JÖNKÖPING UNIVERSITY
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Can lean and reconfigurability be combined?

From a manufacturing system investment perspective

PAPER WITHIN *Production Development*

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Abstract

Purpose: The study aims to investigate the possibility of combining lean and reconfigurability into one concept through the use of a new set of investment criteria. To fulfil the purpose of the study was three research questions created:

1. *What are the similarities and differences between lean and reconfigurability?*
2. *How do existing investment criteria support lean and reconfigurability?*
3. *How can the existing investment criteria be combined into a set of investment criteria that facilitates lean and reconfigurability?*

Method: A literature review was conducted to explore the existing research content regarding the lean, reconfigurability, and investment criteria, and thus formed a theoretical framework. In order to complement the theoretical framework, a single-case-study within the automotive industry was carried out, including interviews and document studies. Once all the data at the focal company was collected, the pattern match process against the literature started. The first research question was answered through the use of both literature and interviews, meanwhile the second research question was answered using literature, interviews and document studies. The result of both research question one and two was then used together with additional interview data in order to answer research question three. Due to that the study's research question is within sensitive fields for the focal company, some of the collected data could not be disclosed.

Result: The study shows that it is possible to combine lean and reconfigurability into one concept through the use of a new set of investment criteria. Thus, achieving a manufacturing system that is both cost-efficient and reconfigurable, thereby being less sensitive to present and future market fluctuations. The combination can be achieved in different ways, one possible way that is presented within the study is to use the lean concept as a foundation since it is comprehensive and includes a lot of different management principles, methods and tools which are applicable within the reconfigurability concept as well. Then later add the reconfigurability principles into the lean concept, which will help the lean concept to become less sensitive to the present and future market fluctuations.

Implications: Practitioners are shown the possibility of combining lean and reconfigurability through the use of investment criteria. Theoretically, the study contributes with a comparison, which focuses on the similarities and differences between the two concepts.

Delimitations: The study includes three delimitations, the first one is regarding the study has chosen to focus on investments that are being made from a system level down to each individual workstation, and therefore, does not include investments concerning external logistics or other sites. The second delimitation is about the project process within the focal company. Within this study are only the concept phase studied, and thus the realisation phase is not included. The study's last delimitation is about that the study has only included the reconfigurability concept within the overarching AMS-field.

Keywords: Lean, Reconfigurability, Investment criteria, Manufacturing system

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1 Introduction

The chapter starts by presenting challenges triggered by the globalisation and the increased demand regarding customisation and continue to present what todays manufacturing systems are missing in order to face these challenges. Then are reconfigurability introduced. The chapter continues with discussing the problems regarding implementing reconfigurability into today's organisation which leads to the study's purpose and research question. At last are the study's delimitation presented together with an outline of the report.

1.1 Background

Followed by globalisation, manufacturing companies face challenges such as quickly changing customer demands, increase demand for customised products, and fast developing technologies regarding products, production, and communication (Westkämper, 2006). When the demand for new products increase the product life-cycle is shrinking and increases the demand for faster product and production development, faster product launches, and more and faster ramp-ups (Koren et al., 1999; National Research Council, 1998; Schmitt & Schmitt, 2013; Zhang, Liu, Gong, & Huang, 2006). In order to remain competitive, manufacturing companies need the ability to design, re-design, and operate manufacturing systems that are reconfigurable, i.e. systems that can be continuously upgraded and changed over time to meet the new market demands and still remain cost-efficient (Mehrabi, Ulsoy, & Koren, 2000).

Traditionally, two fundamental manufacturing strategies have dominated the field of manufacturing: Dedicated Manufacturing System (DMS) and Flexible Manufacturing System (FMS). DMSs are cost-efficient dedicated systems for achieving high capacity with low flexibility thereby, have DMSs often been used within mass production (Koren et al., 1999; Mehrabi et al., 2000). FMSs includes often Computer Numerical Controlled (CNC) machines for high flexibility with low capacity, which were developed to meet the new market demands regarding increased customisation (Koren et al., 1999; Mehrabi et al., 2000). DMSs have received huge acceptance over the years due to high and stable demand on the market but are now facing problems due to the challenges triggered by globalisation and the increased need for products with higher degree of customisation (Koren et al., 1999). On the other hand, did FMSs only have limited success. Even though FMS could handle short ramp-ups and many variants did the system often get too expensive due to too much flexibility was invested into the system (Mehrabi et al., 2000).

Also, around the same time as FMS was developed and introduced to the market was the manufacturing strategy lean manufacturing introduced to the market. Lean manufacturing derived from the success of Toyota and the Toyota Production System (TPS), presented by Womack, Jones, and Roos (1990). Lean showed the world that it was possible to produce cars with high output and cost-efficiency, and at the same time being

able to handle some variation (Womack et al., 1990). This was achieved through focusing on eliminating all non-value-added activities (also called waste) within the processes (Liker, 2004; Ohno, 1988). Lean included several strategical principles, methods and tools, which an organisation could use in order to eliminate all the waste (Liker, 2004). This made manufactures wanting to adopt lean (Mehrabi et al., 2000; Shah & Ward, 2003). Since then has lean according to Samuel et al. (2015) been the dominating operations paradigms around the globe. Lean enabled reduction through less human effort, manufacturing space, and investment in tools, etc., at the same time as the new concept generated higher quality and less inventory than the traditional DMS (Samuel et al., 2015). Lean gained acceptance throughout many industries due to its high cost-efficiency and simplicity (Kolberg, Knobloch, & Zühlke, 2017). Even though lean allows variation to some extent, it still faces the same challenges as DMSs in today's market, i.e. increased demand of customised products, shrinking product life-cycle times, and increased demand for faster product and production developments and launches (Mehrabi et al., 2000; Shah & Ward, 2003).

Thus, in order to respond to shrinking product life-cycles, increasing demand for faster and more efficient ramp-ups, together with the global economic pressure, there is a need for investing in new manufacturing technologies. Advanced manufacturing systems (AMS) is an overarching concept of modern manufacturing technologies, which uses technologies such as automation and flexible systems, in order to achieve e.g. higher quality, cost-efficiency and flexibility (Gupta, 2017; Kumar, Zindani, & Davim, 2018). According to Matta and Semeraro (2005) are reconfigurability included within AMS, and according to Koren et al. (1999) are reconfigurability a good possible solution to the changing market and increasing demands. Reconfigurability combines the cost-efficiency and high throughput of DMS with the flexibility functions of FMS (Mehrabi et al., 2000; Zhang et al., 2006), and therefore, are less sensitive to the present and future market fluctuations at the same time it achieves cost-efficient high throughput lines. Zhang et al. (2006) believes that reconfigurability are the manufacturing paradigm of the future, and the idea of reconfigurability is that the manufacturing system should be reconfigurable over time, enabling better adaption to future market demands and trends (ElMaraghy, 2006; Koren et al., 1999; Mehrabi et al., 2000). The reconfigurability level within an organisation is affected by several factors such as the machines, tools and technologies within the manufacturing processes (ElMaraghy, 2006; Koren et al., 1999; Mehrabi et al., 2000). Thus, for an organisation to reap the virtues of reconfigurability (or any concept for that matter), it is necessary to invest into the required equipment. In order to justify investments within an organisation are the use of financial criteria (i.e. financial principles used to help with making decisions (Oxford Learner’s Dictionaries for Academic English, n.d.) a commonly used method.

1.2 Problem description

To justify investments in traditional manufacturing systems such as DMSs are financial criteria often used as a central support, since the investments have a tangible focus, such as: cost reduction or capacity expansion (Meredith & Suresh, 1986). However, Proctor and Canada (1992), Kaplan (1986), and Saleh et al. (2001) argues that financial investment criteria are ill-suited to be used alone while evaluating investments in AMSs. Because, investments in AMSs do not have the same intended outcome, due to AMSs benefits are of a more strategic and intangible character; e.g. flexibility, floor space or product quality (Chung, 1993; Meredith & Suresh, 1986; Saleh et al., 2001). Saleh et al. (2001) continues to argue that strategic investment criteria alone would neither provide the full picture of the possible investment. Therefore, is it important to use the combination of tangible and intangible investment criteria, and Kuzgunkaya and ElMaraghy (2009) does suggest adding intangible criteria regarding reconfigurability to the existing pool of investment criteria to enable investments in reconfigurability. The notion to use a combination of both tangible and intangible investment criteria while evaluating investments in AMS are employed by other authors like: Durán and Aguilo (2008), Ordoobadi (2012), and Iakymenko, Alfnes, and Thomassen (2016). However, according to Bi et al. (2008) are reconfigurability not widely reported to have been successfully implemented. Bi et al. (2008) continues to explain the reason for the absence of success stories as organisations are lacking support tools to help with the transition towards reconfigurability. Within a case study made by Rösiö and Säfsten (2013) was it described that the case companies had an intent to move towards becoming more reconfigurable, but the case companies themselves felt that they lacked the support tools to justify the investments. Thus, for organisations to incorporate reconfigurability within their manufacturing system is it necessary to add intangible investment criteria that facilitate reconfigurability to the already existing pool of both tangible and intangible investment criteria (Bi et al., 2008).

Since lean has reached global acceptance within multiple industries (Samuel et al., 2015), it is lean-organisations that can be enabled to become more reconfigurable (thus less sensitive to the present and future market fluctuations) through investments into the organisation’s manufacturing system.

1.3 Purpose and research questions

The already mentioned increase global pressure which drives organisations to faster develop products with shorter life-cycles and higher degree of customisation, together with the increasing need for new products with more variants, puts increasing pressure on the manufacturing system, to faster be able to ramp-up the production and at the same time stay cost-efficient with high quality. A solution to handle the problems with faster product development and launches could be reconfigurability that enable short ramp-ups, cost-efficiency, high throughput, the capabilities to produce different variants, and to change reconfigurations over time. However, to enable organisation that employ lean to move towards a more reconfigurable manufacturing system is it imperative to enable justification of the necessary funds and effort for development and investments. Therefore, it is important to increase the awareness for organisation regarding how investments could be done in order to further both lean and reconfigurability. Based on this reasoning are the purpose of this study:

> *To increase the awareness regarding how investment criteria can enable the combination of the two concepts lean and reconfigurability.*

To be able to fulfil the purpose of the study are mapping of the lean and reconfigurability required, which is the foundation behind the studies first research question:

1. *What are the similarities and differences between lean and reconfigurability?*

Secondly, in order to succeed with the goal of creating a balanced set of investment criteria, further information regarding investment criteria and its influence on lean and reconfigurability is needed, therefore, the second research question is:

2. *How do existing investment criteria support lean and reconfigurability?*

At last, by combining research question one and two will it help to finalise the purpose of the study, i.e. the creation of a new set of investment criteria, thus the third research question is:

3. *How can the existing investment criteria be combined into a set of investment criteria that facilitates lean and reconfigurability?*

1.4 Delimitations

The study includes three delimitations in order to ensure that the scope of the study is within reasonable limits. The first delimitation is focusing on which organisational level the investments are being studying. Both the two concepts and investments in general can take place at different levels within an organisation, and thus creates a tremendous amount of possible perspective to study. Thereby have this study focused on investments that are being made from a system level down to each individual workstation, and therefore, does not include investments concerning for example external logistics or other sites included within an organisation etc.

The second delimitation of the study is regarding the focal company development process, which consists of multiple phases, see Figure 1. The delimitation regarding the development process is represented by the circle in Figure 1, excluding the realisation phase of the development process. The reason behind this delimitation is because once the concept phase is completed and the investment decision is taken approximately 80% of the project is frozen. Thus, can the biggest amount of impact regarding the end-result be made in the concept phase, and it is also within the investment decision the investment criteria are strongly considered.

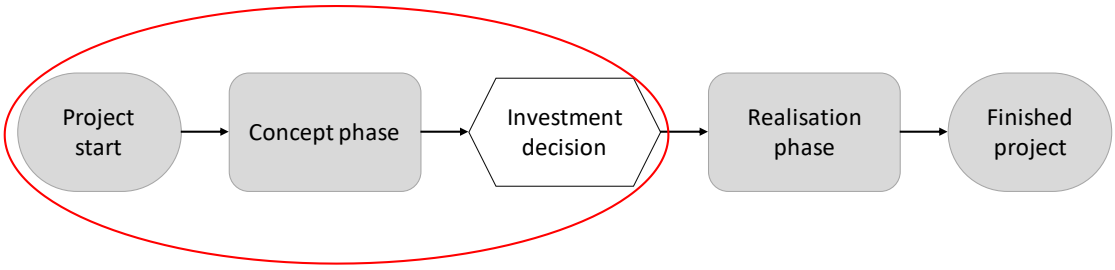

Figure 1. Delimitation.

At last has also the research field regarding increasing flexibility, reconfigurability and changeability (i.e. the AMS-field) within an organisation been delimited to focus on reconfigurability. The study is only focusing on the lean and reconfigurability intersection, since lean are the predominate strategy used and the combination of lean and reconfigurability is an interesting combination worth investigating to see if they have the possibility of working together. However, the literature regarding investment criteria are including literature outside reconfigurability, due to that most of the literature are connected to the AMS-field.

1.5 Outline

In the first chapter are the study area introduced together with the study's purpose and research question. The second chapter of the report is the Method, which describes how the study was conducted. Following the method are the Theoretical framework where the all the theory is presented. Later within the chapter Findings are all the empirical data from the focal company presented. Which are then are then analysed within the chapter Analysis. The findings of the study together with the choice of method are then discussed and summarised into the study's conclusion, which are presented in the chapter Discussion and conclusions. At last are the references presented followed by the study's appendices.

2 Method

Within this chapter the proposed methodology is presented for the study, which aim is to give the reader a possibility to follow how the research were conducted. The chapter starts with presenting the design of the study and continues with presenting how the literature research was conducted. Later the case selection is motivated, and the study's interviews and document studies are presented. At last are a structure of the data analysis presented together with which actions the authors has taken in order to increase the trustworthiness and ethical levels of the study.

2.1 Study design

To answer the study's purpose were three research questions (RQs) were created, the first RQ investigate what lean and reconfigurability has for similarities and differences. The second RQ were aimed to understand how the found investment criteria supported or hindered the use of lean and reconfigurability. Finally, were the third RQ created to create a new list of investment criteria which facilitate lean and reconfigurability.

A single case study design was deemed as a good fit to be able to study the phenomena in-depth. According to Yin (2007) and Eisenhardt (1989), case study is an appropriate research method when studying a complex phenomenon and there is need to investigate the phenomenon in-depth.

A literature review was used as the foundation and then were interviews and document studies used to further gain insight in the phenomena. In Figure 2 are a visualisation of how the three RQs are connected and what data collection methods that were used. As seen in Figure 2 were RQ 1 and 2 answered separately to bring necessary knowledge to be able to answer RQ 3. RQ 3 used the result from RQ 1 and 2 together with additional interview data, in order to answer how the existing investment criteria can be combined into a set of investment criteria that facilitates both a cost-efficient and reconfigurable manufacturing. The study was continuously discussed with the supervisors at the focal company in order to get their perspective and thoughts, and thus were used in order to double check the result.

