds of improvements are most likely to actually result in capability improvement. Without the previous scoring phase, this task would be daunting and bear a high risk of initiating useless improvement projects. Instead, now one is able to focus not only on the most underperforming activities, but also on the ones that are important for the entire manufacturing system capability-wise.

The planning of the improvement projects starts from scrutinizing the activities located in the red cubes. This is because these activities have relatively highest value to capability and are inherently more predictable. They should be gone through one by one, starting from the one with highest value to capability. Generally when working on an activity first the problems causing the poor improvable performance and their root causes should be identified. Once identified, different possible methods or scenarios of improvement should be developed before moving on the next one. Once the necessary improvement scenarios have been identified, they must be evaluated before making choices of which to execute.

It is essential to understand that just high combined value on the three variables is not good enough justification for any improvement initiative. It is merely a good justifications to start evaluate how the activity could be improved. Instead, each plan has to be considered in terms of likeness of success. As emphasized earlier in this thesis, an SME has to be especially careful when making resource commitments. Furthermore, this is the essential step to be taken to gather the necessary momentum to support project initiation.

6.8. Root causes

When working through the list of the individual activities that hold potential capability-wise, the most difficult task is to identify what is the real problem and what is just a result, i.e. what is the effect and what is the cause. The analysis of this problem is usually referred as Root Cause Analysis or RCA (Sarkar et al. 2013). The term root cause has various definitions in literature and it seems that no exhaustive definition can be decided upon (Rooney and Hopen, 2005). However, in the context of this thesis root cause has following features:

Table 7 Root cause definition

Rule	Conclusion	Reasoning
Root cause can be affected	If the cause identified results from something that cannot be fixed, it shouldn't be treated as root cause	Concentrating resources on something that cannot ultimately be changed is inefficient
Root cause is never a result of effectible cause	If an effectible cause can be identified for the cause, the cause is not a root cause	It is important to carry on the analysis deep enough to avoid fire fighting
If the affect does not have result on the cause, it cannot be root cause	Sometimes a root cause is identified and it has effectors that contribute to it. The effector is however minor to the result and removing they will not eliminate the root cause. Thus, they cannot be root causes.	While deep enough RCA is important, there lies a danger. Practically everything is connected to something. Even root cause can have something causing it but if the elimination of the effector does not make the effect vanish, perhaps the cause is the actual root cause

Root cause affects	Root cause has always major effect and eliminating it significantly changes the outcome	Based on previous reasoning, root cause has an effect significant enough to truly dictate the action
Effective solutions for root cause can be developed (Rooney and Hopen, 2005)	If the developed solutions are unfeasible, then the cause is not root cause	Root cause should be such a major problem and within the reach of control that solutions for it really change the outcome of what is affected by it

For RCA various tools are developed and some of them are presented later in this section. Deciding what is the actual key underlying “root cause” is often difficult for practitioners. Usually in the RCA process a set of potential root causes are identified and then the potential ones’ criticalness is evaluated through experiments or trials (ibid, McDonald and Leyhane 2005) Therefore it is very difficult to define exactly how the root cause is found. Instead, RCA is an iterative process where application of tools is necessary. The found root causes should meet the previous definitions in order for elimination to result in improvement.

6.9. Identifying niggling factors in activities

To begin this process one must be able to turn the scored activity into a workable problem. The first step is to remind oneself of the previous steps completed in this methodology. Firstly, the activities have been assigned to dimensions of capability. Therefore, any problems that occur should be related to that dimension and the root causes identified should affect that dimension negatively. For example, the activity of inspection the final product would have been assigned to quality dimension. Secondly, the current performance, or its equivalent controllability have been evaluated and scored. For the sake of the argument, consider that a customer has been sending back parts shipped them due a manufacturing failure. Therefore current performance of the inspection activity has been scored, say two, due to the failure to meet the set internal quality goal measured by proportion of returned products. Thus, this activity would lie in the dark red eight since clearly quality inspections has tremendous capability value but is also theoretically predictable activity. From here, it follows that the initial problem is a combination of these two factors: high value to quality but poor performance. Hence, it is necessary to figure out, why the final inspection fails to recognize poor quality. This is the workable problem.

As said previously, because problems are very contemporary, a specific guideline that would always work is practically impossible to develop. Instead, there is a set of popular, well-known tools that will help one to identify the underlying root causes. The choice of a tool or tools is up to the users and depends mostly on the personal preferences and the assumed nature of the problem. In addition, various tools may be applied for the same problem.

The goal is common for all the tools: To work on the problem until the problem is solvable. I.e. the previous example, the failing quality inspection, is not yet solvable per se. One must find the actionable root cause. For this, the following methods are presented; 5 whys, Ishikawa diagrams, Kepner – Tregoe (K-T) approach and affinity diagrams, issue trees and hypothesis trees.

5 whys

5 whys is a simple methodology. According to Chen et al., after identifying where a problem is located throughout the system, the 5 whys is efficient way to remove it. The ‘5 whys’ method is a process that begins with identifying specific problem and writing it on a piece of paper. Then by asking why the problem happens, answering and asking again five times. If the answer given does not identify the root cause of the problem, the engineers keep asking why until the root cause of the problem is identified. This method is recommended due its simplicity, but the assumed linear relationship of underlying problems is not always valid (Sarkar and al. 2013). Linear relationship means that problems logically result from one and another. Acknowledging a problem would inevitably lead observer to its root cause. Although the name implies asking why a total of five times, some situations require fewer and some require more than five questions. However, it is believed that five is enough to take one to the root cause (Andersen and Fagerhaug 2000). The root cause is usually the question that cannot be answered. E.g. why did the cake burn? – Oven was too hot → Why was oven too hot? – It was set wrong → Why was it set wrong? → The recipe book said so → Why did it say so? – Cannot be answered! ← Root cause!

Ishikawa diagrams (CED)

The Ishikawa is also known as the fishbone or the Cause-and-Effect diagram (CED). This tool is commonly used at the microanalysis level in analyzing the causes of a certain event (effect or problem) that could range from proper product design to a qualify defect elimination. This gives managers the ability to ask the right questions when addressing their complex set of challenges or when needing to make far-reaching decisions on their business's profitability and long-term viability (Bloomsbury 2007, Bauer 2005). In practice, an Ishikawa diagram is conducted so, that once you an activity or defect identified, the major activity inputs are chosen first in a brainstorming session for example. This helps grouping of the causes, which is actually one of the objectives of this method. Then these inputs are analyzed to elaborate how exactly they are contributing to the activity. Usually to jumpstart the process of creating and Ishikawa diagram, a set of 5 M factors is used. The five M factors are machine, management, medium, mission and man. Each of them has their own branch that is used to elaborate the problem.

K-T Approach

This method of problem solving consists of asking the basic simple questions and their opposites, e.g. when does the problem occur and when does it not occur? The point is to narrow the focus down to few issues and thus, make the process more efficient (Sarkar et al. 2013).

