CHALMERS
UNIVERSITY OF TECHNOLOGY

Approaching new production technologies

A standard for how Volvo Trucks should identify, evaluate and implement new production technologies in the Tuve plant

Master's Thesis in the Production Engineering Master's Programme

CARIN EKMAN
AUGUST IRHEDE WIRÉN

Department of Technology Management and Economics
Division of technology management and economics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018
Report No. E 2018:011

MASTER'S THESIS E 2018:011

Approaching new production technologies

A standard for how Volvo Trucks should identify, evaluate and implement new production technologies in the Tuve plant

CARIN EKMAN
AUGUST IRHEDE WIRÉN

Tutor, Chalmers: PATRIK FAGER
Tutor, company: ESBJÖRN SJÖBERG

Department of Technology Management and Economics
Division of technology management and economics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

Approaching new production technologies
A standard for how Volvo Trucks should identify, evaluate and implement new production technologies in the Tuve plant

Master's Thesis E 2018: 011

Department of Technology Management and Economics
Division of technology management and economics Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2018

Abstract

Technology is advancing faster than ever before. The risk of not keeping up with ever changing production technology has never been more tangible. Not continually updating the production system at a manufacturing company can result in disadvantages in production performance in relation to competing companies. Volvo Trucks is not exempt from the reality of continuous technological advancement and with that the threat of falling behind. Although Volvo Trucks Tuve has a sufficiently effective production system (i.e. they are competitive), some areas suggest the lack of a standard for how to identify, evaluate and implement new production technologies in the production system. By introducing an effective standard for how to continually update and advance the production system in Tuve, Volvo Trucks can expect improvements in performance areas such as productivity, quality and flexibility and ultimately become a more competitive manufacturing company. Hence, the purpose of the thesis *is to identify how new production technologies can be effectively identified, evaluated, and implemented in the production system at Volvo Trucks in Tuve*. The purpose was fulfilled by conducting a thorough literature review as well as multiple case study comprising four cases of recent introductions of new technology at Volvo Trucks. The project was performed as a qualitative study, with semi structured interviews as the main data collection method. The thesis concluded that Volvo Trucks primary problem is that they don't have a standardized approach that is continuously improved upon, resulting in limited learning and unwanted variation in the process of introducing new production technologies. A standard was created in order to remedy this problem. The standard was intended to be an overview of all important aspects to consider when approaching new process technology in general but is especially aimed at addressing Volvo Truck's specific problems. The standard should be considered as a basis for further development and perhaps a more concrete and streamlined standard. Nevertheless, the standard is structured in a step by step manner for ease of use and Volvo Trucks can expect a more effective approach towards new production technologies by utilizing it.

Acknowledgement

Firstly we would like to thank Volvo Trucks Tuve for giving us the opportunity to write our thesis project in your organization. We would like to express our gratitude to our supervisor at Volvo Trucks, Esbjörn Söberg for many interesting and fruitful discussions. In addition, we would like to thank you for the support, guidance and feedback we have received throughout the project. Furthermore, we would like to thank all interviewees who participated in the case study for their time and attention.

We would also like to extend our gratitude to our supervisor at Chalmers University of Technology, Patrik Fager. Thank you for your great engagement in our project and the guidance and support you have given us throughout the process. You supported us with near-instant feedback and suggestions all throughout the project.

Gothenburg, June 2018

Carin Ekman and August Irhede Wirén

Table of Contents

FIGURES

1 Introduction

The chapter presents the background of the thesis followed by the practical problem. Furthermore, the purpose and research questions are presented as well as the scope and delimitations. The chapter ends with an outline of the content for the rest of the report.

1.1 Background

In 2005 Kurzweil suggested that technology is advancing faster than ever before. Thirteen years later, there is no reason to think that this has changed. This reality poses a lot of exciting possibilities for manufacturing companies, whether it be increased productivity thanks to new automation technology or increased quality as a result of more precise machines. However, the risk of not keeping up with ever changing production technology has never been more tangible. Not continually updating the production system at a manufacturing company can result in disadvantages in production performance in relation to competing companies. At the edge of this argument is the concept of disruptive technology. Disruptive technology is a term that basically means how some new technologies can alter the existing market and value network (Christensen, 2011). It is usually used when describing innovations that drastically change a product's design, but can as easily be applied when talking about production technology. Examples of such technologies could be augmented reality, internet of things and artificial intelligence. These are technologies that have the potential to radically alter how things are done and that arguably are applicable in large parts of a production system, meaning that the area of effect is extensive.