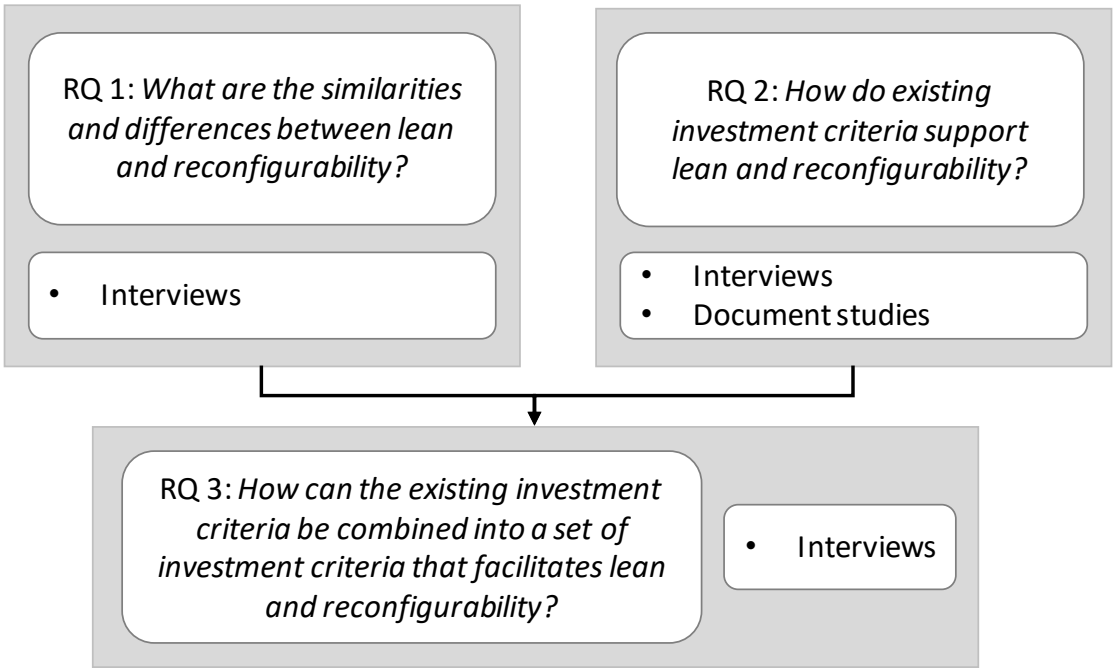

Figure 2. Connection between data collection and research questions

2.2 Theoretical framework

The creation of the theoretical framework is based on the search method of Wolfwinkel, Furtmueller, and Wilderom (2013). The method is a five-step method with the steps: *(1) Define, (2) Search, (3) Select, (4) Analyse,* and *(5) Present*. First, it will is described how the articles were found and selected in the *Literature search,* followed by how the analyse of the selected articles were conducted, which is described in the *Literature* section.

2.2.1 Literature search

Within the study literature searches were conducted through the areas of lean, reconfigurability and investment criteria. The search was divided in two major searches: lean and reconfigurability, and investment criteria.

2.2.1.1 Lean and reconfigurability

The search terms that were used in the literature review stage *Define* is presented in Table 1, and is the foundation for the stage *Search*. In the stage *Search,* were the search of literature conducted, which created the body of literature that were considered in the literature search. The search was conducted through the database *Scopus,* which provide peer-reviewed articles from multiple publishing firms and journals. The result of the search included 79 articles, and the search was made with the "*Title-Keywords-Abstract"* search field. Following the stage of *Search* are *Selection*, where the criteria was used to decide if the found literature was worth using for the literature review. The first tier selection, removed unwanted search result based on their title and the keywords used, second tier selection was based on their abstract, and the third tier are the articles

that where not possible to access via the universities databases or through the internet. The number of articles that were left after each tier are presented in Table 1. The 19 articles presented in Table 1 made the foundation for the literature regarding lean and reconfigurability and was complimented through the use of backward and forward citing, in order to follow up on research trends, interesting conclusions and reasoning.

Table 1. Search Result, Lean and Reconfigurability

Search Term	Database	Search Hits	Tier 1	Tier 2	Tier 3	Result
(“Lean Manufacturing” OR “Lean Production” OR Lean) AND (Change* OR RMS OR Reconfigur*) AND (Manufacture OR Production)	Scopus	79	60	30	19	19

2.2.1.2 Investments criteria

The search terms used in the search for investment criteria field generated 1634 different articles. The search terms used, and their corresponding hits are presented in Table 2. Due to the problem of finding a limited area for the literature search, forward and backwards citing was the predominated used method. Through the help of supervisors and other researchers were the structure for the forward and backward citing created. Articles that were found through all the searches and deemed relevant were also added to the foundation for the forward and backward citing. The found articles went through the same selection process as in Lean and reconfigurability, but the selection started at tier two, reading the abstract, then if accessible the article was accessible were, they were read.

Table 2. Search result, investment criteria

Search Term	Search Hits
Investment AND Criteria AND (Manufacturing OR Production)	1 643
Lean AND Investment AND Criteria AND (Manufacturing OR Production)	10
(Reconfigur* OR changea* OR RMS OR “Advanced manufacturing” OR AMS OR AMT) AND Investment AND Criteria AND (Manufacturing OR Production)	51
Investment AND model AND (Manufacturing OR Production)	13 431
Lean AND Investment AND model AND (Manufacturing OR Production)	104
(Reconfigur* OR changea* OR RMS OR “Advanced manufacturing” OR AMS OR AMT) AND Investment AND model AND (Manufacturing or Production)	222

2.2.2 Literature analyses

After the articles went through the selection process, it was time for the *Analyse* step followed by the *Present* step. The two areas lean and reconfigurability, and investment criteria were analysed separately, and the categorisation will be described in the following section.

2.2.2.1 Lean and reconfigurability

The selected articles were read through and marked for interesting data and potential snowballing possibilities. Each article was classified through different colours, either a green, yellow or red colour depending on how relevant the article was for the study, together with a short summary of what aspects the article brought up. The classification and relevance document where then used as a foundation to create the text in the lean and reconfigurability chapters within the theoretical framework.

2.2.2.2 Investment criteria

The articles deemed relevant were read through and marked for interesting data, facts, and reasoning. After all the articles were read and marked the content was classified into different categories, such as: economical, analytical, strategic justification methods, tangible criteria, or intangible criteria.

2.3 Case study

The case selection and the used data collection methods i.e. interview, and document studies are described and presented in the following section.

2.3.1 Case selection

The focal company used for the case study was selected based on two criteria: (I) *The company should use lean,* and (II) *The company should have an interest or need for reconfigurability in their production system.* The focal company are active within the automotive industry. The industry is now facing new challenges due to new emergent technologies, stricter rules from legislators, and more aware customers. Therefore, the focal company is interested in investigating the possible use for reconfigurability within their manufacturing system, to better be able to mitigate the risks the industry is facing. The focal company are today reliant on the methodology and tools of lean and are interested in the combination of lean and reconfigurability. However, the research fields of the study are quite sensitive to the focal company, thereby, all existing data will not be available to present within the study, due to a secrecy-agreement with the focal company have been signed.

The phenomena that were chosen for the study were the focal company's investment process regarding new product development, and thus also development of new lines and manufacturing systems. The investment process was chosen since decisions regarding what to invest in at this early stage will come to affect the possibility of creating a manufacturing system that are cost-efficient and reconfigurable.

2.3.2 Interviews

The interviews were used as a complement to the literature review with the goal to gather both general and case specific qualitative data. By using semi-structured interviews this goal has been achieved. Saunders et al. (2015) says that semi-structured interviews are good to use in order to gather both general and detailed information, which was needed within the study. Semi-structured interviews are also an effective method to use in order to follow interesting leads that occurred during the interview (Saunders et al., 2015).

The respondents were chosen in collaboration with the focal company based on the type of information that were needed and who could possess the information. According to Eisenhardt and Graebner (2007), the risk for biases can be reduced if the respondents are chosen based on their knowledge and access to the relevant information. The respondent number and role at the focal company, the date, time and method of the interview are presented in Table 3.

Table 3. Interviews

#	Date	Role in organisation	Method	Time
1	27-03-2019	Industrial concept leader	Semi structured	1,1 hours
2	29-03-2019	Concept investment manager	Semi structured	1,2 hours
3	29-03-2019	IT responsible - manufacturing	Semi structured	1 hour
4	29-03-2019	Developer of lines & equipment	Semi structured	0,9 hours
5	28-03-2019	Business developer	Semi structured	1,2 hours
6	28-03-2019	Business developer	Semi structured	1,2 hours
7	03-04-2019	R&D - future components	Semi structured	1,3 hours
8	26-03-2019	Production flow simulator	Semi structured	0,9 hours
9	03-04-2019	Investment controller	Semi structured	1 hour
10	28-03-2019	Maintenance developer	Semi structured	1,3 hours
11	01-04-2019	Assembly line developer	Semi structured	1,1 hours

The purpose of all the interviews were to get an insight into how the people within the focal company worked with the investment criteria and how the investment criteria either hindered or supported their work tasks. Another focus during the interviews were the relation between the two concepts lean and reconfigurability. Both regarding how the respondents were affected by and worked with the two concepts within their daily tasks. Also, what could be done in order to further the development of the two concepts. The structure of the interview and all prepared questions are presented in Appendix 1. Before the interviews, all the respondents were asked if it was ok to record the interview in order to increase the quality of the possible input, and all respondents were ok with this. Also, when the respondents were chosen their knowledge level regarding the two concepts were considered in order to make sure that the input was going to be of high quality.

Meanwhile, during the interviews had the interviewer's different roles. One had the role of interviewer, mainly focusing on asking questions, and following interesting leads that occurred during the interview. The other interviewer had the role of taking notes and recording the interview, accompanied with asking follow-up questions if deemed necessary. After each interview the two interviewers did recap the interviews to make sure that both had got the same information of the interview. According to Fasick (1977) field notes are superior complement to the transcribed audio records. In between and after the interview occasions, the interviews were annotated to reduce false perception of the interviews and to make sure that nothing important were missed (Creswell & Creswell, 2018; Saunders et al., 2015; Williamson, 2002). The respondents were informed about the topic area and was given a general introduction to the purpose of both the study and the interview before the interview started. But the respondents were not given the questions on beforehand, which according to Yin (2007) creates a better open discussion. The interviews were held in the respondents' offices or conference rooms to create a comfortable environment to lower stress levels and increase the quality of the answers. All the respondents were also available during the remaining time of the study in case any further questions or reflections arose.

2.3.3 Document studies

Document studies were performed by extracting data from already existing documents (Dahmström, 2011; Merriam, 1993) and is a good complement to other data collection methods (Skärvad & Lundahl, 2016). It is crucial to handle internal documents carefully, due to the risk that the company have corrected and refined the data (Yin, 2007). Therefore, questions regarding the collected data were asked during the interviews, in order to minimise the risk of any misjudgements during the assessment of the data (Yin, 2007). The document studies were used both as practical complement to the theory gathering from the literature review, in order to connect the study to the focal company, and as a foundation behind the interview questions. The documents included information regarding how the development process is structured at the focal company, and how the focal company historically worked and prioritised in their investment process, i.e. what the investment was based upon. The documents also included information about how the focal company tend to change their investment process. See Table 4 for the document studies.

Table 4. Document studies

Date	Purpose	Source	Method	Time
18-03-2019	Review of documents	Design principle developer & Project manager	Structured	1,5 hours
21-03-2019	Review of documents	Design principle developer	Structured	1 hour

The data collection was conducted by a representative from the focal company due to the sensitive information available within the system, and the documents included information regarding the focal company's investment criteria and process. The documents were handed over during a meeting between the authors and the responsible representative from the focal company, where the authors had the possibility to ask any questions in order to minimise the risk of any misjudgements. This meeting was extended into a second meeting due to the complexity of the documents. The representative from the focal company were also available during the remaining time of the study, in case further questions or concern arose.

2.4 Data analysis

The data within the study were analysed through identifying similarities and differences between lean and reconfigurability, and later trying to connect how these similarities and differences are affecting how the two concepts response to the existing investment criteria. The used method within the study can be seen as equal to what Trochim (1989) chose to call pattern matching. The identified patterns within the study were identified through use of data triangulation between the literature review, document studies, and the interviews.

2.5 Trustworthiness

To make sure the right considerations have been made to ensure a study that is trustworthy have the concept of *Trustworthiness* by Halldórsson and Aastrup (2003) been used. Trustworthiness were chosen because the concept was developed for qualitative studies in contrast as to the historically popular concept of: Reliability, validity, generalisation (Halldórsson & Aastrup, 2003). The concept is based on four parts: *(1) Credibility, (2) Transferability*, *(3) Dependability*, and *(4) Conformability*. Further in this chapter are an account of the actions taken within the study in order to achieve high trustworthiness.

2.5.1 Credibility

To ensure that the study achieve high credibility (i.e. high degree of assurance that what is intended to measure/collect are the things collected (Halldórsson & Aastrup, 2003)) were a structure for the study formed, e.g. creating interview guide, literature search strategy, and a general plan for the data collection, thus ensuring better results (Saunders et al., 2015). By letting the interviewee respondents having the possibility to go through and check the transcripts can the data collected be of a higher degree of credibility (Patel & Davidson, 2011). By using multiple sources of information can the studies data-quality be, to a higher degree, assured, than if only a single source of data where used (Yin, 2007).

2.5.2 Transferability

The chosen research design is case study, which have implications on the transferability of the result of the study, by limiting the transferability of the design (Patel & Davidson, 2011). It is thus, important to present as transparent as possible in order to enable the readers of the study to decide if the result of the study can be transferred to their own context (Guba & Lincon, 1989). In order to counter this a variety of data collection techniques have been used (Eisenhardt, 1989; Yin, 2007), i.e. data triangulation between literature review, interviews and document studies.

2.5.3 Dependability

By presenting the decisions made through the study within this chapter is it possible to follow the process and thereby, also be able to recreate the study with the same result. According to Guba and Lincon (1989) is it possible to ensure high dependability by presenting the method used and being transparent in decisions making and choices made throughout the study.

2.5.4 Conformability

Conformability is achieved by presenting the result of the study in an objective way without being influenced by the authors (Yin, 2007). In order to decrease the risk for any biases has several actions been taken. For example, by having the knowledge regarding biases, and thus realising the risk of biases, has decreased the risk of biases occurring. Also, each field within the study consist of a broad amount of literature, which decrease the risk for any not thoroughly thoughtful or subjective thoughts, which also increases the conformability level.

2.6 Ethical considerations

According to Creswell and Creswell (2018) are ethical considerations something that should be classified as crucial within all research, and thus is it something that has been considered within this study. Due to that the study is included within a research project, which the given supervisor is responsible of, the risk for biases increases. In order to prevent as much biases as possible, did the study strive for objectivity at all times, which is in line with the guidelines included within the European Code of Conduct for Research Integrity (2017). The objectivity was achieved through thoroughly review all available data and by the use of data triangulation.

In order to strengthen the ethical considerations within the study all involvement has been voluntary, e.g. the respondents had the choice of being interviewed or not and they did not have to answer all questions. Also, all collected information has been treated in a confidentially way, and only titles of the respondents are mentioned. Any company or personal information has either been excluded from the study or rewritten and later approved by the company. At last, are the final version of the study also published in the database Digital Academic Archive Online (DiVA), which is a database that is open for everyone. The study is available for anyone to read, and thereby contributes to the society.

3 Theoretical framework

In this chapter are the study's used literature presented. It starts with presenting lean and reconfigurability and ends with a description of the existing literature within the investment criteria field.

3.1 Lean

The term lean manufacturing was first introduced to the market 1990 through the book "The Machine that Changed the World" (Womack et al., 1990). The lean concept started to evolve in the 1950s when Eiji Toyoda studied in the USA. Since 1990, large volume of publications regarding lean has emerged, which usually includes TPS, Just-in-Time production (JIT), or lean production as synonymous and equal (Shah & Ward, 2003; Womack et al., 1990). The main goal of the lean philosophy is to reduce cost without increasing the production volume, which is achieved through eliminating all kind of non-value-adding activities (Liker, 2004; Ohno, 1988). Ohno (1988) identified seven waste categories; *(1) overproduction, (2) waiting, (3) transportation, (4) over processing, (5) inventory, (6) movement and (7) defect products.* Liker (2004) later added one more waste; *(8) waste of unused employee creativity*, and together they constitute the seven plus one wastes to eliminate.

Followed by the lean research, Shah and Ward (2003) conceptualised lean production as: *"an integrated socio-technical system, whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability"* (Shah & Ward, 2003, p. 791). Within the integrated socio-technical system it exists several methods and tools to identify and eliminate the different wastes, e.g. Just-in-Time, 5 Why's, and Continuous Improvements. According to Liker (2004) could an organisation still improve by only implementing some of the lean tools, but the organisation would never improve as much as if they would implement the whole philosophy. Liker (2004) continues with presenting the 14 management principles of lean, which is the core of how an organisation should think and act regarding most (if not all) business decisions. The 14 principles are presented in Table 5.