Affinity Diagrams

Affinity diagram is a visual tool that is used to organize related ideas (Duffy 2012). Affinity diagrams are perceived good tools when the need is to quickly gain understanding of relations between collected results (Santa-Rosa and Fernandes 2012). In practice, this is done by writing gathered information on post-its, for example quotes from floor workers, and they are assigned to similar topics. Below you see and example from an article of Journal for Quality and participation (2012) where affinity diagrams were utilized quite nicely. In the article conference discussion were summarized in this form to establish understanding of the following issues discussed:

Figure 17 Affinity diagram, Journal of quality and participation, 2012

- How can we help others see poor performance/failure as opportunities for learning/improving
- How can we tie quality improvement efforts to the balance sheet (e.g., financial savings)?
- How can we overcome barrier to creating good operational performance?
- How can we close the gap between what we know and what we do (e.g., improve execution)?
- How can we ensure improvement efforts demonstrate value that will drive the management/leadership support and sustainment?

Hypothesis and Issue Trees

The tree approach has several variations but the general idea is that an observed failure or a problem is often caused by more than just one factor (Sarkar, 2013). This most efficiently explained through an example:

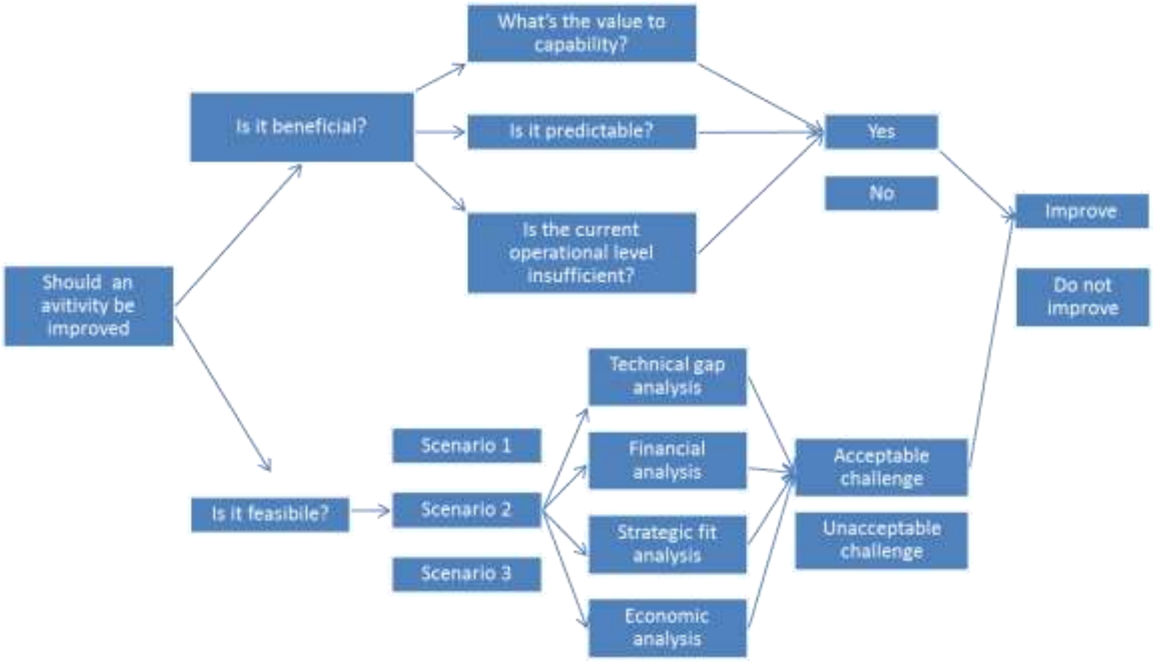

Figure 18 Issue tree, example

Above, is an issue tree built from the logic of the presented methodology. Tree approach to problem solving is comprehensive in the way that it enables analysis of various effecting issues. Tree approach often starts with acknowledging an issue and then working in a question-answer manner towards an answer, which often is a hypothesis formulated before tackling the issue. The example in the figure 18 demonstrates this: the final answer and the initial question are bridged together via various questions and their answers. Regardless the used tool, the found root causes should be documented per activity as in demonstrated in the table below.

Table 8 Methodology phase iv

#	Activity	Dimension	Value to capability	Current performance	Controllability	Predictability	Potential root cause
1	Painting	Quality	4	***2***	NA	4	Wrong calibration
	Painting	Quality	4	***2***	NA	4	Insufficient time to dry

6.10. Evaluation of solution models for root causes

Regardless of the used problem-solving tool, after the previous phase one should have come up with possible root causes for each activity. From the found root causes the actual improvement starts. In this phase solutions for how the root causes could be eliminated are developed. These solutions are de facto improvement ideas that once implemented should improve the capability dimension that root causes are connected to. They will be referred as improvement scenarios from this point on. This is because the actual execution is out of this thesis's scope. This is because the execution depends on the created improvement scenario.

Moreover, the developed scenarios cannot be detached from the actual problem and company context. They must be developed in practice based on the factual situation and available resources, this particularly true for SMEs as said already in the literature review section.

Instead, the final phase of the methodology is a feasibility evaluation of these hypothetical improvement projects in order to create an action plan for the company. As explained before, following strictly the previous scoring of the activity is not sufficient to decide which improvement projects to initiate. While the scoring still remains as the basis for this decision making process, it is important to evaluate the viability of the formulated solution scenarios and the decision to execute should be based on the both factors.

So the question is how to evaluate the viability of the plan? There are plenty of different models to be used for decision-making support, particularly from the field of project management. However, in the SME environment the considered factors and to evaluation methods have to be chosen according to the reality of the SMEs.

6.11. The Iron Triangle and Feasibility Analysis in a SME

As stated already in the introduction section of the study; for an SME it is extremely important to ensure that any projects chosen are feasible. Feasibility refers to the business case of a project: what is the input-output relation or do the gains justify the investments. Common project management metrics time, quality and cost known as the iron triangle (see. e.g. Atkinson 1999, Saputra and Ladamay, 2011) are the general metrics that describe how any project could be measured. The Iron Triangle's three attributes capture well the dilemma that projects tend to have. It is widely accepted by practitioners that in project management achieving a project that would be high in quality, cheap in cost and executed in a fast manner is practically impossible (Saputra and Ladamay, 2011, Cariaga and al, 2007). One of the aspects is always compromised. Therefore, based on these constrains there are three combinations available: fast and good but not cheap, cheap and good but not fast, fast and cheap but not good. While theoretically, this train of thought may be an over-simplification and hard to prove, it is still a good reality check for any feasibility analysis. When conducting feasibility analysis and monitoring an initiated project, it is extremely important to constantly evaluate the assumptions that evaluations are based on and how the project is doing against allocated time, money and quality expectations. For example, if the project budget is after all too low, one should ask were the initial cost assumptions false or was the time requirements assumed poorly. The Iron Triangle constrains are thus a good way to monitor whether a project delivers accordingly to feasibility analysis. Feasibility analysis itself is used to improve decision making in terms of which improvement projects to choose. From here, it follows that where the Iron Triangle is the manner in which to analyze the on-going project, a feasibility analysis sets the baseline against which time consumed, money spent and quality achieved is monitored (Meade and Sarkis, 1999).

There is a wide range of useful tools for assessing different projects' feasibility ranging from Net Present Value calculations to different versions of Gap Analysis. In this methodology, the goal is to combine the aspects of gap analysis, which have been scientifically proved important. Another key input for the feasibility study is the previous activities' capability scores that enable comparison of different scenarios without being too laborious. Depending on the complexity of a particular improvement project, more detailed and holistic analysis may sometimes be necessary.

The methodology aspects presented here is formed combining findings from the article written by Asadullah Khan (2006) and famous phase-gate model (Cooper, 2008). Khan states in his article that before any full scale projects are initiated there has to be a feasibility study carried out. In his view, three aspects should be evaluated; technical, financial and economic feasibility. The phase gate model is more comprehensive approach and it has been applied for new product development projects especially (Cooper, 2008). There a project has to pass through phases (stages) where the development of the project is assessed opposed to the plan (Nielsen 2008). If the process fails to meet previously set requirements then it is rejected. Along the model there have been a set of variables for feasibility analysis developed (Cooper, 2008) far more comprehensive than Khans. In addition the project is recommended to be scored from one to 10 on the different variables, much as have been done in this methodology in terms of capability dimensions.

However, not every variable is necessary to assess with regards to improvement scenarios. Therefore, the model cannot be applied per se. Instead, one key point from that model is adopted along to the Khan's recommendations: strategic fit. As has been observed before, the overall goal of this methodology is to ensure that company's focus remains on the right track. Therefore, the lack of strategic fit assessment is a huge shortcoming in Khan's model.

From here it follows that in this methodology for the preliminary assessment of improvement scenarios feasibility following variables are used.

Figure 19 Variables of feasibility

It shall be pointed out that the exact definitions for these gaps would be impractical. The fact of the matter is that each scenario is based on different set of assumptions, ideas, methods and objectives. Therefore rather than formulating a strict set of question to be answered, it is more preferable to consider each scenario from the explained perspective.

6.12. Critical values

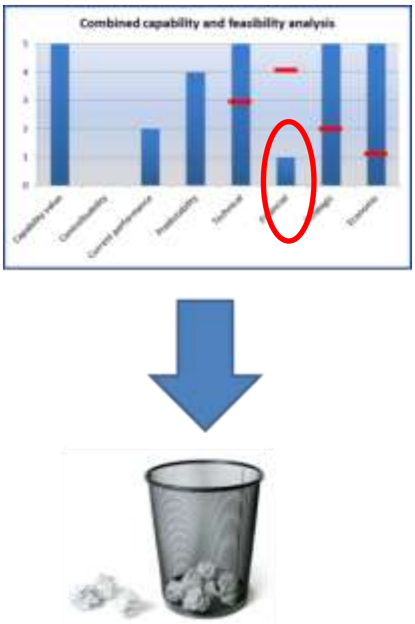

Figure 20 Critical values and prioritization

Before the improvement scenarios are scored based on the four gap variables, there is one important step to be taken. That is deciding upon the relative importance of the four variables. Depending on the current situation of the company, it might not be wise to treat every gap equally. For example, the business strategy might dictate that only financially feasible improvement scenarios are to be taken, regardless of the other gaps. Of course, sometimes it might be useful to treat the gaps equally indeed. The point is to go over them and define what their purpose from the company's practical perspective is. To take the criticality of a given variable into account there are several ways: One is to score activities very strictly or very loosely on the variable or weight them mathematically. This method however will make the assessment of total sums more complex. In addition, over the course of scoring the activities subjective perceptions might further make things difficult if loose/strict scoring is applied. Therefore, it is recommended to set fixed critical values for every variable. In addition, when a scenario is scored below that it is ditched regardless of the scores on other gaps. This method is also simple, yet systematic where the critical value is fixed prior to actual scoring. Therefore, it will not hamper the analysis of total scores. It is also easier to implement into scoring process if basic tools, such as MS Excel or white boards are used. It is noteworthy that even if there is not any previously set need to reject projects on any basis, i.e. no crucial values are necessary, it still important to establish common understanding what is the relative importance of these variables. This subject will be later elaborated, but at this point it is crucial to understand that in practice tradeoffs are seldom completely avoidable. Therefore, companies are likely to face choices whether to support strategy execution, avoid economic of financial risk or take upon a technical challenge for later benefit.

6.13. Analysis of feasibility

In practice, the initial improvement scenarios might have to be elaborated to enable assessment of the recommended variables. For example, say that the identified root cause is lack of skilled work force, and one possible scenario is starting internal training. For the company to be able to analyze this solution, it has to be discussed how the training could actually be completed. As said before, the gaps should be scored from one to five. The objective is to use the same scale as in the previous phase to make feasibility score combinable with the capability score. Therefore score one means that gap is unfavorably large and five means a perfect fit. Therefore, the total score that a scenario gets varies between four and 20 as showed in the figure below.

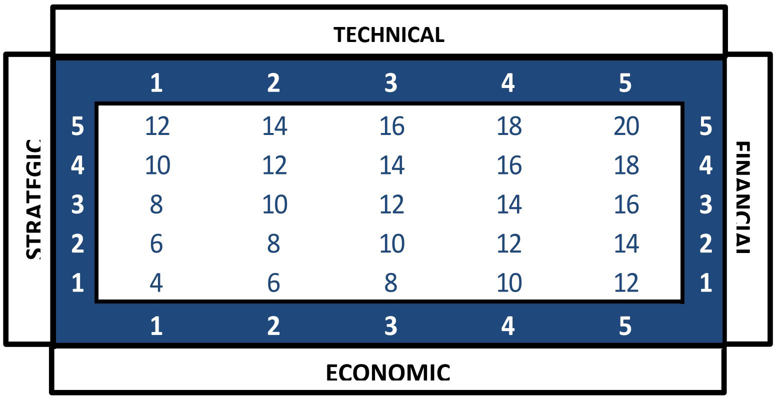

Figure 21 Improvement scenario score possibilities

Table 9 Methodology phases v - vi

#	Activity	Dimension	Value to capability	Current performance	Controllability	Predictability	Potential root cause	Scenario	Tech	Fina	Strat	Econ
1	Painting	Quality	4	*2*	NA	4	Wrong calibration	Establish a control protocol	3	3	4	3
	Painting	Quality	4	*2*	NA	4	Insufficient time to dry	Turn on the heat	5	5	2	5

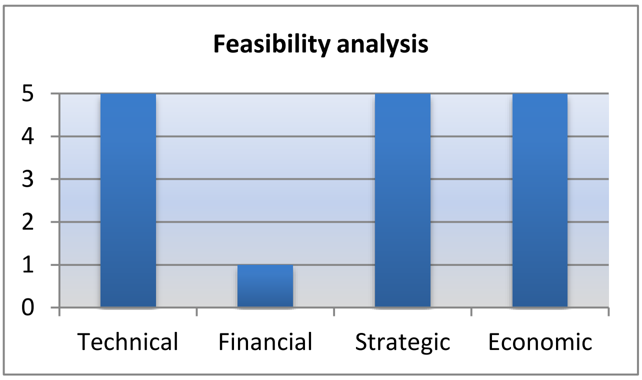

Figure 22 Feasibility analysis

It is simple to interpret that the more feasible the scenario is, the higher the score. Therefore, theoretically the highest scoring improvement scenario created for the activity improvement should be executed. However, it is important to understand that the figure above only illustrates a sample of possible scores that a scenario may get when all the variables are treated equally. This may result in high scores even if one the aspects is poor as showed in the adjacent figure, where total score is 16 but financial just one. Focusing solely on the total score would have the company initiating this project with poor financial prospects.