In order to make sure that the 14 principles are considered in each decision, within all levels of the organisation, the lean philosophy advocates and uses a strategical management method called Hoshin Kanri (Liker, 2004). Hoshin Kanri's underlying idea is to base the company vision on the 14 principles, which then is broken down into tangible goals and improvement areas within each level of the organisation. By spreading the company vison, the goals and continuous improvements within each level contributes to achieve company strategy, i.e. the 14 principles get considered in most (if not all) decisions that are made (Liker, 2004).

Table 5. 14 Management Principles.
Source (Liker, 2004)

#	Definition
1	Base your managed decisions on a long-term philosophy, even at the expense of short-term financial goals.
2	Create a continuous process flow to bring problems to the surface.
3	Use “pull” systems to avoid overproduction.
4	Level out the workload (work like the tortoise, not the hare).
5	Build a culture of stopping to fix problems, to get quality right the first time.
6	Standardized tasks and processes are the foundation for continuous improvement and employee engagement.
7	Use visual controls so no problems are hidden.
8	Use only reliable, thoroughly tested technology that serves your people and process.
9	Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.
10	Develop exceptional people and teams who follow your company’s philosophy.
11	Respect your extended network of partners and suppliers by challenging them and helping them improve.
12	Go and see for yourself to thoroughly understand the situation.
13	Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.
14	Become a learning organization through relentless reflection and continuous improvement.

3.2 Reconfigurability

Koren et al. (1999) introduced reconfigurability as Reconfigurable Manufacturing System (RMS), and is included within the umbrella field Advanced Manufacturing System (AMS) (Matta & Semeraro, 2005). As mentioned in the background, the reason behind why reconfigurability was introduced, was due to the market changes triggered by the increased globalisation and customer knowledge, e.g. increased customisation of products, and large fluctuations in product demand and mix (Andersen, Brunoe, & Nielsen, 2015; Koren et al., 1999). Since then, the market changes have only increased together with the increased interest/activity by politics regarding legislations affecting the manufacturing companies, and therefore, in order to stay competitive, manufacturers need a higher level of reconfigurable regarding their manufacturing system (Andersen et al., 2015; Rösiö & Säfsten, 2013). Farid (2008) define the term reconfigurability as:

“the ability to add, remove and/or rearrange in a timely and cost-effective manner the components and functions of a system, which can result in a desired set of alternative configurations” (Farid, 2008, p. 1276).

Koren et al. (1999) continues with pointing out the benefits of reconfigurability as the opportunity to combine the high throughput of DML with the flexibility functions of FMS, which enables a cost-effective manufacturing system that is responsive to the market changes over time. Thus, reconfigurability meets today’s challenges in a way

that the traditional approaches are not able to, and therefore is a more suitable response (Koren, 2006). Some of the factors that affect the success of the reconfigurability of an organisation is how well reconfigurability has permeated the organisation (Wiendahl & Hernández, 2006), according to Andersen et al. (2016) are there also some prerequisites that affect the implementation.

3.2.1 Reconfigurability within an organisation

As other systems and concepts reconfigurability starts with the design process, and due to its complex elements, it increases the complexity of the design process, which should be regarded as possible barriers towards an effective implementation of reconfigurability (Andersen et al., 2016). Rösiö (2012b), and Rösiö and Jackson (2009, [Through (Andersen et al., 2016)]) presents seven prerequisites that is important to consider, in order to achieve a successful increasement of reconfigurability within an organisation, see Table 6.

Table 6. Prerequisites for Reconfigurability
Adapted from: (Andersen et al., 2016)

#	Prerequisites	Author
1	A life-cycle perspective on production systems	(Rösiö and Jackson, 2009 [Through (Andersen et al., 2016)])
2	Correlation between production system design and the product portfolio development	(Rösiö and Jackson, 2009 [Through (Andersen et al., 2016)])
3	Having long-term view on investments in production capacity	(Rösiö, 2012b)
4	Having a structured production system design process	(Rösiö, 2012b)
5	Having a holistic perspective on production systems	(Rösiö, 2012b)
6	Having staff that is skilled in system design and have knowledge of reconfigurability	(Rösiö, 2012b)
7	Existence of product families for customised flexibility in production	(Rösiö, 2012b)

As Andersen et al. (2016) states, it is clear that the prerequisites presented in Table 6 can have very different nature, the prerequisites can be defined as a specific condition, capability, or knowledge needed within the organisation to become reconfigurable. All prerequisites might not be present within the organisation, and therefore it is crucial to identify which activities and investments that can be carried out in order to develop the missing prerequisites (Andersen et al., 2016).

As mentioned before, when choosing to work towards and increasement of reconfigurability, it will require changes affecting the whole organisation, i.e. all levels within the organisation (Wiendahl & Hernández, 2006). According to Wiendahl and Hernández (2006) and Wiendahl et al. (2007) it exists following six levels: *(1) Network, (2) Factory, (3) Segment, (4) System, (5) Cell, and (6) Workstation.* Each level is shortly defined in Table 7 below:

Table 7. Reconfigurability levels.
Sources: (Wiendahl et al., 2007; Wiendahl & Hernández, 2006)

Level	Definition
Network	Highest level, all sites of the organisation
Factory	Single site level, covering building and its infrastructure
Segment	All processes involved in manufacturing ship-ready products
System	All processes used for manufacturing variants of a product
Cell	A subsystem containing group of work stations and material handling, to work on the product
Workstation	Lowest level, single workstations and machines that add value to the product

The different levels affect each other, and it is important to be aware of their interdependencies. In the higher levels, it is usually organisational changes that are discussed and being conducted e.g. strategical goals, vision, etc., which affects the levels below (Andersen et al., 2015). Some changes in the lower levels might just affect the level where the change is made, therefore in order to succeed, it is crucial to choose the right level according to the appointed need of change.

3.2.2 Reconfigurability characteristics

Reconfigurability within manufacturing could be described in terms of its characteristics, which slightly differ depending on author (Rösiö, 2012a). According to Koren et al. (1999) and Mehrabi et al. (2000) the core characteristics is: *(1) Integrability, (2) Modularity, (3) Customisation, (4) Convertibility, (5) Diagnosability, and (6) Scalability.* Additional research has also included*: (7) Mobility, and (8) Automatability* (Wiendahl & Heger, 2011). Each one of the characteristics is essential for reconfigurability, they are described in the following section.

(1) Integrability within a system is where the interfaces between the components, e.g. machines, control modules, and software are designed for component integration (Koren et al., 1999). Thus, is the integration possible between both hardware and software components (Napoleone, Pozzetti, & Macchi, 2018). The integrability is crucial to have in mind when designing future modules in order to match and be integrable with the present modules (Rösiö & Säfsten, 2013).

(2) Modularity is closely related to integrability (Mehrabi, Ulsoy, Koren, & Heytler, 2002; Shaik, Rao, & Rao, 2014), and is the ability to design all system elements to be modular (Rösiö & Säfsten, 2013), i.e. the ability to integrate and/or remove modules (e.g. controls, axes, software, and tooling) within the system. According to Mehrabi et al. (2002) is a key enabler behind a reconfigurable manufacturing system that these change of modules does not negatively affect the rest of the system. By making the system more modular it increases its competitiveness, due to it creates an independence between the components within the system, since the modules can be interchanged easily, fast and cost effective (Napoleone et al., 2018).

Increased (3) Customisation, which evolves into changes in the product functionality and capacity is what reconfigurability is built around (Goyal, Jain, & Jain, 2013). Customisation within the system is basically about having the right level of capacity and flexibility, in order to be able to manufacture the products to be produced in the system (Rösiö & Säfsten, 2013). The capability and flexibility concern e.g. machines, tools, and competences (Rösiö & Säfsten, 2013).

(4) Convertibility is the ability for a system to being able to react fast and cost-efficient regarding converting both between existing products, but also regarding future products (Koren et al., 1999; Mehrabi et al., 2000). Therefore, it is crucial that convertibility is synced with the modularity and integrability characteristics, elsewise the converting between present and future products will neither be fast nor cost-efficient. This includes both machines and equipment but also the personnel competence (Rösiö & Säfsten, 2013).

(5) Diagnosability increases the ability to quickly identify sources of quality and reliability issues (Liu, Luo, Chu, & Chen, 2004; Rösiö & Säfsten, 2013), which is crucial due that a reconfigurable system frequently modified (Koren et al., 1999). Some authors have also added the ability to quickly correct the identified problems to the diagnosability principle (Gumasta, Kumar Gupta, Benyoucef, & Tiwari, 2011; Koren & Shpitalni, 2010; Singh, Khilwani, & Tiwari, 2007).

(6) Scalability is the ability to be able to easily adjust the system capacity in order to meet the demand fluctuations (Rösiö & Säfsten, 2013). According to Rösiö and Säfsten (2013) can the system capacity be adjusted in several ways, e.g. by the material handling systems, number of machines, amount employees, and number of shifts. It is crucial that the capacity adjustment is both time- and cost-efficient and it can change incrementally (Napoleone et al., 2018), and according to Wang, Huang, Yan, and Du (2017) and Kolberg, Knobloch, and Zühlke (2017) is this achieved through standardised interfaces and procedures.

(7) Mobility is the ability to be able to easily move machines and equipment to another location (Rösiö & Säfsten, 2013), by e.g. having wheels on the machines, light equipment, or a tool wagon. According to Rösiö & Säfsten (2013), it is also important to ensure that the used information systems are adapted for location changes.

(8) Automatability is the ability to easily being able to change the level of automation within the system according to the conditions, e.g. the automation of machines, information handling, and material handling (Rösiö & Säfsten, 2013).

The eight principles are summarised into Table 8 with their definition and their origin.

Table 8. Reconfigurability principles.

#	Principle	Definition	Author
1	Integrability	The ability to design all modules (present and future) to easily integrate into the rest of the system	(Koren et al., 1999; Mehrabi et al., 2000)
2	Modularity	The ability to design all system elements to be modular	(Koren et al., 1999; Mehrabi et al., 2000)
3	Customisation	The ability to have the right level of capability and flexibility in order to be able to manufacture the products to be produced in the system (both present and future products)	(Koren et al., 1999; Mehrabi et al., 2000)
4	Convertibility	The ability for a system to react fast and cost-efficient regarding converting both between existing and future products	(Koren et al., 1999; Mehrabi et al., 2000)
5	Diagnosability	The ability to quickly and efficient identify the sources of quality and reliability problems	(Koren et al., 1999; Mehrabi et al., 2000)
6	Scalability	The ability to easily adjust the system capacity in order to meet the demand fluctuations	(Koren et al., 1999; Mehrabi et al., 2000)
7	Mobility	The ability to easily and quickly move and install machines and equipment to another location	(Wiendahl & Heger, 2011)
8	Automatability	The ability to easily change the level of automation within the system	(Wiendahl & Heger, 2011)

3.3 Investment

Organisations perform investments in different forms to keep their competitive advantages and not to fall behind the competition (Chung, 1993; Meredith & Suresh, 1986). According to Chung (1993) are there three traditional common types of investments for organisations to do within a manufacturing environment *(1) Replace obsolete equipment, (2) Expansion of plant capacity*, and *(3) Initiation of new models or product lines*. Chung (1993) continues to explain that investments are also used for the riskier undertakings of *(4) New ventures* and *(5) New technology*. The chosen course of action for investments within an organisation should have its foundation in the organisation's mission, vision, and strategy (Almannai, Greenough, & Kay, 2008; Krantz & Thomason, 1999), and each investment should help the organisation to come closer to their vision. However, some investments are themselves not beneficial or low-beneficial, but

beneficial follow-up investments will be made possible through the specific investment (Chung, 1993; Meredith & Suresh, 1986). According to Meredith and Suresh (1986) are low- and non-beneficial investments often clustered together with the follow-up investments to increase the understanding of why the low- and non-beneficial investments should be approved. Thereby are some of investments deemed too important to turn down for the future development of the organisation, even though they do not fulfil the organisation's financial criteria (Chung, 1993; Meredith & Suresh, 1986).

Since there are multiple reasons for why an investment is deemed important for the organisation are there also multiple justification methods (Almannai et al., 2008; Frank, Souza, Ribeiro, & Echeveste, 2013; Karsak & Tolga, 2001; Meredith & Suresh, 1986; Proctor & Canada, 1992; Saleh et al., 2001). Meredith and Suresh (1986) presented a classification of three categories of justification methods for advanced manufacturing techniques: *(1) Financial, (2) Analytic*, and *(3) Strategic*. The *Financial* justification category are quantitative methods such as payback, return on investment and discounted cash flow (Karsak & Tolga, 2001; Meredith & Suresh, 1986). The *Analytic* justification category are to the majority also quantitative methods, but include more information, can handle more uncertainty than the *Financial* method, multiple decision criteria, and can value subjective criteria in to the justification through methods like Analytic Hierarchy Process (AHP) (Karsak & Tolga, 2001; Meredith & Suresh, 1986). S*trategic* justification is directly coupled with the goal of the organisation and uses qualitative methods (Karsak & Tolga, 2001; Meredith & Suresh, 1986), and consider information such as business goals and technical importance (Karsak & Tolga, 2001).

According to Krantz and Thomason (1999) framework for investments, is one step in the investment process to break down the organisation's strategy in to decision criteria. The decision criteria take an area of importance e.g. floor space, Net Present Value (NPV), or cost per unit being produced, which is based on what is valued as important from the organisation i.e. the organisation's strategy. The decision criteria can be both tangible, often economical e.g. NPV or intangible e.g. flexibility (Almannai et al., 2008; Krantz & Thomason, 1999; Proctor & Canada, 1992; Saleh et al., 2001). The intangible decision criteria are hard to value for obvious reasons, but the evaluation does not become complete if they are overlooked (Saleh et al., 2001). Hastie (2007) states that the financial justifications techniques are only one part of the solution, and that more methods than the financial should be used. According to Proctor and Canada (1992), Kaplan (1986) and Saleh et al. (2001) are the old ways of evaluating manufacturing investments (i.e. financial evaluation) ill-suited for Advanced Manufacturing Systems (AMS). Furthered does Proctor and Canada (1992) and Saleh et al. (2001) continue to explain that the old evaluations techniques, mainly financial, were used because investments in manufacturing technology were made to improve tangible criteria like cost reduction, but today are AMS investments mostly done to improve intangible criteria e.g. flexibility and adaptability. The intangible criteria do often see their improvements after a longer time-period compared to the financial criteria, the intangible criteria are closer

linked to the strategic justification category and follow the same pattern of brining value over a longer time period (Meredith & Suresh, 1986; Proctor & Canada, 1992). According to Meredith and Suresh (1986) should not the strategic justification process be used on its own, but instead be used together with the financial and analytical justification techniques, to better grasp the possible benefits of an AMS, which might have not evaluated if only one method were used.

3.3.1 Investment criteria

Criteria are, principles used to help with making decisions (Oxford Learner's Dictionaries for Academic English, n.d.). Within the study are investment criteria used for describing the criteria used for evaluating investments in a manufacturing system. By screening portions of the body of literature that exists regarding investment criteria, within both traditional manufacturing systems and within advanced manufacturing systems were several criteria identified. The criteria represent different possible benefits that the investment proposals are evaluated against. The criteria will now be presented in the following section to then be summarised into a table.

Flexibility, productivity, quality and dependability are some of the biggest competitive priorities for manufacturing companies according to DeMeyer, Nakane, Miller, and Ferdows (1989), based on their survey made in Europe, North America, and Japan. Proctor and Canada (1992) mean that flexibility, productivity, quality and dependability are intangible criteria that need to be in balance to succeed with the business strategy. Flexibility can be defined as "*the ability to respond to changes in product, product mix, and volume*" (Saleh et al., 2001, p. 1267). Flexibility are deemed important because it enables higher through-put (Kaplan, 1986; Karsak & Tolga, 2001; Kulatilaka, 1984; Saleh et al., 2001), lower cost for retooling (Kulatilaka, 1984), greater ability for volume adjustment (Kulatilaka, 1984), reduced inventory (Kaplan, 1986; Saleh et al., 2001), and better handling of unforeseen changes (Saleh et al., 2001), etc. Karsak and Tolga (2001) and Meredith and Suresh (1986) and Saleh et al. (2001) discuss different types of flexibility that could be important in investments decisions, the types of flexibility are process flexibility (i.e. the ability to produce different variants, also called flexibility of function), volume flexibility (i.e. the ability to produce different levels of volumes within the system), and material flexibility (i.e. ability to change the used material). Quality is defined by Saleh et al. (2001, p. 1268) as "*Conformity (uniformity), consist in product and easiness in product testing"* and according to DeMeyer (1989) are quality deemed the most important competitive factor in USA. There are multiple reasons for why high quality is important, such as less scrap and rework (Kaplan, 1986; Saleh et al., 2001), fewer inspections (Kaplan, 1986; Saleh et al., 2001), reduced necessary inventory (Kaplan, 1986; Saleh et al., 2001), and higher through-put (Frank et al., 2013). According to Slack and Lewis (2011) can dependability be defined as keeping delivery promises to the customers, i.e. delivering the right quality and quantity at

the right time. According to DeMeyer (1989) did manufactures in Europe, North America, and Japan find it important to be able to make dependable deliveries i.e. they valued dependability.