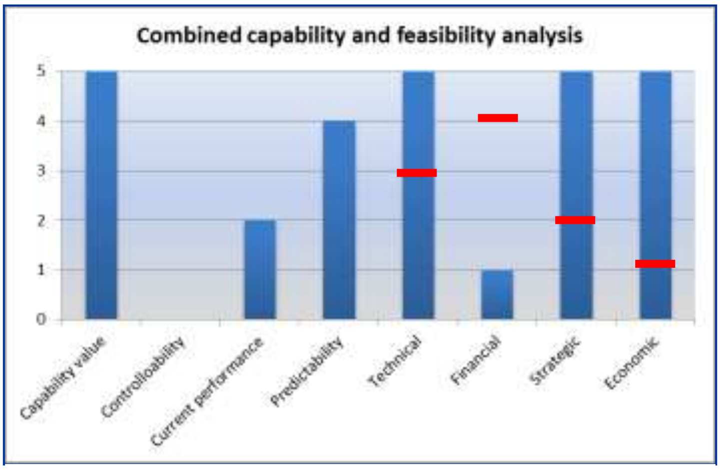

Figure 23 Capability and feasibility analysis

The underlying problem of analyzing feasibility is that it is dependable on the firm specific circumstances as was stated in section of critical value. For example, for some company the funding might be such a difficult obstacle to overcome that all the improvement projects should be based mostly on that factor. Therefore, as said before, prior to conducting the feasibility analysis the company should consider each gap in relation to others. In the figure above is an illustration of complete scoring for one activity with one of its improvement scenarios. The critical values used have the company abandoning the proposed improvement scenario due low financial score, regardless high total score.

In addition, as said before, feasibility was important to analyze because the capability value was not sufficient alone to justify initiation of different improvement projects. However, neither is feasibility sufficient alone. The key is to combine the two. The final phase of the methodology is to combine the two. That should be focused upon next.

6.14. The Action Plan for Capability Improvement

By following this methodology, one has worked through the entire manufacturing capability, identified activities that form it, defined the key ones through scoring, assessed their value to capability and current performance, forged improvement scenarios, evaluated the created scenarios but not drawn the action plan yet. That is in the sight now as the final phase of methodology.

The approach to establish that is simple: combining the scores from capability and feasibility analysis. Were there critical values applied or not, the highest scoring activity with the highest scoring scenario will be the highest priority for execution. In a similar manner second highest scoring activity-scenario combination is the second priority. In this manner, the action plan for capability improvement forms out. Note that when two activities are scored the same in toll, the deciding factor is the critical values of the gap variables.

What about the interpretation of the scores? The number that results from scoring the activity and its respective improvement scenarios, describes the perception of how important it is to improve the given activity and how easily it is possible to do. From here it follows that the action plan is formed on this basis; start from the improvement project with most value to capability and easiest to execute. Then move on to the more challenging ones that are still valuable improvements. This way the company musters valuable improvement experience before taking on the more demanding improvement projects.

What is maybe even more important though is that every realizable improvement scenario has also been evaluated based on business strategy and operational requirements. Therefore, as the company executes the once formed action plan, the overall course of action will remain towards the main business goals. So even if SME sometimes gets tied up to a particular development project, it is reliable to know that the purpose and the need of the project have been ensured to relate to the core objectives of the business.

6.15. Manufacturing capability assessment methodology

Below is a simple process flowchart type of picture that illustrates each phase that has been gone over in this methodology.

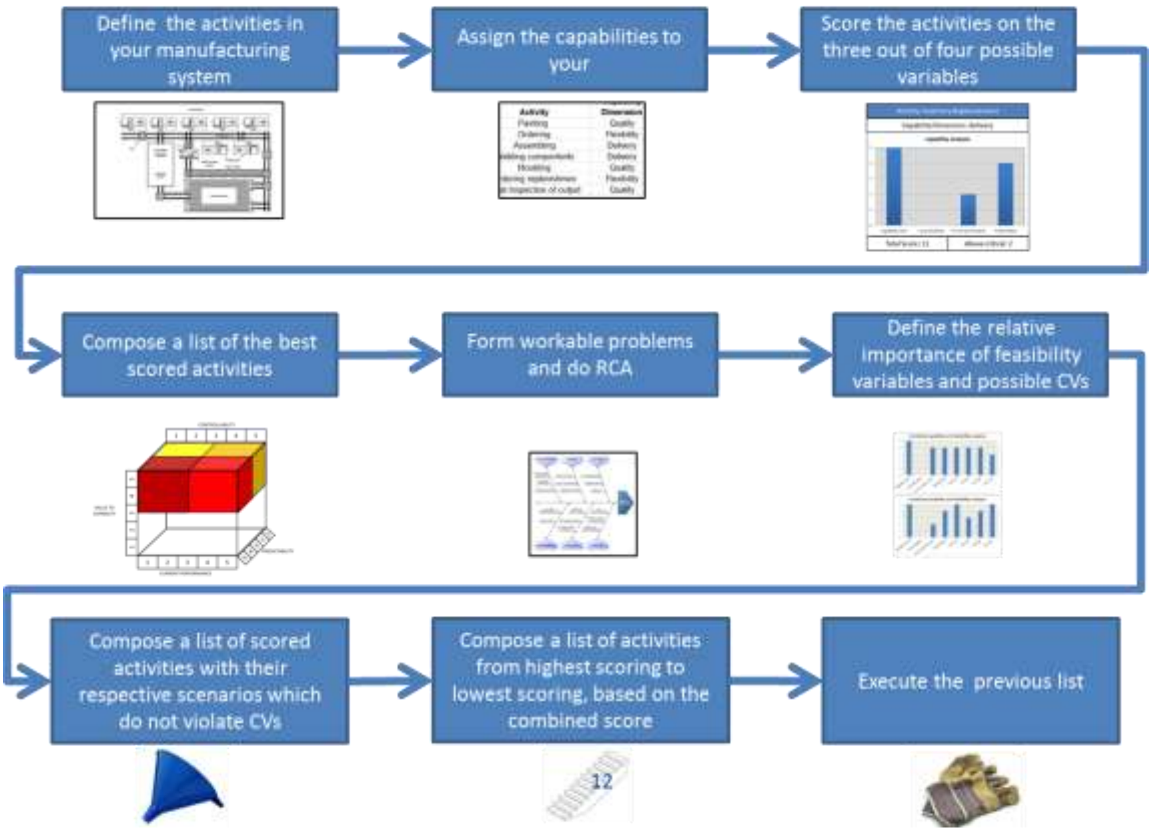

Figure 24 Methodology recap

In the beginning of this section the remaining research problem that was going to be answered with methodology was: How should the dimensions of manufacturing capability be analyzed in a manufacturing SME environment in order to prioritize possible necessary development projects?

To truly evaluate to what extent this problem is solvable with the proposed methodology a case study is required. That is the topic of the next section. However, from theoretical point of view the proposed step-by-step methodology can be concluded to do the following: It Gives clear methodology how to analyze current level of capability based on scientific grounding. The most important grounding is the theory of manufacturing capabilities. It also gives clear guidance how to prioritize necessary development projects. This was one of the key issues stated by the case company and a part of the identified research gap. It also gives a strong indication of what improvement projects are necessary and likely to provide results. This based on utilizing the understanding that company possess of its skills and abilities. This is the key element that also supports answering the research question.