According to Saleh et al. (2001) and Almannia, Greenough, and Kay (2008) can the safety of the people working within the manufacturing system increase with AMS, where safety is defined as "*the ability to avoid injuries and death accidents*" (Saleh et al., 2001, p. 1267). Grimaldi and Simon (1989, [Through (Saleh et al., 2001)]) mean that by increasing the safety for the workers, can also multiple benefits for the company be achieved, such as reduced: sick days, overtime due to lost time, and activities in handling, recording, and investigating injuries.

Training are also deemed an important criterion while investing, depending on the training provided can the implementation become more or less successful. Saleh et al. (2001, p. 1267) define training in the context of AMS investment as "*the availability and quality of training procedure for implementing a complicated technology*". Saleh et al. (2001) points out that training quite often happens to be dropped in the last minute or are planned to be conducted under the start-up phase. The effort needed to complete a good quality training are almost always underestimated according to Majchrzak (1988, [Through (Saleh et al., 2001)]) and Rothwell (1987, [Through (Saleh et al., 2001)]). According to Saleh et al. (2001) are training and vendor support closely linked to each other, and define vendor support as "*Quality dimension of the services and support function performed by vendor before and after sales"*(Saleh et al., 2001, p. 1267). Vendor support are important for more reasons such as how fast they react upon requests (both pre and after sale), quality of the service, how professional they act, and how available they are towards the customer (Kennedy and Young, 1989, [Through (Saleh et al., 2001)]).

Within AMSs is it possible to encounter challenges for workers in the system as a result of changes to the technical and organisational system (Saleh et al., 2001). According to Saleh et al. (2001) may the challenges for the workers result in uncertainties for the system, affecting the moral and performance of the individuals. To counter the uncertainty is it important to provide both technical and management support, which can be done through earlier involvement for the employees within the system (Hughes Aircraft Company, 1992 [Through (Saleh et al., 2001)]). The areas of interest for technical and management support are according to Saleh et al. (2001) planning, directing, marketing and contracting, procurement and subcontracting, organising and staffing, space and facilities, and develop engineering.

By changing focus from the traditional cost-saving or cost-reduction goals for investing in the manufacturing system, to more intangible goals as higher flexibility, has the need to change cost focus appeared. According to Saleh et al. (2001) is it necessary to put focus on the total cost for the manufacturing system, across it life-time, resulting in the criteria system cost. Saleh et al (2001) continued to present a revised version of the

system cost after controlling the sub-criteria with the industry and concludes that the costs that should be included are all costs related to acquisition and installation cost, quality cost, material handling cost, personnel support cost, operating equipment cost, research and development cost, facility and utility costs, documentation costs for production control, and logistics support cost.

Even though financial criteria are ill-suited for investments in AMS by itself (Kaplan, 1986; Meredith & Suresh, 1986; Saleh et al., 2001), could financial criteria be used as a compliment to the intangible criteria, to get a more detailed picture of the investment (Chung, 1993; Kaplan, 1986; Karsak & Tolga, 2001; Meredith & Suresh, 1986; Proctor & Canada, 1992; Saleh et al., 2001). To perform the financial evaluation are there many different financial criteria but some of the most frequently used are return of investment (ROI) (Karsak & Tolga, 2001; Meredith & Suresh, 1986), net present value (NPV) (Chung, 1993; Meredith & Suresh, 1986; Proctor & Canada, 1992), and payback (Meredith & Suresh, 1986).

With the changing market demands does the ability to keep up become important and therefore also to keep the manufacturing system compatible with future and existing system parts (Saleh et al., 2001). Compatibility are defined by Saleh et al. (2001, p. 1268) as "*ability to be compatible with the existing (or future) software, hardware, and people"*. The compatibility level of system parts affects how much effort are needed to integrate parts that are not compatible with each other, which is time consuming, expensive, and hard to achieve (Saleh et al., 2001).

The different criteria are summarised within Table 9, together with a definition, and which authors that have found the criteria to be important in investment considerations.

Table 9. Investment criteria

Criteria	Definition	Author
Flexibility	Ability to handle planned and unplanned changes caused by internal and external environments less expensively and quickly (Saleh et al., 2001, p. 1268)	(DeMeyer et al., 1989; Proctor & Canada, 1992) (Kaplan, 1986), (Saleh et al., 2001) (Karsak & Tolga, 2001) (Meredith & Suresh, 1986)
Quality	Conformity (uniformity) consistency in product and easiness in product testing. (Saleh et al., 2001, p. 1268)	(DeMeyer et al., 1989; Proctor & Canada, 1992), (Saleh et al., 2001), (Hill, 2002) (Park & Son, 1988) (Meredith & Suresh, 1986) (Frank et al., 2013)(Kaplan, 1986)
Financial	Large consensus that some financial measures should be used in the evaluation process, but not which one.	(Proctor & Canada, 1992) (Karsak & Tolga, 2001) (Meredith & Suresh, 1986) (Almannai et al., 2008) (Frank et al., 2013) (Chung, 1993)
Dependability	Dependable deliveries out to the customer (based on the context in DeMeyer et al. (1989))	(DeMeyer et al., 1989)
Compatibility	Ability to be compatible with the existing (or future options) of software, hardware, and people (Saleh et al., 2001, p. 1268)	(Saleh et al., 2001)
Training	Availability and quality of training procedure for implementing a complicated technology (Saleh et al., 2001, p. 1268)	(Saleh et al., 2001)
Safety Performance	Ability to avoid injuries and death accidents due to a reduced exposure of workers to hazardous situations (Saleh et al., 2001, p. 1268)	(Saleh et al., 2001)
Total system cost	Includes acquisition costs for new equipment/system, operational and maintenance costs, and disposal costs of the products, equipment, and the manufacturing system (Saleh et al., 2001, p. 1268)	(Saleh et al., 2001)
Vendor Support	Quality dimension of the services and support functions performed by vendor before and after sales	(Saleh et al., 2001)
Technical and management support	Availability and quality of training procedure for implementing a complicated technology	(Saleh et al., 2001)

4 Findings

Within this chapter all the collected data from the focal company will be presented. It starts with a short historical introduction regarding the focal company's approach to investment criteria and what factors that made them develop their new production design principles. Later the focal company's concept process will be described in order to help the reader to understand how the focal company makes new investments. Then the production design principles will be presented followed by four different sections that the interview data have been divided into: (1) Lean within the focal company, (2) Reconfigurability within the focal company, (3) Investment within the development projects, and (4) Holistic view throughout the development projects.

4.1 Investment approach

Traditionally, the focal company based their investment decisions on two criteria; investment cost and volume capacity. This worked fine due to that the product life-cycles were about the same length as the manufacturing system's life-cycles. However, from the 21st century the gap between product's life-cycles and manufacturing system's life-cycles has increased, which increased the importance of having a flexible and changeable manufacturing system where multiple variants and product-families can be produced in the same system. At the same time, the competition increased due to several reasons, e.g. the globalisation which was an additional reason to the need of more reconfigurable systems. Thus, the focal company started to look into reconfigurability as a potential solution for the increased customisation problem. The increased need of more reconfigurable manufacturing systems together with the focal company's high focus on lean are the foundation behind the development of the new the production design principles. The new production design principles are a set of principles which includes all the central factors the focal company rank as important. These design principles are meant to work as a support when designing and developing the new products and manufacturing system.

4.2 The development process

The development process of new products and the manufacturing system connected to producing the new products can be divided into a concept phase and a realisation phase. The concept phase starts with a new forecasted demand of a new or existing product or variant which call for changes to some extent of the current manufacturing system. The manufacturing system is divided into different production lines where the different parts of the product is produced, there are two major types of production lines: assembly lines and machining lines. The new forecasted demand is handed over by the upper management to the concept group together with expected investment cost, volume (units/year), product mix, floor space (area-layout), and number of workers. Based on these demands are several possible concept solutions are generated through using experience to find

what manufacturing techniques that should be used, which are then made into the production lines required to produce the product. The production lines are then tested through production simulation to find suitable configurations of the equipment that accommodate the decided manufacturing techniques. The manufacturing techniques and configuration that are supposed to be used at the production lines are based on the production design principles. All these solutions meet the initial demands, i.e. the economical budget and volume capacity but differs when it comes to the procedure and how well they fulfil the production design principles. The generated solutions are frozen to around 80% of the finished project, in regard to both the product but also the manufacturing system. Once all the work of generating the different solutions is done, the solutions that matches the initial demands and the production design principles best are presented to the upper management. The upper management are then responsible of deciding which of the solutions to continue with and thereby also which solution to invest in. The investment criteria are used to support the upper management to take the investment decision, and the investment decision is where the concept phase transition into the realisation phase and a new realisation group takes over (and the realisation phase has been delimitated from the study, and therefore it will not be further explained). An illustration for the development process is presented in Figure 3.

Figure 3. Development process at the focal company.

4.3 Production design principles

The production design principles consist of 25 principles that originate from lean and were adapted to the focal company by introducing principles that focus on the ergonomics for the workers, and to some extent reconfigurability. The principles include factors such as the safety and ergonomics of the processes, how to design in order to achieve the most efficient flow (e.g. strategically buffers, tact time, visibility, and sequences with sub flows, etc.), common working areas on the product, and the ease of reconfigurable within the processes. The principles were recently introduced to the focal company and are in the process to become more adapted to the focal company and to be spread throughout the whole company. See Table 10 below for a presentation of the main- and sub-categories of the production design principles.

Table 10. Production design principles

Main category	Sub-categories
Lean	Standardised process and tasks
	Takt time
	Buffer control
	Continuous flow and pull system
	Andon, visibility and traceability
Ergonomics	Safety of factory
	Safe and ergonomically workstations
Reconfigurability	Reconfigurability and scalability
	Easy manageable products and processes
	Reduction of variation and losses

With the new production design principles, the focal company has started to realise their lean strategy by increasing the focus on reducing waste sources. The new principles and investment focus challenged the engineers to think outside the box to be able to accommodate the new demands. However, there were also concerns raised regarding the intensified use of the floor space criterion, which focusing on reducing the used floor space by the production lines by making the pre-allocated floor space for possible future expansions seen as waste. The respondents mean that a more compact production line could come back and haunt them in the future since the criterion has made then reduce the future flexibility for a more space efficient production line.

The principles are supposed to work as a common foundation during the decision process regarding how to design and think when developing new products and investing in manufacturing system. Thus, help to take the best possible decision through making sure that all the focal company's central factors are included and considered. By using this as common ground the aim is to take more holistically and comprehensive decisions that will minimise the risk of sub-optimisation at the same time it encourages lean, ergonomics of the workers, and reconfigurability. Although, the principles are new as official principles did several respondents mention that they had worked in a similar way before but without the principles as official guidelines.

4.4 Reconfigurability within the focal company

Within the focal company, three areas connected to reconfigurability were discussed: (1) *flexibility of function*, (2) *scalability*, and (3) *reuse of old equipment*. The respondents working with designing and creating different manufacturing concepts described the flexibility of function as high within the processing machines. Historically, the focal company has bought machines that can be relatively easy to adapt to new products or variants. Respondent 10 was quite sure that the focal company has enough competence and flexible machines in order to manage if all machine providers would disappear. However, it is also mentioned that it is not enough to have flexible machines, it is also necessary to have a flexible logistics system and room for remodelling the layout. The respondent continues to explain that the production plant is old, which leads to that

there are multiple factors to consider when creating the different manufacturing concepts. Some of the factors to consider are the production line to be retired, other operational lines, if the floor quality needs to be improved for new heavier machines, etc. The context does influence how the new production lines can be designed and implemented into the manufacturing system. There are different prerequisites for the machining and assembly lines since they have different manufacturing techniques. Within the assembly lines the layout and function of the assembly stations are standardised, that combined with having an adaptable logistic system enables reconfiguration of the workstations layout, sequence, flow, etc. The respondents agree that the machining and assembly departments experiences different difficulties. The assembly has a higher running-cost since much of the assembly is done through manual work, but thus, also have a lower need for high investments, while the machining has lower running-cost but higher need for investments.

Besides the interview with the IT-responsible at the focal company was the information technology (IT) barely mentioned. IT was today far ahead in their mindset and internal strategy regarding reconfigurability, IT had the ambition of creating a library of IT-solutions which would be able to be used by anyone. The library was intended to decouple IT from the development phase by already having the necessary solutions ready when they needed to be installed, enabling the manufacturing department themselves to adapt and install the manufacturing system without IT's help, both in new projects but also in remodelling projects. The mindset behind IT's own strategy was to become an enabler for the rest of the organisation, i.e. not wanting IT to be the reason for something being delayed or not being possible to be implemented.

Reoccurring in the interviews was the fact that the product itself sets the limits for the manufacturing system. The operating machines have high flexibility within their functionality and can produce multiple product variants and generations. In order to produce multiple product variations and generations in the same production lines is it required for the products to have the same fastening and interaction areas. Which will affect how new products and manufacturing techniques can be developed, they need to accommodate the historical products. If too big alterations are done to new products, then they cannot be produced in the existing production lines. Therefore, are efforts to standardise the interface between products and the manufacturing system being conducted, with a focus on a long-term solution overarching the next coming generations of new variants and products. In certain cases where the development of the product is uncertain, the development has instead focused on standardising the interface between fixture and machine, and thus having a cheaper standard fixture adapted for one or a small set of products. Respondent 1 and 7 put emphasis on the collaboration between product design, production design, and operations because good collaboration could help to reduce the investments needed for introducing new variants and products to the manufacturing system.

Historically at the focal company, the default option has been to automate, especially in the machining department. The high amount of automation created a cost-efficient manufacturing system, however, the focal company has been optimising each individual resource, creating separate highly efficient production lines that are not in sync with the each other. According to respondent 1, and 2 have the automation level generated unnecessary complex systems which are hard to adapt and have high investment cost. To decrease unnecessary investment cost and complexity have the default solution options for the manufacturing lines shifted to manual and automation be implemented where it is necessary and justified. Respondent 1 and 10 thinks that the having manual solutions as default option is a good idea since it can help with the scale up of the production lines. The manual solution option is thought to help with reducing the risk in over investing in the manufacturing solutions, and instead investing when sufficient volumes are reached for the automation solutions. The postponement of building fully automated production lines reduces the financial risk the focal company are exposed through lowering the investments done before the sufficient product volumes are reached.

Due to the new market demands and how it has increased lately, the focal company's interest of scalability has increased. machining once again different prerequisites. Based on the respondents are the prerequisites the same as regarding the flexibility of function. According to respondent 1, can the assembly department quite easily change some workstations to be able to produce another variant or product, enabling the assembly system to easily change the product mix. Respondent 9 and 11 add that the assembly often invested in stages, enabling the postponement of investments until there is a need to increase the volume. On the contrary, are the machining department according to respondent 9 often requesting the full investment from the beginning, due to the difficulties in scaling the necessary machines, the machines can often everything or nothing. Respondent 1 explains that the machining production lines of course can be scaled, but that is mostly done by changing the number of shifts the production line can be used. The difficulty of scale the processing department in regards of the investments needed a risk for binding capital in a manufacturing system that are underutilized or to lose the possibility to invest in something else because the prognosis of the product was wrong.

The final part of what is discussed within the focal company is the reuse of old machines and equipment. The concept of reuse is of interest for the focal company because it helps to lower the necessary investment when new variants and products are introduced, but also to ensure that the equipment can be used during its full life-time. At the time of the data collection were mapping over potential machines and equipment for reuse purposes being conducted to increase the efficiency of the reusability to next coming development projects. Respondent 1 and 7 did however say that the reusability of the equipment was not consider during the design phase of the manufacturing system, it has become a reaction to the reality that the focal company lives in.

4.5 Investments within the development projects

The production design principles provide a foundation for both the concepts and detail design teams throughout the product and production development with common principles to guide them. Based on the production design principles, KPIs have been developed to also help with the development of both the concept plans and detailed plans. The KPIs are also used to follow up and to see if the project is going in the right direction. The concept design team present one or a few concepts to move forward with, the upper management then decides which alternative or alternatives to continue with. The respondents describe the evaluation as four criteria: investment cost (investment needed for the whole project), running cost (i.e. the cost for operating the system, largely the cost for manpower), floor space (i.e. the used area for the system), and project feasibility. All the respondents point out that the investment cost is the most important criteria for the upper management and that the teams are pushed to keep down the investment cost. According to the respondents does the upper management only look at the investment cost. The investment cost is important because the organisation only has certain amount of funds available and if the investment cost is too high it is impossible to invest. However, the respondents say that the upper management is willing to take a much higher running-cost to lower the investment cost, which can create cases were the total manufacturing cost (cost per produced product) will become higher.

The respondents did mention that together with the new production design principles have also the focus on the usage of floor space become more important. The floor space focus has resulted in changes in concepts and designs, which removed floor space not being used. The respondents explained that the extra floor space was thought to be a buffer for future changes in the products and production that would come into play two to three years in the future. The respondents feared that the focus of planning for what is happening right now might be dangerous in the long-term. Several of the respondents thought that the feedback from the upper management were lacking regarding why a certain alternative was chosen. Some of the respondents felt that the lack of transparency hindered them in understanding how the decisions were made and what was the true evaluation criteria for a concept. Three of the respondents did also express that they felt that the upper management did not understand that in order to successfully implement the new production design principles would it in most cases create a need of higher investments, i.e. they were afraid of getting the same amount of funds but with increased demands. The respondents mentioned that the expected flexibility (product mix) of the system given at the beginning of the development process are often reduced to keep the investment cost down.

Respondent 2 mentioned a that the upper management and the manufacturing design teams have different approaches for investments in uncertain environments, which can be used in order to explain the respondents fear of the new production design principles. The difference in method are that the upper management want to reduce their exposure

to the uncertainty by limiting their investment in that area, while the manufacturing design team wants to invest more to higher the flexibility and reconfigurability to handle the uncertainty. Leaving one party wanting to invest less to see what will become the best alternative to move forward with, and the other party asking for more funds to be able to invest more to prepare for the uncertainty.

4.6 Holistic view throughout the development process

Nine out of the respondents expressed that the organisation could benefit of an increased holistic view of the organisation and the development process, e.g. increased collaboration between departments and clearer common goals and directives. A common strategy for the organisation to base different decisions was requested. The lack of strategy and holistic view were named causes for disalignment within the organisation. The respondents shared the view that the different functions within the organisation did not always work towards the same goal. Furthermore, it was stated that the lack of collaboration created unnecessary costs down the internal supply chain due to sub-optimisations done locally. From the respondents that had contact with and had started to work with the production design principles, were the principles viewed as they could create the foundation for a common ground in the organisation. However, seven of the respondents still saw a need for a more distinctive directive of how the principles should be used throughout the development phases. Respondent 6 and 7 named the organisational structure as one reason for the lack of holistic view and collaboration deficit. The respondents continued to explain that the organisational structure was of a functional character where the different functions had some conflicting KPIs. Respondent 1 explained one case where the purchasing department made cost savings through changing to a new supplier, but the new supplier had quality problems and ultimate resulted in a higher manufacturing cost. According to most of the respondents, the project structure force investments and product designs to a short-term perspective, thus risking creation of sub-optimisations in the long-term. According to the respondents are the projects only fulfilling what the project have been tasked with, and thus do not consider the next coming generations, products, or variants. There are individuals trying to consider the next generations while designing the manufacturing system, creating strategies for enabling larger investments by pushing some parts of the full investment to another project planned for later. However, there is a risk that the individuals trying their best to consider the next coming product generations are nor aligned with the each other, which could create sub-optimisations. From several interviews were the use of lean and reconfigurability seen as a collaborating force. Respondent 1 speaks of the principles of lean where the focus is on creating plans and partnership in the long-term. The respondents speak about the capacity to scale the production lines, and that with no scalability would there be waste generated due to unbalances within the product flow as a whole, which generates buffers and inventory. Lean and reconfigurability are believed to be possible to work great together, but it depends on how much of the two that should be

used. The balance between the two concepts is the crucial thing, according to respondent 11 are neither of the concepts, or any other concepts useful if the concept are implemented into exaggeration. The respondents believe that a more holistic view and a long-term strategy are necessary in order to become more reconfigurable, and thus tackle the global competitive market.

5 Analysis

Within the analysis chapter are all the presented data analysed, which is structured by dividing the analyse chapter into three sections, which represents the study's three research questions. All three main sections are summarised at the end with a corresponding table.

5.1 What are the similarities and differences between lean and reconfigurability?

The following section will compare and analyse lean and reconfigurability on a holistic level. The second section will then dive deeper and analyse how the lean principles presented in Table 5 are either supporting or hindering reconfigurability. Each principle will be analysed individually within the section *Analysis of lean's management principles* and then summed up together into Table 11.

5.1.1 Holistically comparison

The goal of the two concepts is quite similar; the goal of lean is to create a lean philosophy within the organisation which purpose it to help eliminate all non-value-adding activities, also call waste (Liker, 2004; Ohno, 1988). Meanwhile reconfigurability's goal is to make the organisation less sensitive to present and future market fluctuations through increasing the reconfigurability level within the organisations manufacturing system (Koren et al., 1999; Mehrabi et al., 2000). Thus, the two concept's goal can be seen as similar since both of them are to strengthen the organisations position on the market by making them more efficient and profitable. But the holistically biggest differences between the two concepts is their strategically approach on how to achieve a more efficient and profitable organisation, together with the size difference of how comprehensive and fully covering the two concepts are.

Lean is a comprehensive concept that have been developed during a much longer time, (i.e. have gotten more attention in both research and practice), and includes a lot of different methods and tools, which purpose is to help the whole organisation develop a lean philosophy (Liker, 2004). The goal with developing a lean philosophy are to make sure that the lean principles is always being valued into every decision and activity and thereby, help the organisation to become more efficient and profitable by eliminating all non-value-adding activities (Liker, 2004; Ohno, 1988). The methods and tools within lean are not only involving the manufacturing department, but all departments and levels within an organisation, and thus helps the whole organisation to become more efficient and profitable. Meanwhile, reconfigurability is more of a strategical mindset regarding how to structure the manufacturing system, that were developed in order to make organisations less sensitive to the increased customisation demand on the market, which is achieved through increased reconfigurability levels within the manufacturing systems (Koren et al., 1999; Mehrabi et al., 2000). The mindset is mainly

about how to think and design the manufacturing system in order to increase the flexibility and reconfigurability level, and compared to the lean concept it does not include the same number of developed methods and tools which the whole organisation can use in order to furhter the reconfigurability concept.

Compared to lean, reconfigurability is less comprehensive and therefore, alone reconfigurability lack a lot of parts, e.g. it does not fully cover the whole organisation together with the lack of methods and tools. Therefore, reconfigurability need to adapt and use already existing methods and tools in order to increase the reconfigurability level within an organisation. As mentioned, by several of the respondents a lot of the principles, methods and tools within lean matches reconfigurability and therefore can be used in order to further the reconfigurability level as well. Also, due to that the goal of the two concepts is similar it strengthens the use of the lean principles, methods and tools. The analysis regarding the potential of sharing the same methods and tools are presented in the next section.

5.1.2 Analysis of lean's management principles

In order to compare the two concepts on a more detailed level will each of the lean's management principles presented in Table 5 be analysed regarding how similar or different they are compared to reconfigurability. The analyse result in which of leans management principles that is applicable within the reconfigurability concept as well. Each individual analysation of the lean principles is then summarised into Table 11.

5.1.2.1 Base your managed decisions on a long-term philosophy, even at the expense of short-term financial goals

One difference between the two concepts is the view on the two criteria flexibility and reconfigurability. Within reconfigurability is an investment in flexibility and reconfigurability seen as insurance against the present and future market uncertainties i.e. product and volume fluctuations. For example, in the focal company they wanted to collateral that future variations should be able to be produced in the same line as present variations, which increases the need of a higher level of flexibility and reconfigurability in the production line from the start. Which corresponds with Rösiö and Jackson (2009 [Through (Andersen et al., 2016)]) prerequisite regarding having *"a life-cycle perspective on production systems"*. Meanwhile in lean, does Ohno (1988) and later Liker (2004) state the main goal of the lean philosophy is to eliminate all kind of non-value-adding activities, and the classification of activities is usually done in present time. Therefore, can flexibility and reconfigurability easily become classified as wastes, i.e. non-value-adding activities, due to that they do not always add direct value to the process at the present time. However, at the same time is Liker's (2004) first principle *"Base your managed decisions on a long-term philosophy, even at the expense of short-term financial goals"* and Rösiö's (2012b) analysis regarding prerequisites for recon-

figurability; *"Having a long-term view on investments in production capacity"*, comparable and can be seen as similar to each other. The similar view regarding long-term vs the short-term financial goals can be used as a justification behind an agreement between the two concepts, and thereby overcome the above-mentioned difference.

5.1.2.2 Create a continuous process flow to bring problems to the surface

By creating a continuous process flow the whole production line stops if any problem occurs, which is negative from a process flow perspective. But when the production line stops the organisation get forced to solve the problem immediately, and thus also gets more motivated to solve the root cause (Liker, 2004). Reconfigurable manufacturing system is about being able to produce the exact number of variants needed (which can differ a lot during a production line life-cycle) within the same production line and therefore a continuous process flow is almost a prerequisite. Elsewise, if each variant at some point need to be taken out of the common production line it will create a lot of extra work, which is not value adding. Thus, through creating a continuous process flow it does help reconfigurability to bring up problems to the surface, which is the goal of the *Diagnosability* principle (Koren et al., 1999; Mehrabi et al., 2000), and therefore Liker's (2004) second principle can be classified as a central part within reconfigurability as well.

5.1.2.3 Use "pull" systems to avoid overproduction

The use of pull systems is known as an effective method in order to avoid overproduction, which is seen as the worst type of waste within lean (Liker, 2004; Ohno, 1988). Through avoiding overproduction, it also helps keeping the stock level low, which is essential from reconfigurability perspective, because a reconfigurable system is often designed to produce a high level of variants within the same line. Therefore, it is crucial to keep the stock levels of each variant as low as possible, elsewise the total inventory will become high, which affect the organisation negative through e.g. the need of more space, time and the risk of increasing the scrap levels. For example, in the focal company they have limited amount of space, so each extra space that can be saved on unnecessary stock is vital for them, and therefore the use of pull system is essential for them.

5.1.2.4 Level out the workload (work like the tortoise, not the hare)

This principle is about having an even workload within the production process, and a lot of the respondents' mentioned the importance of having a flexible production capacity, both during the ramp-up time but also once the production line is fully implemented and running. Thereby, through levelling out the workload within the process it can help to ease the work regarding achieving a higher level of production capacity flexibility. This is quite similar to what reconfigurability call scalability, which is the ability to be able to easily adjust the system capacity in order to meet the demand fluctuations (Rösiö

& Säfsten, 2013). Which also can help to further the reconfigurability principle *Customisation*, which is about the ability to have the right level of capability and flexibility in order to be able to manufacture both the present and future products (Koren et al., 1999; Mehrabi et al., 2000). Therefore, Liker's (2004) fourth principle can be used to ease the work with the two reconfigurability principles scalability and customisation, and thus further reconfigurability.

5.1.2.5 Build a culture of stopping to fix problems, to get quality right the first time

Problems is something that always will appear, no matter which concept an organisation are using, therefore it is always crucial to fix problems in an efficient way. Also, no organisation wants to manufacture scrap-products (i.e. a product that does not meet the quality levels), and therefore this principle is applicable within all organisations and concepts, including reconfigurability. Due to the often high level of complexity within a reconfigurable manufacturing system it also increases the risk for highly complex problems, which can be even more crucial to fix in a quickly and efficient way. Thereby, through developing a culture of stopping to fix problems, will help organisations identify problems in an early state and thus give organisations a possibility to achieve a higher quality rate. This principle, same as Liker's (2004) seventh principle can be compared with the reconfigurability principle *Diagnosability*, which also is about identifying and solving sources of quality and reliability issues in a quickly and efficient way (Koren et al., 1999; Mehrabi et al., 2000).

5.1.2.6 Standardised tasks and processes are the foundation for continuous improvement and employee engagement

Standardised tasks and processes are something that facilitates the work regarding continuous improvements (Liker, 2004), and therefore, is something that are crucial for all concepts and organisations that want to improve any process. Reconfigurability is no exception, and due to the implication of increased complexity within the manufacturing systems are standardised tasks and processes needed to achieve and retain a high level of reconfigurability. Thereby, by having standardised tasks and processes it can help organisation to decrease the complexity level, which will further the success of reconfigurability. Also, standardised tasks and processes ease the work regarding continuous improvements, training, etc., which are common important fields for both lean and reconfigurability.

5.1.2.7 Use visual controls so no problems are hidden

The goal with Liker's (2004) seventh principle is to have visual control systems that will help to identify problems, and thereby give organisations a better chance to identify and solve the problems in a quick and efficient way. The reconfigurability principle *Diagnosability* is also about the ability to quickly identify the sources of quality and reliability issues, and thus being able to quickly and efficient solve the identified issues

(Gumasta et al., 2011; Koren & Shpitalni, 2010; Rösiö & Säfsten, 2013). Also, one of the respondents pushed extra regarding the importance of visual control systems if the reconfigurability level would increase, due to that the complexity level usually increase parallel with the reconfigurability. Therefore, can this be classified as a similarity between the two concepts.

5.1.2.8 Use only reliable, thoroughly tested technology that serve your people and process

This is a principle that the focal company identified as a potential difference due to that they are quite small compared to their other competitors and therefore do not have the same economic possibilities. Due to the focal company's economic disadvantage, do they sometimes need to take risks by investing into new technologies that are not thoroughly tested in order to advance and not lose shares on the market. This is due to the context of the focal company, and therefore it is not always the case, therefore Liker's (2004) eight principle does not always need to be classified as a difference. For example, due to the increased level of complexity within a reconfigurable manufacturing system, it can be wise to consider Liker's (2004) eight principle when designing and choosing which technologies the system should include. Thus, this principle is something that is dependent on the organisation and its context, and therefore it is crucial as an organisation to thoroughly understand all principles, methods and tools before applying them within the organisation.

5.1.2.9 Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others

Grown leaders that has enough knowledge and experience regarding the concept in order to teach others, is something that is crucial no matter which concept an organisation choose. It can also be classified as a prerequisite for Liker's (2004) tenth principle because without great leaders does it becomes hard to develop exceptional people and teams due to that this is usually the leaders' responsibility. Thereby, this principle is important to consider within reconfigurability as well. For example, a lot of the respondents at the focal company felt that one of their biggest challenges to become more reconfigurable were the lack clearly communicated directives of how to work in order to further reconfigurability. It was notable that the organisation lacked a clear common vision regarding reconfigurability and therefore it was hard for anyone to interpret the design principles and apply them into their own work. Thus, developing leaders who thoroughly understand the work, philosophy and concept, could help the focal company to overcome this challenge.

5.1.2.10 Develop exceptional people and teams who follow your company's philosophy

Developing exceptional people and teams who follows the organisations philosophy is something that all concepts would benefit from, and reconfigurability does not distinguish regarding this. It is quite comparable with the sixth prerequisites in Table 6 identified by Rösiö (2012b) *"Having staff that is skilled in system design and have knowledge of reconfigurability".* Also, by interviewing the respondents at the focal company it was notable that the level and dispersion regarding the knowledge of reconfigurability is vital in order to increase the reconfigurability level. Thus, by developing exceptional people and teams who follows the organisations philosophy, means that the organisations will developing staff that is skilled and have knowledge of the concept, therefore can this be seen as a similarity between the two concepts.