Additional strength of the methodology is the fact that no prior data is required but if available, can be utilized. As was mentioned earlier in the literature review section, many methodology's make an unrealistic assumption of data availability. The methodology also takes into account SME environment where available resources are scare. In other words, no high investments are needed to employ the methodology.

Perhaps from the practitioner's point of view, most importantly the methodology helps the managers to maintain focus on the overall strategic objective while supporting necessary operative decision-making. This mitigates the risk of firefighting and being tangled up by issues of minor importance. When the focus remains on the overall strategic objectives, some distractions are not likely to be as harmful. Due to the insight gathered with the methodology, managers are able to quickly return to the right track.

Additionally, evaluation of business critical factors as a part of the methodology gives supporting justification why to initiate a project. As was noticed as part of the literature gap, this aspect is often neglected in capability and methodology literature. This was also the main concern of the case company in the summer of 2013. Therefore, the methodology seems to sufficiently answer the proposed research question.

However, to truly assess the value of the methodology the evaluation must be done against a preset criteria and utilizing real life evidence. This was done as over the course of developing the methodology in collaboration with Ratesteel. The next section introduces these findings in more detail in a form of a case study.

7. THE CASE

The introduced methodology has a strong connection to recent academic literature and therefore one can argue that it is reasonable to expect the methodology to be useful when applied in practice. This section describes the observations that were made when the methodology was tested in an actual business environment to validate the argument. The methodology was developed and tested iteratively and Ratesteel provided the process with valuable input by reviewing the model and commenting on its expected usefulness.

To test the validity of the methodology Ratesteel agreed to apply the methodology in an internal development project. Ratesteel had identified that its delivery reliability was not on the desired level. Ratesteel has set clear objectives what the level of untimely deliveries should be at most, and the company has observed unacceptable variation. Therefore, the management had decided to initiate a project that aims to find ways to improve the delivery reliability. The setting provided a snapshot picture of the overall situation that the company was in. They knew that improvements should be made but they were looking for efficient ways to gather understanding where the improving actions should be targeted to. Therefore, the project provided a fruitful opportunity to test the proposed methodology.

The methodology was applied as presented in the previous sections to tackle this improvement project. The company would break down then elements that contribute to its delivery capability into activities. Then the company assessed the current capability level of each activity, their predictability and current performance or controllability. After this phase, company would do root cause analysis and generate improvement schemes for them, which would be worked into an action plan.

It should be noted that due the emphasis to collect sufficient data in a fast manner the case was mostly limited to focus only on one element of manufacturing capability, namely delivery. This however should not have an effect on the reliability of the findings. This is because as literature review showed, there is no conclusive evidence that elements of capabilities have any interdependencies (see literature review, sand cone model and trade-off theory). Therefore, it is fair to assume that the methodology may be validated in an inductive manner, i.e. if the methodology works for one capability element; it is fair to assume that it works for others and the results could be combined to assess the entire manufacturing capability. The methodology was handed over to the company for application after two formal meetings where the methodology was tested through examples alongside with MS-Excel tools that company will use when working through the methodology.

In addition to the formal meetings, multiple less formal, unstructured discussions took place both face-to-face, on-site, on the phone, via video conferencing and via e-mail to gather understanding how the company would perceive the proposed methodology. The discussion included multiple practical examples, theoretical considerations and bouncing off ideas between the author and the company. These discussions took place during an eight-month period from May 2013 to December 2013. The following paragraphs describe the observations that were made as the methodology was tested with the company step-by-step. Observations from each step are reported in the order dictated by the methodology

Defining the activities in the manufacturing system

The first step of the methodology was a subject to a broad discussion. As was pointed out earlier, it is important that activities are thought in a broad sense. The objective is to acknowledge value of activities, which are not traditionally considered as part of the manufacturing system. In the discussion, the focus was on the delivery dimension, i.e. what activities contribute to the number of timely deliveries. Many activities were identified quickly from job descriptions and recorder into an Excel-file.

To the surprise of the author, an activity that was pointed as an important one by the management team was employee motivation. This was followed by discussion to determine whether the concept is too abstract to be included and evaluated. The management team felt that employee motivation has a significant effect on the delivery aspect as sometimes to make the expected delivery times the employees must work overtime. In addition, it was pointed out that management is able to influence the motivation through compensation and remuneration. Therefore, the activity of motivations was left on the list and treated as any other of the recorder activities. It was clear that working this way would result in a long list of activities. However, management felt that long list is important to ensure holistic approach to manufacturing capability and to ensure that no blind spots are left, as was also recommended earlier along the methodology chapter.

Assigning activities to capabilities

The second step required most iteration. While activities that have only single objective are easily assigned to dimensions, some are less likely to contribute to just one dimension. It seems that to assign the activities efficiently there are two options. Firstly, they are broken down to the level where tasks are simple and have more narrow objectives. I.e. such activities as ordering process is broken down to the individual tasks it consists and each task is then easier to assign to a dimension. Secondly, the discussion may remain on the level of larger entities. Instead of breaking down, the management discusses the activity thoroughly to establish common agreement of the prime purpose of the activity. Then the activity is assigned to dimension even though it is understood that the activity has secondary purposes. The key objective of this phase is to create understanding what the company does to deliver on each of the manufacturing capability dimensions. From the practitioners' point of view it seems to be better just to establish common agreement of the activities' prime purposes rather than breaking them down and forcing the pieces to different dimensions.

Scoring the activities

The third step is the one where most insight was created. As only one of the used four variables are based on data, the step requires thoroughly discussions, comparisons and even debate to actually end up with the scores. In practice, the scoring was done one dimension at the time. The scoring was started from the activity on the top of the list. As the scoring proceeded, the management ended up going back to previously assigned scores and revising them. A valuable tool that caused this revision of the scores was MS-Excel. In the MS-Excel it was quite easy to constantly sort the activities from highest scoring to lowest scoring. When this was done, management could instantly evaluate whether the list truly illustrated their perceptions of the relative importance of different capabilities. Indeed, it sometimes happened that management realized that the some activities are scored too high and some too low. In these occasions, the scores would be revised as said, and eventually the scores reflected accurately the management's perception of which capabilities are more critical to manufacturing capability dimensions and which are less critical. In the process, management had ventured in assessing what effect predictability has in the capability. This seemed like a good practice, as it created instant insight to the management in terms of what kind of processes they can improve. Simultaneously, it was agreed on some processes that the management is unable to fully control the output. Therefore, to mitigate risks related to improvement projects, it is preferable to focus on activities that are more predictable.

As it was already pointed out earlier, the list of activities is quite lengthy. Therefore, the clustering that can be done by utilizing the earlier presented cubes and colors proves to be effective in the end. It seems that the clustering is able to effectively pick out the kind of activities that are worth to improve. This way this step may be carried out in a quicker manner. Focusing the management discussions based on the presented color coding, management is able to go through specific topics, which they find important at the time. For example, it is possible that occasionally the management wants to identify just the least critical activities. In such a setting, the management would simply go over the dimensions that are color-coded blue.

However, it should be pointed out that the discussions related to this step are very valuable for management. The insight gained from the discussions establishes a common understanding for the management about what builds the manufacturing capability of the company. Therefore, it is not recommendable to rush through this phase. Perhaps later, when the development projects have been initiated and the management wants to review progress and assess whether the status has been improved the clustering effect is more important.