5.1.2.11 Respect your extended network of partners and suppliers by challenging them and helping them improve

Since reconfigurability is usually involving a lot of complex machines and tools due to the need of more flexible and reconfigurable solutions, the relation with partners and suppliers are crucial. As the focal company mentioned, their machines usually demanded extra work and features and by having a good win-win relation with their suppliers it gives them a possibility to demand the extra work needed. Through working more closely with their suppliers, the focal company has increased their own machine knowledge within the organisations, and thereby has decreased the knowledge gap between them and their suppliers, which has made their collaboration more efficient and better. Thus, due to the more complex machine solutions reconfigurability usually implies, it is essential to have a good relationship with the suppliers and partners of the organisations, therefore Liker's (2004) eleventh principle is useful within reconfigurability as well.

5.1.2.12 Go and see for yourself to thoroughly understand the situation

Liker's twelfth principle is quite hard to analyse how it could affect reconfigurability. On one hand it could be classified as a difference due to that the complexity of the manufacturing system usually increase when reconfigurability increases. Therefore, it could become hard to always "go and see four yourself" due to the enormous amount of knowledge and experiences needed to understand complex systems. However, sometimes it could also help to go and see for yourself, and thus understand the situation better in order to take the best possible decision.

5.1.2.13 Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly

Due to that reconfigurability is relatively new and not practical tested yet together with the high level of complexity, it is a lot of different factors that needs to be considered

when taking decisions. Therefore, by taking decisions slowly and thoroughly considering all options, it can help to better structure all the different factors, and thereby increase the chance of taking the right decision from the concept perspective. Also, in order to being able to make decisions slowly by consensus and thoroughly considering all options it is necessary to have a holistically view and knowledge regarding the organisations different departments and how the correlate to each other, which Rösiö (2012b) and Rösiö & Jackson Rösiö and Jackson, 2009 [Through (Andersen et al., 2016)]) mention as important prerequisites for reconfigurability, see Table 6. Thus, Liker's (2004) thirteenth principle can be used to further reconfigurability as well.

5.1.2.14 Become a learning organisation through relentless reflection and continuous improvement

No matter which concept an organisation are using it is crucial to be open and willing to learn through reflection and continuous improvements, because no organisation or concept are perfect. Due to the lack of practical knowledge and testing of reconfigurability, it is even more crucial to include reflection and continuous improvements as a central principle, and thus decrease the risk of both present and future mistakes. A lot of both big and small mistakes will be made in the beginning and by working with reflection and continuous improvements it will help the organisation to decrease the number of mistakes, and thus increase the benefits of reconfigurability. However, no matter how well developed an organisation is, it is always crucial to constantly work with reflections and continuous improvements, because elsewise the organisation risk to fall behind and lose market shares. Therefore, Liker's (2004) fourteenth principle is crucial within reconfigurability as well, and therefore can be classified as a similarity.

5.1.2.15 Summarisation of each individual principle

How reconfigurability position itself against the lean principles, and which sources the analyse is based upon are presented in Table 11. How reconfigurability position itself against each lean principle is classified into Similar, or Different. One of the principles is classified both as similar and different, which depends on the context and situation of the organisations and is explained in each section regarding that principle.

As presented in Table 11 above and within the earlier section *Holistically comparison*, it exists both similarities and differences between the two concepts. Besides the presented principles it also exists other lean tools that is applicable within reconfigurability. For example, the method SMED, which goals is to reduce the set-up times within an organisations processes, which becomes crucial within a reconfigurable manufacturing system due to the increased number of variants produced in the same line usually implies more set-ups. Therefore, it is crucial to make the set-ups as efficient as possible, and therefore the adoption of the lean tool SMED can help to further reconfigurability as well. Thus, even though it exists differences between the two concepts, it seems to be possible to combine the two concepts due to a lot of the principles, methods and tools within lean are applicable to reconfigurability as well.

Table 11. Lean management principles and reconfigurability

#	Lean principle	Position against reconfigurability
1	Base your managed decisions on a long-term philosophy, even at the expense of short-term financial goals	Similar
2	Create a continuous process flow to bring problems to the surface	Similar
3	Use “pull” systems to avoid overproduction	Similar
4	Level out the workload (work like the tortoise, not the hare)	Similar
5	Build a culture of stopping to fix problems, to get quality right the first time	Similar
6	Standardised tasks and processes are the foundation for continuous improvement and employee engagement	Similar
7	Use visual controls so no problems are hidden	Similar
8	Use only reliable, thoroughly tested technology that server your people and process	Similar
9	Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others	Similar
10	Develop exceptional people and teams who follow your company’s philosophy	Similar
11	Respect your extended network of partners and suppliers by challenging them and helping them improve	Similar
12	Go and see for yourself to thoroughly understand the situation	Both similar & different
13	Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly	Similar
14	Become a learning organisation through relentless reflection and continuous improvement	Similar

5.2 How do existing investment criteria support lean and reconfigurability?

The following section will analyse how the investments criteria from theory presented in Table 9 and the investment criteria from the focal company are supporting or hindering the use of lean or reconfigurability. The analysed criteria are presented in Table 12. Each of the criteria will be analysed individually then summed up together into Table 13.

5.2.1 Connection between investment criteria and lean and reconfigurability

In the following section will each of the investment criteria presented in Table 12 be analysed regarding if they are supporting or hindering lean and/or reconfigurability. The answer for the second research question is the summary of the analysation and presented in Table 13.

Table 12. Investment criteria for analysation

#	Criteria	Source
1	Flexibility	Theory
2	Quality	Theory
3	Financial	Theory
4	Dependability	Theory
5	Compatibility	Theory
6	Training	Theory
7	Safety performance	Theory
8	Total system cost	Theory
9	Vendor support	Theory
10	Technical and management support	Theory
11	Investment cost	Focal company
12	Running cost	Focal company
13	Floor space	Focal company
14	Project feasibility	Focal company

5.2.1.1 Flexibility

The definition of flexibility is: *"the ability to respond to changes in product, product mix, and volume"* (Saleh et al., 2001, p. 1267) which gives the picture of that flexibility can help organisations to better adapt for changes in the environment both internally and externally. Which is similar stated by respondent 10, who says that flexibility is a type of insurance for an organisation to handle unforeseen changes. The theory states multiple benefits with flexibility, which can be linked with reconfigurability such as: greater ability for volume adjustment (Kulatilaka, 1984), lower cost for retooling (Kulatilaka, 1984), and better handling of unforeseen changes (Saleh et al., 2001). Which is further strengthened with the three types of flexibility that Karsak and Tolga (2001) and Meredith and Suresh (1986) and Saleh et al. (2001) discuss which are process flexibility (i.e. the ability to produce different variants), volume flexibility (i.e. the ability to produce different levels of volumes within the system), and material flexibility (i.e. ability to change the used material). The three flexibility types have a part in some of the criteria of reconfigurability presented in Table 5, specifically: (3) *Customisation*, (4) *Convertibility*, and (6) *Scalability.* It could thereby be argued that flexibility is supporting reconfigurability.

From a lean perspective can flexibility be regarded as both an asset and a hinder. Flexibility can enable higher through-put (Kaplan, 1986; Karsak & Tolga, 2001; Kulatilaka, 1984; Saleh et al., 2001) and reduce inventory (Kaplan, 1986; Saleh et al., 2001), which can be seen as supporting lean with minimising waste and increasing the through-put of the manufacturing system. However, multiple of the respondent argue that the extra cost associated with flexibility can be seen as waste within lean, because the flexibility is not necessary in today's manufacturing system. On the other hand, could it be argued that the first principle of lean (see Table 5) would enable the use of flexibility to ensure long-term goals, even though it jeopardise short-term financial goals. The use of the

first principles is connected to the level of how well the lean philosophy is implemented within the organisation. Thereby, can flexibility be seen as a waste within an organisation, if the organisation has not reached the necessary level of lean to be able to take the necessary long-term decisions, thus, are flexibility both supporting and hindering lean.

5.2.1.2 Quality

For lean is quality important, because quality is the foundation for what organisations stands on, within USA is quality the most important competitive factor (DeMeyer et al., 1989). Within lean are several of Liker's (2004) principles aimed to ensure high quality for the customer, see principle 2, 5, 6, 7, 8, and 12 in Table 5. Quality does also enable: less scrap and rework (Kaplan, 1986; Saleh et al., 2001), fewer inspections (Kaplan, 1986; Saleh et al., 2001), reduced necessary inventory (Kaplan, 1986; Saleh et al., 2001), and higher through-put (Frank et al., 2013) which is in-line with the goals of lean. Thus, can it be argued that quality supports lean.

For reconfigurability can quality be viewed as the foundation, and a necessity for being reconfigurable. There is no profit in being able to be reconfigurable if the quality of the product being produced is not up to standard. All the reconfigurable criteria are linked with quality, but especially *diagnosability* which regards the ability and ease of finding quality defects within a reconfigurable manufacturing system. However, reconfigurability does not provide any tools of increasing or decreasing the quality of the products. Thus, reconfigurability does neither support nor hinder the quality with investment decisions.

5.2.1.3 Financial

As earlier mentioned, are there many criteria within the theory which are financial criteria, such as NPV or payback. None of these types of criteria were used at the focal company for larger investments, at least not when making the decision on what conceptual solution to go forward with in the development process. According to the theory it is important to use financial justification when taking investment decisions and should complement other intangible investment criteria to get a holistic view on the different investment options (Chung, 1993; Kaplan, 1986; Karsak & Tolga, 2001; Meredith & Suresh, 1986; Proctor & Canada, 1992; Saleh et al., 2001). The theory base does argue that financial criteria are hindering long-term decisions which often hinder investments in concepts like reconfigurability (Kaplan, 1986; Meredith & Suresh, 1986; Saleh et al., 2001), since reconfigurability often need a longer perspective on investments. While looking towards lean, could it be argued that financial criteria are also hindered by Liker's (2004) first principle. Of course, does it depend on which financial criteria and what time-frame are used for the criteria. Thereby, are the financial criterion hindering both lean and reconfigurability.

5.2.1.4 Dependability

As DeMeyer (1989) said do the industry value making dependable deliveries to their customers, and both lean and reconfigurability are concepts used to fulfil the customers' demands. Lean strives to get a continues-flow of products with minimum waste to the customer, when they want the goods, in the right quantity and the right quality (i.e. just-in-time). The methods used within lean does strive to make the production flow stable and reduce the variation which enables dependable deliveries.

Reconfigurability can be argued that it enables dependability over longer time, because reconfigurability makes the manufacturing system ready for changes in the environment and the customers' demands, to faster enable adaption to the new context. It could be argued that dependability could enable the need for reconfigurability, but in a longer time-frame than for lean. Thereby, dependability supporting lean and reconfigurability.

5.2.1.5 Compatibility

The definition of compatibility is "*ability to be compatible with the existing (or future) software, hardware, and people"* (Saleh et al., 2001, p. 1268). The ability to be compatible is a large part of what reconfigurability is. Especially the reconfigurability principles (1) *Integrability*, (3) *Customisation*, and (4) *Convertibility* (see Table 8) which regards how the manufacturing system are designed to be able to adjust and customised to meet the present and future demands of the customers. It can thus be argued that compatibility is supporting reconfigurability.

Lean on the other side, is also focused on using technologies that are compatible with the existing system, by only using existing, proven technologies, i.e. the eight principle of lean (see Table 5). Lean does thereby take a more cautious route to make sure the different parts of a manufacturing system work together. However, does lean also use standards to make it easier to introduce new changes to the system and lean make sure that the whole organisation is informed on what changes that are happening, principle 6 and 13 (see Table 5). It could thereby also be argued that compatibility is supporting lean, but not to the same degree as to reconfigurability.

5.2.1.6 Training

No matter if its lean or reconfigurability are training important, according to Saleh (2001) can training improve the implementation of the investments, especially if it is a complicated technology. The level of training within a certain new investment, e.g. a new machine, will not affect lean or reconfigurability. However, is one of the prerequisites for reconfigurability that the organisation has training within reconfigurability (Rösiö, 2012a), it could be argued that the same is true for lean. Thereby can it be argued that training is neither supporting lean nor reconfigurability even though lean has principles for learning, and that knowledge of reconfigurability is a prerequisite for using reconfigurability.

5.2.1.7 Safety performance

According to Grimaldi and Simon (1989, [Through (Saleh et al., 2001)]) is it possible to increase the amount of available time for the company by reducing the number of sick days and the activities necessary to handle the administration, which can be seen to reduce the waste within the system. It could also be argued that by using AMS can the safety performance be increased. According to the respondents are there hinders for increasing the manual work within the manufacturing system regarding the safety for the operators, which could hinder the push for more manual work. It could thereby be argued that safety performance is supporting lean as a mean to reduce waste. Looking towards reconfigurability are there not nothing special with safety performance, the level of safety performance is neither supporting nor hindering reconfigurability.

5.2.1.8 Total system cost

By using total system cost is it possible to use longer perspective for the investment, since it regards the whole cost over the life-time of the system (Saleh et al., 2001). The prolonged perspective does enable reconfigurability investments, as the first and third prerequisite of reconfigurability is: *"A life-cycle perspective on production systems"* and *"Having long-term view on investments in production capacity"* (Rösiö, 2012a). The respondents at the focal company did also argue for the use of a similar criterion which combined the initial investment with the running cost of the system. With this investment criteria could it be possible to invest more initially expensive solutions to later reduce the cost during the life-time of the system. It can thus be argued that total system cost is supporting reconfigurability.

Total system cost does provide the same long-term perspective for lean, which would help to increase the use of Liker's (2004) first principle (see Table 5). Thereby, the investment criterion is supporting lean. However, since reconfigurability is often heavier than lean regarding the initial investment does this criterion support reconfigurability relatively more than lean.

5.2.1.9 Vendor support

Good vendor support is important for lean as of principle 11 in Table 5; *"Respect your extended network of partners and suppliers by challenging them and helping them improve"*, without it will it be harder to create a good network for the company. Also, could it be argued that the use of just-in-time could be viewed as service provided by the company's vendors. Thus, vendor support is supporting lean. From a reconfigurability perspective can vendor support also be important, the respondents mentioned that the development of a reconfigurable system would have to be done together with machine and system suppliers. Thereby, vendor support is supporting reconfigurability.

5.2.1.10 Technical and management support

The level of technical and management support for the workers within the manufacturing system is important for both lean and reconfigurability. Without it can the uncertainty affect moral and performance (Saleh et al., 2001), however, the investment criterion is affecting both of lean and reconfigurability, if kept at a low level could it have hindering effects of the manufacturing system. But if it is kept at high level can it help with the introduction of new technologies and changes to the manufacturing system. Thereby can the criterion be hindering or supporting for both lean and reconfigurability.

5.2.1.11 Investment cost

Within the focal company are investment cost the most important criterion, the respondents meant that the upper management pushed to keep the investment cost down. With the focus of investment cost together with the project-based investment time-frame is concept solutions that have a lower initial investment cost favoured. The respondents mean that concept solutions that have low investment cost and high running cost still gets favoured, even though the running cost can be much higher than the alternatives. Thereby, do the respondents mean that solutions that have a higher initial investment cost and with lower running cost, or with a better adaptability to outside changes as: volume, functionality, or technology changes, solutions with longer time-frame gets disfavoured. Wiendahl et al. (2007) says that reconfigurable tools typical has a higher investment cost than its non-reconfigurable counterpart, which makes a reconfigurable system have a higher initial investment cost. It can thereby be argued that investment cost hinders reconfigurability.

Looking from a lean perspective can investment cost also become hindering, however does the investments needed within lean usually not require large capital investments. The respondents 5 and 6 meant that their lean activities usually revolve around continues improvements and some kaizen-events. Thereby can it be argued that the investment cost also is hindering for lean. However, when evaluating different concept solutions were there are one lean option and one reconfigurability option does the investment cost criterion relativity disfavour reconfigurability.

5.2.1.12 Running cost

The second investment criterion at the focal company, running cost would premier concept solutions that have low running cost. To lower the running cost could the manufacturing systems automation level be increased. On the other hand, are solutions with high number of humans working within the system have a higher running cost. According to the respondents are solutions connected to higher number of humans within the system also connected to lean. By comparing the two concepts are solutions connected to lean having reduced automation level and increased running cost. Reconfigurability does not necessarily have the push for more or less automation within a manufacturing

system but are of course also pushed to reduce the running cost. Lean and reconfigurability are hindered by running cost, but since lean are increasing their level of humans within the manufacturing system at the focal company are lean see to relatively to reconfigurability.

5.2.1.13 Floor space

The investment criterion floor space is a relatively new at the focal company. According to the respondents have the floor space affected the development project by making the concepts of some production lines more compact, decreasing the used floor space. According to the respondents does this affect the next coming generations planned at the production lines. It could thereby be argued that floor space is reducing the development team's investment perspective, to only the first product generation. However, does Saleh et. al (2001) and Kaplan (1986) mean that the usage of reconfigurable machinery could reduce the used floor space, by reducing the number of machines used. Floor space can thus be argued to both hindering and support reconfigurability.

Turning to lean, according to the respondents does the use of floor space favour low-tech solutions and increase the motivation for manual work. Liker (2004) says that it is possible to use less floor space if lean principles are used, one reason is the reduced inventory needed and produced. It can thus be argued that floor space is supporting lean.

5.2.1.14 Project Feasibility

The evaluation of a project's feasibility is important, however does the realisation of a project not necessarily hinder any of lean or reconfigurability. At least not on a concept level, only at the specific concept solutions. Thus, can it be argued that the project feasibility is neither supporting nor hindering lean and reconfigurability.

5.2.1.15 Summary of investment criteria

How the investment criteria affect lean and reconfigurability, and if they are used at the focal company are presented in Table 13. If the criterion is supporting or hindering, then are (Supporting) and/or (Hindering) written in the table. When the criteria are neither hindering nor supporting then the table are marked with (N/A). Some of the investment criteria are deemed to affect one of the concepts relatively more than the other and are marked with (*). The investment criteria from literature and the focal company and how they are deemed hindering, supporting or neither which are answering research question two; "*How do existing investment criteria support lean and reconfigurability?"* are presented in Table 13.

Table 13. Investment criteria analysation

#	Criteria	Lean	Reconfigurability
1	Flexibility	Both Supporting and Hindering	Supporting
2	Quality	Support	N/A
3	Financial	Hindering	Hindering
4	Dependability	Supporting	Supporting
5	Compatibility	Supporting	Supporting*
6	Training	N/A	N/A
7	Safety performance	Supporting	N/A
8	Total system cost	Supporting	Supporting*
9	Vendor support	Supporting	Supporting
10	Technical and management support	Both Supporting and Hindering	Both Supporting and Hindering
11	Investment cost	Hindering	Hindering*
12	Running cost	Hindering*	Hindering
13	Floor space	supporting	Both Supporting and Hindering
14	Project feasibility	N/A	N/A

5.3 How can the existing investment criteria be combined into a set of investment criteria that facilitates lean and reconfigurability?

The result given by the second research question: *"How do existing investment criteria support lean and reconfigurability?"* provided Table 13 where each of the investment criteria found in the theory base and at the focal company, are classified as either supporting, hindering, neither supporting or hindering, or both supporting or hindering for lean and reconfigurability. Based on these criteria will the following section explore the possibility of creating a better than the focal company's set of investment criteria for creation of a cost-efficient and reconfigurable manufacturing system. The result of the analysation is then presented within Table 14.

5.3.1 Investment criteria

Each of the investment criteria presented in Table 13 will be evaluated individually if the investment criteria are deemed to fit to be used within the new investment criteria list.

5.3.1.1 Flexibility

The criteria for flexibility are important as shown in *5.2.1.1 Flexibility*, however, there are many different types of flexibility that are important such as the three types discussed by Karsak and Tolga (2001), Meredith and Suresh (1986) and Saleh et al. (2001). The three types of flexibility were: process flexibility, volume flexibility, and material flexibility. As seen by the difference in the character of the three flexibility types, can it be argued that the all the types should be used to enable different types of flexibility, depending on what requirements the markets put on different parts of the manufacturing

system. The flexibility criterion can thus be said to have three sub-criteria: *Process*, *Volume*, and *Material flexibility*.

5.3.1.2 Quality

As stated within *5.2.1.2 Quality* is quality important and without the right quality will customers not buy the products that are produced. However, it can be argued that quality is a qualifier, and if the investment options do not have the right level of quality then will the option be discarded within the concept generation phase and not evaluated against the other options. Thus, the criterion quality is necessary as a qualifier and not an investment criterion when evaluating different investment options.

5.3.1.3 Financial

Financial investment criteria are important to use to keep the investment still possible to perform. To balance out the intangible benefits with their counterpart of either their cost or possible economic benefit. As respondent 2 said, it is important to prioritise how the available funds are spent, that the funds are used on the best option for the organisation. Thereby are the question not if financial criteria should be used, but which financial criteria should be used when evaluating different investment options. It could be difficult to perform NPV or Payback evaluation when there exist uncertainty of the income and expenses during the investment time-frame. However, it is still important to make an estimation of the benefits and the costs, and to estimate when the investment will be profitable for the organisation. To complicate it even further is the investment situation for many organisations that the equipment's life-time are longer than the products being produced, which mean that the next generation or another product could come to be produced within the same production line. To include both the size of the investment, the reoccurring costs within the manufacturing system, the combination of the two i.e. system cost or total system cost, and when the investment would be profitable for the organisation could financial criteria such as: *Total system cost*, *Investment cost*, *Running cost*, *NPV or Payback* within Table 14 be used. The financial criteria in combination could be used to enable both the long-term time-frame for the investment, together with the total investment cost and the reoccurring running cost. By only using *Investment cost*, as done today at the focal company, are the possibility of doing long-term investments hindered, no matter if it is a reconfigurable solution or a lean solution. By introducing R*unning cost* would the cost of running the new production line be of interest, limiting the manual work as the major work solution, giving the more automated solutions a fair evaluation. By combining the two and getting something similar to *Total system cost* can both the investment cost and the running costs be incorporated. Thus, also shifting the focus of the production line towards more than just the first product, since the whole life-cycle of the production line is evaluated. Which would be in-line with Liker's (2004) first principle for lean (see Table 5), together with the first and third prerequisites of reconfigurability in Table 6. However, it must not be forgotten that the organisation needs to justify the investment by knowing when the investment

is expected to be profitable, thus needs the criteria of *NPV* or *Payback* be included in the evaluation. The four financial criteria will thereby be classified as sub-criteria to financial investment criteria.

5.3.1.4 Dependability

Dependability of the deliveries are as presented earlier, one of the most important competitive factors for companies in Europe, North America, and Japan (DeMeyer et al., 1989). However, the dependability of the equipment being purchased are not what is being evaluated by the investment criterion. The criterion is the *dependability* of the deliveries to the customer, which of course is dependent on the dependability of the equipment. *Dependability* is rather a holistic criterion that evaluates the whole system and its deliverability, which can become hard to predict before the system is up and running but is a criterion worth looking into especially if different investment options have different levels of the deliverability.

5.3.1.5 Compatibility

Compatibility become important when having a long-term perspective, since the manufacturing system will have to endure multiple changes of products, product generations, product variants, but also of manufacturing and product technologies. The exposure to the changing environment makes the compatibility towards future technologies and products important, especially with a reconfigurability perspective as in the first, third, and forth criteria of reconfigurability in Table 8. If the compatibility is not considered when designing and later deciding which alternative to continue develop, can unnecessary cost arise for new development or totally block the possibility of using the same production lines. According to several respondents at the focal company have lack of thought for compatibility in the past led the focal company to not be able to use multiple products within the same production line. The respondents mean that it would have been possible to reduce the investment cost if the compatibility between current and future products would have been considered in the designing phase. It is thereby important to use the criterion compatibility when evaluating between different investment options.

5.3.1.6 Training

As stated within *5.2.1.6 Training* are training important for both lean and reconfigurable manufacturing systems, training enables an easier implementation of complex solutions within a manufacturing system (Saleh et al., 2001). Training can become interesting as an investment criterion when the different investment options require different amount of training, a system with lower training requirement could make the implementation more likely to succeed to a lower cost.

5.3.1.7 Safety performance

Safety performance is important when designing a manufacturing system, due to legislation and the performance of the workforce within the system. As stated in *5.2.1.7 Safety performance* is according to Grimaldi and Simon (1989, [Through (Saleh et al., 2001)] can a high level of safety performance help to reduce sick leave and associated administration within the system. Thereby, it is important to have a manufacturing system that has good enough safety performance to reduce waste and to accommodate the legislation. Which makes safety performance an investment criterion that are similar to *Quality* necessary as a qualifier for the different investment options.

5.3.1.8 Vendor support

Vendor support can be important when designing manufacturing systems, according to the respondents would the best result of the development of a reconfigurable production line be done together with the machine and system suppliers. The collaboration would combine the knowledge of machines and system with the focal company's knowledge of their processes and challenges. In order to make sure that the organisation gets the support that is required to enable efficient and effective development of the manufacturing system is *Vendor Support* important.

5.3.1.9 Technical and management support

Technical and management support would be the same no matter what investment option that are chosen for development. This being said does the level of support the organisation can provide to the workforce affect the implementation of said investment option. Which makes it an important factor when implementing new equipment, technologies, methods, or solutions. The respondents mentioned that they lacked support regarding how they should work with the new production design principles, the respondents requested a clear strategy in how the principles should be used. Some respondents meant that the level of support does not usually vary between different investment options but are instead constant within the organisation. However, if an investment option was suggested that have new technologies or methods that have never been used before then the level of support would most likely be affected negatively. The *technical and management support* provide can affect how well the investment option can be realised and should thereby be included in the investment evaluation.

5.3.1.10 Floor space

The area available within a manufacturing plant often is limited does the *floor space* usage become important in the investment decision. However, as the respondents at the focal company expressed, can a focus on *floor space* hinder the future development of the manufacturing system due to too short perspective on the system. The respondents did also mention that the focal company had limited available area for new production lines, and it can thus be argued that the *floor space* is necessary to have as an investment criterion.

5.3.1.11 Project feasibility

The feasibility of the project was mentioned as the fourth investment criteria at the focal company and was used to evaluate the general success rate for the project from development to success full implementation. By evaluating the *project feasibility* can possible risks with the project be found and prepared for. The evaluation of different investment options enables the upper management to have the possibility to see what risk the project exposes the organisation to. The *project feasibility* is thereby deemed to be important when evaluating different investment options.

5.3.2 New investment criteria list

The different investment criteria and if they are deemed important when evaluating different investment options are presented in Table 14. Some of the investment criteria that were analysed were not deemed important to use as an investment criterion, but instead as qualifiers or important for the investment processes. The criteria will thus be classified as: investment criterion, qualifier, or investment process. Table 14 present a possible list for investment criteria to be used when evaluating different investment options with the aim of developing both a cost-efficient and reconfigurable manufacturing system.

Table 14. New investment criteria list

#	**Main criteria**	**Sub Criteria**	**Type**
1	*Flexibility*	*Process*	Investment criterion
		Volume	
		Material	
2	*Quality*		Qualifier
3	*Financial*	*Investment cost*	Investment criterion
		Running cost	
		Total System cost	
		NPV or Payback	
4	*Dependability*		Qualifier
5	*Compatibility*		Investment criterion
6	*Training*		Investment criterion
7	*Safety performance*		Qualifier
8	*Vendor support*		Investment criterion
9	*Technical and management support*		Investment criterion
10	*Floor space*		Investment criterion
11	*Project feasibility*		Investment criterion

6 Discussion and conclusions

This chapter starts with discussion the methods used within the study. The chapter continues with discussing the result of the study, which is structured into the study's three research questions together with a section that focuses on how the result of each questions has helped to fulfil the study's purpose. At last the chapter presents and discuss the study's conclusion together with presenting further possible research within the studied field.

6.1 Discussion of method

The study consists of a single-case study which has been carried out in a specific context, and therefore has affected the generalisability negative. In order to try to minimise the amount of negative affect has the study's structure been detailed described, and thereby give the readers an honest chance to assess what is applicable within their own context (Guba & Lincon, 1989). If a multiple-case study would have been conducted instead, it could have increased the generalisability, but at the same time decreased the depth of the study. Also, due to the sensitive fields of the study some available data could not be shared within the report due to a secrecy-agreement with the focal company, and thus limited the findings a bit. The effect of the secrecy-agreement is something that is hard to affect. Usually can another company be selected, but in this case was it not possible to select another company due to that knowledge and experience regarding reconfigurability within an organisation is rare. The collected data were thoroughly reviewed and written in a confidential way, and thus increased the amount of possible data to use within the study.

The literature review was conducted using the five-step method by Wolfwinkel et al. (2013), which helped the authors to structure the literature review process and thereby decreased the risks for any mistakes. Also, in order to not miss any relevant literature, was several search terms used. Also, was some literature connected to AMS's transferable to reconfigurability, and therefore was used in order to get a broader research perspective.

The respondents at the focal company were chosen by the supervisors at the focal company, which can have affected the result of the interviews due to some possible relevant data might have been missed. However, the supervisors at the focal company have a better knowledge regarding the focal company and their employees and knows which employees that is most relevant and capable to answer the questions. By interviewing employees within several departments within the focal company, it minimised the risk of any subjective results. The broad spectra of respondents together with, semi-structured interviews, data triangulation and that all interviews were recorded and transcribed increased the data quality of the interviews (Yin, 2007).

Due to that the document studies contained a lot of sensitive information about the focal company, was the available data reviewed and chosen by the focal company's responsible representatives, which enabled and increased the risk of any subjectivity. In order to avoid any subjectivity from the focal company's responsible representatives were the collected data from the document studies double checked with the supervisors at the focal company and during the interviews, and later compared with the literature. Thus, were the data within the study exposed for data triangulation, which according to Yin (2007) increase the data quality.

6.2 Discussion of findings

This study has investigated the possibilities of combining lean together with reconfigurability and thus get a more comprehensive and covering concept which includes the benefits from both concepts. This has been achieved through the development of a new set of investment criteria that is based on the principles of lean and reconfigurability. The following section is discussing each research question individually and then sum-up with a discussion regarding the purpose of the study.

6.2.1 Discussion RQ 1 - What are the similarities and differences between lean and reconfigurability?

In order to be able to combine two concepts it is crucial to know how the two concepts stands against each other, i.e. what similarities and differences that exists between them. Through analysing the existing literature regarding how the principles and characteristics of the two concepts differs from each other, it was clear that further research within the subject was needed. Thus, through analysing both the principles and characteristics of the two concepts in the existing literature, together with analysing how these principles and characteristics were considered as similar or different within the case study, were this knowledge gap decreased.

The biggest difference between the two concepts are that lean is more comprehensive and covering than reconfigurability, and it exist several reasons for this. If the two concepts are compared on a general level, then lean is more of an overarching organisational strategy on how to create more efficient and profitable processes through eliminating all non-value-adding activities within the whole organisation. Meanwhile, reconfigurability is a strategy regarding how to structure the manufacturing system in order to increase the reconfigurability levels and create more efficient and profitable processes by being less sensitive to the present and future market fluctuations. The two concepts take place at different strategical levels, which explains the difference regarding that lean is more comprehensive and covering, i.e. includes principles, methods and tools which organisations can use in order to achieve more efficient and profitable processes. However, even though that the two concepts do not take place at the same strategical level, the goal of the both concepts are similar, and can be seen as an enabler between the two concepts.

Further, as presented in Table 11, depending on the context of the organisation can all the lean principles be classified as similar to reconfigurability. Which enables the use of the lean methods and tools within reconfigurability as well, e.g. continuous flow process, the use of visual control systems, SMED etc. The biggest reason behind why so many of the lean principles are similar to reconfigurability, can be due to their common goal, i.e. to help organisations to strengthen their market position through making the processes more efficient and thus more profitable. It is possible to increase the efficiency and profitability of an organisations processes in a lot of different ways, and one alternative does not need to exclude another. This is something the combination between lean and reconfigurability are a good example of, due to that even though they are two different concepts with both similarities and differences, a lot of the methods and tools within lean is applicable to reconfigurability as well. Thus, can the methods and tools within lean help to further both the concepts.