Compose the list of scored activities

The fourth step is the one where efforts are focused to improve the current state. At this point it is already clear what are the activities in the manufacturing system. The relative importance of the activities is clear as well. From this point forward the objectives is to pick the right activities for improvement in order to develop the manufacturing capability of the company. The list is formed quite simply with help of MS-Excel. The previous phase, scoring, is finished after the composed list is as said, and accurate reflection the management perception of the current state. However, the list is still relatively long if every scored activity from every dimension is included. Therefore, short listing the activities is useful practice.

As it was already pointed out. Clustering and color-coding the activities is an efficient way to identify quickly a short-list of activities for further development. However, as the next step would be identifying root causes and then developing improvement schemes for each identified root case, it is recommended to make the short list even shorter. Instead of focusing just on the red or dark red activities, it is recommended to pick the ones with best capability and predictability scores. A manufacturing SME can manage only a limited number of development projects at once. Therefore, there is no use in trying to stomach too many projects at ones. The management felt that starting from the ones that have high capability value, and high predictability value would possess the least risk of failing the development project. The absolute number of activities, which are taken to the next step, depends on the company circumstances. Experienced managers with strong vision and leadership skills can probably manage a higher number of projects as well.

Next steps

The first four steps were the ones that were worked through with the company management. As it was clear at this point that the initial problem that the company had was resolved, the next steps were left for the management to work over independently. Furthermore, the next steps would require very detailed level of reporting, i.e. reviewing activity scores in a current state and target state as well as assessing how to allocate the resources. That kind of information is not only confidential and cannot be disclosed as a part of this thesis, but also out of the scope of the research problem.

However, management perception of the later stages was at the time of the completion of the project that the following phases are bit more laborious. The logic of the methodology accelerates the later steps somehow, but still the use of different tools to identify root causes requires inevitably more work and man-hours than the first phases. This is understandable perception, as it was explained earlier with regards to root causes that usually to identify them, testing and experiments are required. This often results in lengthy projects, which demand careful planning and execution.

Summarizing the case observations with regards to manufacturing capability theories

The process of working through the methodology with the management of Ratesteel left the author under confident impression that the widely researched manufacturing capability is very practical academic concept. The dimensions were very good domains for discussions with the practitioners and it was confirmed multiple times that they truly cover most of the issues that the management of this mechanical engineering workshop works with in their daily job.

From academic point of view it was interesting to acknowledged that the management of Ratesteel had no strong perception whether the dimensions of manufacturing capability are developed in a sequence (sand-cone theory) or traded for one and another (trade-off theory). Instead, once during one site visitation the management and the author discussed the company processes, as well as the manufacturing capability dimensions. Ratesteel's management emphasized that from their perspective, the operating model of the client sets the requirements what the company must be capable to do. In order for the Ratesteel to be successful, the key is to be able to deliver to client requirements.

When client requirements are in align with current capability, there is no clear incentive for the company to develop dimensions that client do not value. Then again, when clients have conflicting requirements the company should still be able to deliver to the requirements. In this case, the company has scattered incentives to develop all the dimensions, which would not match the client requirements.

Therefore, as an observations it seems that the company is rarely able to evaluate their dimensions independently and out of the current requirements set upon the company. Based on this observations it seems that manufacturing capability research could benefit from further studies like this thesis where information is gathered directly from practitioners to evaluate how do they perceive their opportunities to develop manufacturing capability dimension.

Perhaps some of the disagreement among the researchers concerning the two major theories, trade-off theory and sand cone theory, could be explained by this observation. The theory is not well grounded the actual circumstance of the manufacturing companies. They neglect the practical view to capabilities, which is dictated by external requirements and not by management choice. Could it be possible that that is why the observations of some of the previous studies have reported conflicted results? In the studies, the manufacturing capability dimensions are treated as if they were something that companies could prioritize as they prefer, when actually the preferences are strictly guided by customer requirements. This question is recommended to be addressed in the future research in the field of manufacturing capabilities.

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Validating the methodology

After the methodology was developed to its current form and tested as described with the company, a serious of questions was sent via e-mail to the company. The purpose of the questions was to gather further exact and explicit insight from the practitioners to evaluate whether the methodology really had helped the company with their issues. The two owner-managers of the company answered the questions.

The questions sent were formulated to analyze how valid the methodology actually is. In parallel to the question formulation a criterion for each question was developed. The objective was to decide prior to information gathering how the validation of the methodology would be done to ensure objectivity. The criteria were not sent to the authoring company. The following three aspects were asked with the following validation criteria respectively:

i. **Premises:** Are the premises that the methodology is based on, i.e. the elements of manufacturing capabilities valid methodology to approach business objectives related challenges?
Validated if: Practitioners perceive the elements of manufacturing capability as key factors to achieve business objectives

ii. **Usability:** Is the methodology usable, i.e. are practitioners able to follow the methodology's logic systematically, apply the scoring and truly base their actions on the reasoning incorporated into the methodology?
Validated if: Practitioners feel that elements of methodology, i.e. scoring is actually a usable way to support decision making

iii. **Usefulness:** Does the methodology produce results, i.e. are practitioners able to generate improvement schemes, which will become development projects and actually stick to the prioritization?
Validated if: Practitioners are able to stick to the developed action plan.

7.1. Findings

In the appendix, one finds the unedited answers from the authoring company written in Finnish. Here the answers are summarized against the previously presented validation aspects. Note that square brackets mark thesis author's own interpretations.

i. **Premises:** Are the premises that the methodology is based on, i.e. the elements of manufacturing capabilities valid methodology to approach growth related challenges?
   Validated if: Practitioners perceive the elements of manufacturing capability as key factors to achieve business objectives
   Answer: "In our case success is based on the excellence of production [manufacturing capability] (no own excellent products). To improve manufacturing capability, one must understand manufacturing capability elements". → ***VALIDATED***

ii. **Usability:** Is the methodology usable, i.e. are practitioners able to follow the methodology's logic systematically, apply the scoring and truly base their actions on the reasoning incorporated into the methodology?
   Validated if: Practitioners feel that elements of methodology, i.e. scoring is actually a usable way to support decision making
   Answer: "Methodology helps to formulate the big picture. Just the presented visualization [p. 48] is useful as such in the projects to come". "One is able to observe the entire system or just an element". "The variables of activities are good. The perspective of predictability must be thought broadly". "Many perspectives of scoring [strategic, technical, finance, economic] are good". → ***VALIDATED***

iii. **Usefulness:** Does the methodology produce results, i.e. are practitioners able to generate improvement schemes, which will become development projects and actually stick to the prioritization?

Validated if: Practitioners are able to stick to the developed action plan.

Answer: No action plan developed yet. → ***NOT VALIDATED***

Based on the answers it seems that the premises and usability of the methodology are valid but so far, there is not data to enable evaluation of the action plan. These findings will be discussed more comprehensively in the next section.

Besides the above reported key findings, minor observations were made as well that are more related to the intuitiveness of the methodology itself. Firstly, an issued rose by the practitioners at one meeting was the seeming contradiction between the two capability dimension variables; "controllability" and "predictability". After pointing out the differences, it was acknowledged that the terms are inherently different and are must be assessed separately.