However, the number of similarities and differences between the two concepts variates depending in which organisation the relation is studied, i.e. the context of the organisation has an effect on the result. For example, the twelfth lean principle, which is about go out in the production processes in order to see and thoroughly understand the situation. This can be classified as a difference to reconfigurability due to that the complexity level within the manufacturing system can become very high and therefore going out and see for yourself might not help at all. However, the complexity level of the manufacturing system does not have to increase at all, and in those cases, it can help to go out and see for yourself. Thereby, it is crucial to include the context of the organisation when analysing how the two concepts differ from each other, and thus how successful a combination between the two concepts can become. Even though it exists some differences between the two concepts and they are affected by the organisation's context,

it is possible by the support of this study to say that a combination of lean and reconfigurability is possible. The combination could be achieved in a lot of different ways, but one possible way which was continuously mentioned during the interviews is through using lean as the foundation due to it is more comprehensive and includes different useable methods and tools. Then, through adding the essence of reconfigurability, customise the lean philosophy and create a concept that reaches the benefits from both the individual concepts. Thereby, achieve a concept that is less sensitivity to the present and future market fluctuations at the same time being able to increase efficiency and thus the profitability within the whole organisation.

6.2.2 Discussion RQ 2 - How do existing investment criteria support lean and reconfigurability?

The criteria are defined as supporting, hindering, or N/A depending on how the performance within the certain criteria will affect the two concepts lean and reconfigurability. Level of support or hindering the investment criteria are deemed to inflict are connected to the principles and prerequisites connected to lean and reconfigurability. Some of the criteria are thought to have a larger affect to one of two concepts, e.g. compatibility. Compatibility between product generations and variants within a product family is the foundation of reconfigurability. By investing into systems that are being measured in: to what extent the invested equipment is compatible, are enabling investments in solutions that have the ability to be easily changed for new emerging demands. Meanwhile, lean does focus on introducing thoroughly tested technologies into the manufacturing system, which are then less likely to fail with the integration. By limiting the possible solutions to only thoroughly tested technologies are lean limiting the uncertainty introduced to the system. Where on the other hand, reconfigurability introduces the thought of modularity and integrability to become more changeable and readier to adapt itself to the new possible solution at low cost for the profitability and productivity of the system. The two concepts are using different approaches of how to reduce the uncertainty introduced to the created manufacturing system, by either minimising the uncertainty or making the system or robust and ready to handle the uncertainty. Thereby are comparability deemed to have a larger supporting effect on reconfigurability than on lean.

There exist cases where the context matters, as in the case of flexibility. Flexibility for reconfigurability is imperative, especially with the three sub-criteria volume, process, and material flexibility presented by Karsak and Tolga (2001), Meredith and Suresh (1986), and Saleh et al. (2001) as they are closely linked to the reconfigurability's principles: Customisation, Convertibility, and Scalability. Meanwhile, flexibility within lean can be both supporting and hindering. The effects of flexibility can be supporting lean when looking towards that flexibility enables higher throughput and reduces inventory. However, as seen within the focal company can flexibility be seen as an extra

cost, and then also waste within the manufacturing system. The respondents at the focal company said that since the flexibility is not necessary right now, it is using resources that could be used somewhere else. At the focal company does flexibility become a waste the organisation wants to minimise or eliminate. Even though the first principle of lean is *"Base your managed decisions on a long-term philosophy, even at the expense of short-term financial goals"*. The way flexibility is viewed is depending on to what extent lean has been implemented within the organisation, which is the context of the organisation.

To conclude, there are no criteria that are in direct conflicting relation between lean and reconfigurability. The criteria are depending on the context of the organisation. Similar findings can be found in the general comparison between lean and reconfigurability, were the principles of lean and reconfigurability are not in contradiction to each other. However, the implementation of lean and reconfigurability will affect how the concepts are viewed and how their principles are interpreted, and thus can the result shift in different settings, the context of where lean and reconfigurability are combined will affect if the combination is successful or not.

6.2.3 Discussion RQ 3 - How can the existing investment criteria be combined into a set of investment criteria that facilitates lean and reconfigurability?

From the analysation of the third research question were a new list of investment criteria presented in Table 14. Within the list are there two classification used for the criteria that were analysed: *Qualifier* and *Investment criterion*. The criteria that were categorised as *Qualifiers* were seen as being necessary to be fulfilled to a certain level, and if the alternative did not reach that level would the alternative be discarded or reworked before the evaluation process by the development team themselves. Within the proposed investment criteria were quality, deliverability, and safety performance deemed to be *Qualifiers*, to take safety performance as an example; if the alternative could not fulfil the necessary level of ergonomics or safety for the workers then the alternative could not by law be acceptable or the organisation would be risk facing fines. Laws and expectations vary from markets, industry, and over timer which makes these qualifiers require different levels of fulfilment depending on the context.

Looking towards the category *investment criterion*, these are the criteria that vary in the level of fulfilment depending of the specific alternative and how well the alternative performs within each criterion. As can be seen by looking in Table 14 are there criteria of both tangible and intangible character, e.g. the financial criteria as tangible, and e.g. flexibility criteria as intangible. The combination of tangible and intangible criteria is as Saleh et al. (2001) mention important in order to capture the benefits of concepts like reconfigurability. Some of the intangible criteria that affect reconfigurability are aspects

as convertibility and scalability, and within the investment criteria are the sub-criteria volume and process flexibility a good representation of convertibility and scalability.

The financial criteria *Investment cost*, *Running cost*, *Total system cost*, and *NPV* or *Payback* enables a better picture of how the future manufacturing system could affect the result for the focal company. By using multiple financial criteria that are focusing on different aspects can the organisation see different aspects of the same investment alternative. The investment cost makes it possible to see if it is possible from the beginning, if it is to big then it is not even worth considering if there is not an explanation for why. Running cost enables the organisation to see how much cost the investment alternative would require using to be able to produce the intended product and volume. By combining both the investment cost with the running cost and then adding the expected life-time of the system is it possible to get a picture of how much total cost the investment criteria will assign to each of the products produced. This does also enable to create different scenarios where the volume variates over time, which introduces the uncertainty to the investments and can help to find when the system no longer is profitable, and thus help the organisation to get a better holistic view regarding the investment. The use of NPV or Payback does enable the organisation to compare the solutions, and when adding the component of uncertainty can it be possible to see when the different solutions become unprofitable and thus also what risk the different solutions are connected to. The uncertainty is required to be considered, without any uncertainty are there no need for having a reconfigurable manufacturing system, since the outcome is already known.

However, even if there exist an optimal set of investment criteria that would perfectly enable a manufacturing system that are both cost-efficient and reconfigurable, would the effect of the investment criteria be affected of how the organisation is structured. Every organisation has its own context and history, affecting how the organisation is structured and how the organisation evaluates different investment options. The focal company are heavily steered by their project structure. Their project structure for new manufacturing system are coupled with new products, which limits the timeframe for the investment to the life-time of the product, excluding future generations and variants in the investment consideration. Which neglects the uncertainty of what could happen between and over the product generations by only focusing the first generation.

In order to create manufacturing solutions that are able to work over multiple product generations and variants is the organisation required to have the right competency to design, develop, and create the solutions. The competency to enable the creation of said manufacturing system are not created instantly but are created by trying to accommodate the principles of reconfigurability. The use of having investment criteria that challenges the developers to start thinking about solutions that should be able to work over

multiple variants and generations could trigger the creation of the necessary competency. Several respondents said that the new production design principles were based on common sense, but now were written down to be easier discussed and used throughout the organisation. The same could be true for reconfigurable manufacturing solutions, trying to think long-term and not only on what is in front of us at this specific moment. However, if the investment criteria are actively working against these kinds of investments will the developers not be able to create systems that facilitate multiple product generations and variants. By introducing investment criteria as the ones presented in Table 14 will the developers on all levels be challenged to create alternatives that are to some extent more efficient at the same time, they are more reconfigurable. For example, by introducing compatibility as an investment criterion for the investment decisions must the future variants and generations of the products be considered when designing the system. Which could drive the development of integrability, modularity in the product and the manufacturing system to help to enable the convertibility. By continuing to look towards the financial criteria of *total system cost* is it possible to see that the solutions trying to facilitate total system cost will have a chance of being both efficient and reconfigurable. The higher investment cost can become profitable by the organisation not having to invest in a new system every time a new product is supposed to be developed and produced within the same system.

To enable the organisation's strategy is it important to have investment criteria that reflect the different aspects of the strategy, i.e. including both tangible and intangible criteria. Aspects like being cost-efficient and being competitive on a market that are changing are becoming more important. Thus, it is required to have the right organisation that can facilitate the consideration of uncertainty within the chosen investment criteria that should reflect the strategies employed by the organisation. Which makes the considerations for introducing the proposed investment criteria dependent on the context of the organisation in question.

6.2.4 Discussion of purpose

The study aimed to fulfil the purpose: "*To increase the awareness regarding how investment criteria can enable the combination of the two concepts lean and reconfigurability*.", by answering the three research questions. The three research questions are all contributing to increasing the awareness of the possibility to combine lean and reconfigurability. The research questions are though not testing different investment criteria and how they actually are affecting the combination of lean and reconfigurability. The study is however, investigating the possibility: if the two concepts could work together, based on their principles and prerequisites based in theory, and how these are affected by the investment criteria. The research question one and two does show that it is possible to combine lean and reconfigurability based on the notion that there are not any major conflictions between their principles, and how they affect the investment

criteria. The third research question does present a modified list for investments in manufacturing system, which puts light on the complexity of uncertainty in investments. The three research questions are deemed to help fulfil the purpose of the study and thereby increase the awareness of how investment criteria can enable the combination of lean and reconfigurability. The investment criteria are deemed to enable the combination by increasing the focus on long-term investments and capturing the intangible benefits of reconfigurability and by including uncertainty to the investment decision.

6.3 Conclusions

Lean and reconfigurability do not have any major differences between each other based on their principles and prerequisites. Which does not hinder the use of both lean and reconfigurability within the same organisation. Lean principles like: *"Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals"* facilitating the implementation of reconfigurability into the organisation by emphasizing the importance of having a long-term philosophy for the organisation to tackle the uncertainty that are affecting the organisation over time. The possibility of using both lean and reconfigurability are also affected by the organisational context, e.g. the project structure, and to what extent lean have been implemented into the organisation. By incorporating the principles of lean and reconfigurability into the higher organisational levels and their strategies it entails the dispersion of the principles throughout the organisation.

The focal company is required to implement some changes to increase their possibility of succeeding with the use of both lean and reconfigurability. The investment criteria that are used within the focal company are not enabling the intangible benefits of reconfigurability and the possible risk of only looking for the first product generation to be considered. Thereby, is an introduction of new investment criteria presented in Table 14, which enables both the tangible consideration of an investment together with the possibility of valuing the intangible benefits, important to enable long-term investments and development projects. However, the uncertainty associated with investments in the manufacturing system are not directly considered as a separate criterion but are instead to be considered throughout the list as a whole. It is also important to remake the project structure from a focus of one product at the time to a structure which enable the consideration of multiple product generations within a single project. A project structure that enables multiple product generations for considerations can be achieved by implementing new demands into the requirements that are created for the product itself in the beginning of each project through the representation of uncertainty. Uncertainty could be presented as different scenarios as *Best, Worst,* and *Likely* scenarios for the investment.

6.4 Further research

The study present that lean and reconfigurability do not have any major differences based on their principles and prerequisites. However, as stated by the respondents at the focal company can differences still be perceived in practise, it is thereby interesting to investigate what are the reasons for these perceived differences. It could also be interesting to investigate how lean are perceived in industry in contrast to how it is perceived in literature, and there compare how reconfigurability are possible to combine with lean. In order to generalise the result of the study it is also necessary to carry out more case studies that study the relation between lean and reconfigurability.

The discrepancy between the investment criteria found in literature and in industry is also interesting to investigate, to see what criteria the industry is using and how they affect their development. The new list of investment criteria needs to be tested in industry to validate if the investment criteria facilitates lean and reconfigurability, and thus further the creation of both a cost-efficient and reconfigurable manufacturing system. The realisation process is also interesting to further investigate, and how it affects the success of creating a manufacturing system that are cost-efficient and reconfigurable.

The uncertainty of investing in manufacturing systems and how it is considered is interesting to further investigate and depending on how the consideration is affecting the decisions regarding the investments. Also, the combination of how different level of risk are affecting what types of manufacturing systems that are developed, in relation to reconfigurable, flexible and dedicated manufacturing solutions.

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7 Appendices

7.1 Appendix 1 - Interview guide

7.1 Appendix 1 - Interview guide

Introduction of the interviewers and the subject together with the purpose of the study

Our names are Jesper and Simon and we are studying the master program “Production Development & Management” at Jönköping University. Our purpose is to map the two concepts Lean & Reconfigurability, both on a theoretical level but also in practice, i.e. how you work and think about the two concepts here at the company. Once the mapping is done, we will try to connect the two concepts to your work regarding “the production design principles” and the development process here at the company and try to identify possible changes in order to increase the chance of succeeding with the implementation of reconfigurability.

Short agenda of the interview structure

The purpose of the interview is to get your opinion of the two concepts and how they affect and/or can affect your work in the future, together with getting your insight of how to maximise the relation between Lean and Reconfigurability. The interview is divided into two sections:

1. Several open questions regarding the two concepts and the investment process – These questions are created in order to start discussions between us and you will receive follow-up questions connected to the "main-question" and if you have any questions or concerns you are free to ask us at any time.
2. The second section is more about a “case/scenario” where we will try to connect the discussions of the first section with more case-related questions – These questions will be more of a structured layout but of course create discussions between us based on follow-up questions.

First section – Open questions of the two concepts and the investment process

1. Who are you and what do you work with here at the company?
2. How does a regular workday looks like for you here at the company?
3. What is your role in investment projects regarding the manufacturing systems (Lines, machines, tools logistics etc.)?
4. How affected are you and your tasks by Lean?
    4.1. What do you think is the main benefits and disadvantages of the Lean concept?
5. What is your opinion of reconfigurability?
    5.1. What do you think is the main benefits and disadvantages of reconfigurability?
6. How affected are you and your tasks of reconfigurability?
    6.1. How would you and your work task be affected of a transition towards more reconfigurability?
7. Which similarities, differences and conflicts do you see between the two concepts, and why do you identify them as this?

7.1. What is important for you in order to succeed with this transition?
7.2. Do you see anything that can obstruct the combining of the Lean and Reconfigurability?

8. What do you see as the main difficulties in order to succeed with the transition towards more reconfigurability?
   8.1. Both regarding your work tasks but also general for the organisation?
   8.2. What do you think would facilitate the transition? - Both regarding your work tasks but also general for the organisation?
9. What do you think of the "production design principles"?
   9.1. Do you think any principles are missing and/or unnecessary?
   9.2. Do you see any problems with the principles today when trying to transition towards more reconfigurability?
10. What do you think will be the "key factors" (principles, KPI:s etc) in order to achieve a balance between Lean and Reconfigurability?

Section two - Case/Scenario questions

Due to the increased customer demands regarding number of products and variants it leads to reduced volumes of each individual variant, which shorten the product life-cycles, and in that way increase the demand of faster product and production system releases and ramp-ups – Short summarised increases the importance of a flexible manufacturing system.

1. How well do you think the company can manage this problem at the moment?
2. How well do you think Lean as a concept can manage this problem?
   2.1. Key possibilities and/or difficulties?
3. What do you think is missing today in order to better handle this problem?
4. How do you think reconfigurability can help to manage this problem?
5. Which do you think will be the "key factors" in order to manage this problem the best possible way?

Final part of the interview

- Do you have any further thoughts, questions or concerns you want to say?
  - If you come up with anything you can just contact us through email or phone.
- Is it OK if we contact you if we come up with any further questions or thoughts?
- Thank you so much for your time and input, we value it very much.