Another minor, yet important finding was that the practitioners wanted to include activities to dimensions that may be considered as surprising ones. In the area of delivery, the practitioners wanted to include human resources related factors such as workforce motivation. The inclusion of the motivation as an "activity" resulted in fruitful discussion of its importance to capability, predictability and especially current performance. As a result, the company was able to break down the contributing factors and find workable problems that are likely to result in improvement when they are worked on.

On a negative side, the management was left under the impression that perhaps the methodology is too complex for some employees who are not familiar with various interdependencies that a manufacturing system possess. Therefore, it was not perceived as a suitable tool for e.g. production employees to use without management guidance or support in a development project. While it is evident that to collect activities sufficiently, employees possess plenty of valuable input.

As for today, the company has adopted the methodology as a management tool. It will be used to document initiatives, assess progress and evaluate whether the company is heading as desired or not. The methodology has been valued for its ability to offer a good platform for planning. As reported by the company, the goodness of the methodology as a platform is based on several factors. The dimensions are comprehensive enough to cover vast majority of important topics that management must focus on. Yet, they are focused enough to bring scope for meetings and planning. Furthermore, the logic of the methodology helps structure discussions and communicate how planning process must be executed in order to ensure that decision are carefully aligned with issues and long-term objectives.

8. DISCUSSION

As previous section showed, it is found that manufacturing capabilities are a useful methodology for a manufacturing SME to analyze their own performance when combined with methodology to guide the analysis. It was also found that it is necessary to enable analysis of manufacturing capability in a granular manner. The practitioners are not always in a need to perform analysis over the entire system. Sometimes just one element must be analyzed in depth, as was the case here. Furthermore, it was found that scoring is a useful managerial practice.

From the findings, it follows that the main contributions of this thesis to the ongoing academic discussions are evident. Firstly, the findings further strengthen the theory of manufacturing capabilities. The practitioners did not find any missing capability dimensions nor did they feel that manufacturing capability would somehow limit the management perspective for finding solutions to business issues. As a result, this was quite expected because the manufacturing capability and its elements is widely researched and debated topic. While many issues, such as the sand cone model or the trade-off theory remain controversial the domain is absolutely a solid platform to analyze the industry.

Secondly, the more valuable and unique contribution of this thesis is the mostly validated methodology itself. The research question to be answered after the literature review was:

1. *How should the dimensions of manufacturing capability be analyzed in a manufacturing SME environment in order to prioritize possible necessary development projects?*

According to the answers received from the authoring company, the methodology seems to answer this question well. As one sees from the findings, the practitioners were able to analyze manufacturing capability from both the wider perspective while and the point of a single company, which is the manner how manufacturing capability should be analyzed in an SME.

Furthermore, the methodology incorporates elements that are generally missing from similar tools as discovered, in the literature review. As one can see in the page 16, many other methodologies lack some of the key elements that are incorporated into this methodology as its inherent attributes. The introduced capability assessment methodology:

- Is not built on any assumptions of data availability, it is suitable with zero available data
- It has detailed step-by-step structure
- The approach can be a holistic big-bang one or more granular as the case company did. This means that the application of methodology is not based on any assumption of resource availability and it fits various circumstances in this sense
- While the focus of the activity evaluation is operational, the strategic perspective is included into the methodology ensuring that operations support strategy execution

Due to the positive remarks given by the practitioners, it is suggested that future methodologies should always incorporate these elements. Additionally, as an unexpected finding it was reported that the methodology is also a good communicational tool. This is an interesting observation. However, this is an observation outside of the thesis scope. Therefore, it is not a valid claim or finding.

It must me noted that due to the lack of time no action plan was developed. Therefore, while there is nothing to the knowledge of the thesis author to support conflicting view, it cannot be concluded that the methodology actually results a good action plan that company would be able to follow. Therefore, it must be concluded that so far the methodology is an efficient way to gain insight into manufacturing capability in practice. This observation is further confirmed by the fact that the company has adopted the methodology as a management tool and will use it for the described purposes.

From practitioners' point of view, it is concluded that the most valuable aspect the methodology has is the overall logic of it that guides one from the overall level of manufacturing capability, through the dimensions to the detailed level of individual activities. Using the methodology as the backbone of discussion, one is able to pick a part even a complex manufacturing system, tie its components to scientifically valid aspects of manufacturing capability and finally put them back after gaining understanding of one's core competencies, weaknesses and vision how to improve actions even further. When each step is carefully recorded, a comprehensive database is created, which helps any further development attempts by offering a clear baseline for future projects.

9. SUMMARY AND FUTURE RESEARCH AGENDA

The objective of this thesis was to find answers for what are the key areas of the manufacturing system to be focused on in order for company to be prepared for future requirements of new customers. Moreover, how these issues should be analyzed in an SME environment in order to prioritize possible necessary development projects?

The first part of the set question was tackled by conducting a literature review, which was followed by methodology development, and finally the methodology was applied in a case. Manufacturing capability was found in the literature review as the key concept to assess the areas of manufacturing system. Its usefulness as a methodology was tested in a collaboration with Ratesteel.

Then from the literature review, a gap between the praised manufacturing capability and implementation methodologies was found and a new methodology was developed to connect manufacturing capability better to actual business challenges the theory considers.

The developed methodology was tested in a single-case study when information was collected in a form of inquiry. The collected information was then compared against set criteria to assess the validity of the methodology. The methodology itself was well received by practitioners who found it both useful and insightful. However, due time limitations the last step in the methodology was not carried out.

It was found that for an SME to improve its manufacturing capability it is useful for the company to be able to assess manufacturing capability's elements and the activities that make them up. Furthermore, it was found that scoring the activities is a good and efficient managerial practice, especially when the variables used are value to capability, controllability or current performance and predictability. In addition, to improve manufacturing capability the improvement schemes must be considered as a separate entity as described in the methodology section.

Furthermore, it was found that for a methodology to be effective and usable it must incorporate the same elements that the presented one does: no data requirements, step-by-step structure, possibility to granular or holistic approach and operational focus while ensuring that work completed supports strategy execution.

For future research agenda, it is recommended that the methodology should be tested in other companies and an action plan should be developed. It would be beneficial to follow a company for an extended time to assess whether company will be able to stick to the action plan and do the generated improvement schemes actually improve manufacturing capability. In addition, it would be beneficial to test the methodology without practitioner input to the process and limiting the researcher's role strictly to observing the events.

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11. APPENDIX

11.1. The answers to the questions sent to the company

Onko Metodologiaa, eli tuotantokyvykkyyttä perusteltua käyttää toimintaa ohjaavana raamina?

- Mielestäni on perusteltua. Meidän tapauksessa menestyminen perustuu pitkälti tuotannon ylivertaisuuteen (ei ole omia ylivertaisia tuotteita). Jotta tuotantokyvykkyyttä voidaan kehittää, tulee ymmärtää tuotantokyvykkyyden ulottuvuudet.

Auttaako metodologia kokonaiskuvan muodostamisessa?

- Metodologia auttaa kokonaiskuvan muodostamisessa. Jo työssä esitetty metodologian yhteenveto hyvin visualisoituna on käyttökelpoinen sellaisenaan tulevissa projekteissa. Työ kokonaisuudessaan lienee liian raskas esim. tuotannon henkilöstölle. On tärkeää ymmärtää itse ja auttaa projektiryhmää ymmärtämään tuotantokyvykkyyteen liittyviä osa-alueita ja niiden keskinäisiä vaikuttavuuksia.

Onko metodologiaa helppo käyttää? Onko pisteytys käytännön kannalta järkevä ratkaisu?

- Pisteytys on järkevä ratkaisu. Joskin kehitettävien aktiviteettien syy-seuraussuhteiden arviointi on tehtävä huolella, järjestystä ei määrää pelkkä pistemäärä.

Onko aktiviteettien ja niiden kehitysongelmien erillinen arviointi järkevää?

- Kehitysongelmia on tarkasteltava erikseen ja huolellisesti. On hyvä pystyä arvioimaan kehitysongelmia samalla aikaa eri näkökulmista (hyöty ja toteutuksen helppous, sekä näihin johtavat seikat)

Onko muodostetut johtopäätökset (so. pisteytetyt kehitysprojektit) järkeviä ja toteutettavissa?

[Ei vielä toteutettuja projekteja]

Muuta vapaata palautetta

- Aktiviteettejä voidaan hakea laidasta laitaan (eli ei tarvitse olla vakavuusjärjestyksessä)
- Herättelee varmasti keskustelua aihepiireistä
- Voidaan tarkastella kokonaista systeemiä kerralla tai pelkästään sen osa-aluetta (esim. ostotoiminta tai hitsaustoiminta)
- Saadaan näytettyä kokonaiskuvaa koko ryhmälle. Eli kapean toiminnan merkitys suurempaan systeemiin
- Aktiviteettien muuttujat ovat hyvät. Ennustettavuus- näkökulma tärkeä ymmärtää laajasti. On prosesseja, joissa on todella huonosti ennustettavia piirteitä.
- Monia näkökulmia sisältävä pisteytys on hyvä!

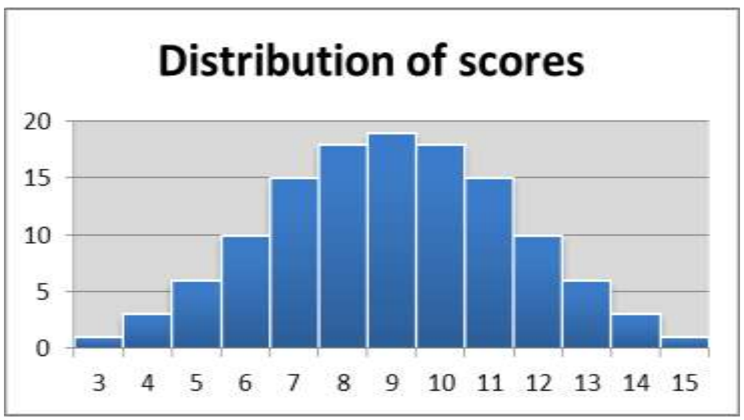
11.2. Heat map for scored capabilities

Capability score heat map - Intepretation of scores with value to capability >= 3

Capability value		5	5	5	5	5	4	4	4	4	4	3	3	3	3	3
Controllability/Current performance		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
SUM		6	7	8	9	10	5	6	7	8	9	4	5	6	7	8
Predictability	1	7	8	9	10	11	6	7	8	9	10	5	6	7	8	9
	2	8	9	10	11	12	7	8	9	10	11	6	7	8	9	10
	3	9	10	11	12	**13**	8	9	10	11	12	7	8	9	10	11
	4	10	11	**12**	**13**	**14**	9	10	11	**12**	**13**	8	9	10	11	**12**
	5	11	12	**13**	**14**	**15**	10	11	12	**13**	**14**	9	10	11	12	**13**

Capability score heat map - Intepretation of scores with value to capability >= 3 | Activities with value to capability <3

Capability value		5	5	5	5	5	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1
Controllability/Current performance		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
SUM		6	7	8	9	10	5	6	7	8	9	4	5	6	7	8	3	4	5	6	7	2	3	4	5	6
Predictability	1	7	8	9	10	11	6	7	8	9	10	5	6	7	8	9	4	5	6	7	8	3	4	5	6	7
	2	8	9	10	11	12	7	8	9	10	11	6	7	8	9	10	5	6	7	8	9	4	5	6	7	8
	3	9	10	11	12	**13**	8	9	10	11	12	7	8	9	10	11	6	7	8	9	10	5	6	7	8	9
	4	10	11	**12**	**13**	**14**	9	10	11	**12**	**13**	8	9	10	11	**12**	7	8	9	10	11	6	7	8	9	10
	5	11	12	**13**	**14**	**15**	10	11	12	**13**	**14**	9	10	11	12	**13**	8	9	10	11	12	7	8	9	10	11



Picture 1 Distribution of scores

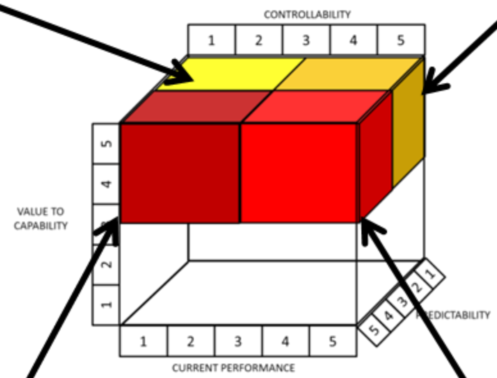
11.3. Interpretation of color indicators

Korkea kyvykkyysarvo
Huono suoritustaso
Huono ennustettavuus

Aktiviteettia ei kannata kehittää ensimmäisten joukossa. Onnistuessaan saavutetaan suuret hyödyt mutta aktiviteetti on vaikeasti ennustettava, joten kehitystyö on vaikeaa. Lisäksi tämän hetkinen huono suoritustaso saattaa edellyttää suuria investointeja

Korkea kyvykkyysarvo
Korkea suoritustaso
Huono ennustettavuus

Aktiviteettia ei tarvitse kehittää ensimmäisten joukossa. Onnistuessaan saavutetaan suhteessa muihin vain vähän hyötyä. Lisäksi aktiviteetti on vaikeasti ennustettava, joten kehitystyö on vaikeaa. Lisäksi kustannus-hyöty näkökulmasta tämän hetkinen hyvä suoritustaso tekee kehitystyöstä suhteellisen tarpeetonta.



Korkea kyvykkyysarvo
Huono suoritustaso
Korkea ennustettavuus

Aktiviteettia kannattaa kehittää ensimmäisten joukossa. Onnistuessaan saavutetaan suhteessa muihin suurin hyöty. Aktiviteetti on ennustettava, joten kehitystyö on helpompaa. Huono suoritustaso voi kuitenkin kertoa siitä, että kehitystyö on kallista.

Korkea kyvykkyysarvo
Korkea suoritustaso
Korkea ennustettavuus

Aktiviteettia voi kehittää ensimmäisten joukossa. Onnistuessaan saavutetaan suhteessa muihin vain vähän hyötyä. Mutta aktiviteetti on ennustettava, joten kehitystyö on helpompaa. Kyseinen aktiviteetti saattaa kuulua yrityksen ydinosaamisalueeseen, joten kehitystyö tekee vahvuuksista entistä parempia.