A manufacturing company that does not have an effective method for how to approach new process technologies in their production system might arguably find themselves in two scenarios. The first scenario being slowly falling behind their competitors as a result of neglecting to make incremental improvements to their production system as technology is evolving. The second scenario consists of failing to detect and implement a disruptive technology and consequently, often in quite a short time period, end up with a substantial production technological disadvantage. Although these two scenarios have radically different timeframes, the source of the problem is the same and to an extent also the end result. Additionally, there is another possible problem that can arise as a result of having an ineffective approach to new production technology. That is when the evaluation aspect of the approach to new production technology fails and "dead end" technology gets implemented. In other words, choosing the "wrong" technologies.

Volvo Trucks (also referred to as "Volvo" in this report) is not exempt from the reality of continuous technological advancement and with that the threat of falling behind. Talking to a director from Volvo Trucks in Tuve, it becomes evident that there exists an organizational problem; the lack of a concrete standard for how to approach new production technologies. And although Volvo Trucks' production system is sufficiently effective (i.e. they are competitive), some areas suggest the lack of a standard. For example, order sequences and work instructions for the assembly line are being printed daily and placed by respective work station. This method of conveying information to the assembly operators is both expensive and, in many cases, ineffective. The expected outcome of the thesis is an effective standard for how to continually update and advance the production system at Volvo Trucks in Tuve. With this, Volvo can expect improvements in performance areas such as productivity, quality and flexibility etc. and ultimately become a more competitive manufacturing company.

1.2 Practical problem

In the report, the process of approaching new process technology is divided into three subprocesses. These are, in chronological order, *identifying*, *evaluating* and *implementing* new process technology. This is not an academically established division, rather a logical structuring of the processes necessary for introducing new process technology. It stands to reason that in order to introduce new technology, it first has to be found, *identified*. The subsequent action, of *evaluating* the technology, enables making a substantiated decision on whether or not to *implement* it, which in turn, if done correctly, makes for a successful introduction of new process technology. To support this structure, Dengler et al. (2017, p. 493) states that "a proactive technology management approach is characterized by continuously assessing established production technologies as well as identifying, evaluating and acquiring alternatives and capabilities in advance of needs". Needless to say, having an ineffective approach in either of the three subprocesses will result in an overall ineffective way of approaching new process technology.

1.3 Purpose

Volvo Trucks in Tuve is currently not working with a set standard when approaching new production technologies in their manufacturing system. This can cause unwanted variation and thus inefficiencies in how the processes are carried out, ultimately resulting in a less competitive business. Therefore, the purpose of the thesis is formulated as follows;

The purpose of thesis is to identify how new production technologies can be effectively identified, evaluated, and implemented in the production system at Volvo Trucks in Tuve.

1.4 Research questions

To address the purpose of the thesis, it's important to first understand how Volvo Trucks currently identify, evaluate and implement new production technologies. Such knowledge will represent a performance benchmark for the new standard to improve upon. It is also of interest to determine whether or not Volvo Trucks *indeed* are utilizing a standardized approach. Hence the first research question is:

> *RQ 1. How do Volvo Trucks identify, evaluate and implement new production technologies in the production system?*

In order to create an effective standard, in line with the thesis' purpose, effective methods for identifying, evaluating and implementing new production technology described in literature will be gathered. Such knowledge will ensure that the reasoning behind the design of the new standard is well substantiated. Consequently the second research question is:

> *RQ 2. What methods for identifying, evaluating and implementing new production technologies in a production system can be found in literature?*

The standard for identifying, evaluating and implementing new production technology should be designed in accordance to Volvo Trucks specific needs, hence the third research question is:

RQ 3. What can an effective standard for identifying, evaluating and implementing new production technologies in Volvo Trucks' production system look like?

Answering RQ1 will result in a description of how the company currently identifies, evaluates and implements new production technologies in the production system. The answer to RQ2 will be a compilation of what literature says about how effective methods for identifying, evaluating and implementing new production technologies. The answers to RQ1 and RQ2 will lay as basis for creating a new concrete standard for identifying, evaluating and implementing new production technologies at Volvo Trucks, i.e. answering RQ3.

1.5 Scope and delimitations

The scope of the thesis is limited to studying how Volvo Trucks approach new process technology at Tuve. The phrasing "approach new process technology" is within the thesis defined as the process of identifying, evaluating and implementing new process technology. Only limited consideration will be given to identifying problem areas within the existing production system. The term "*new* process technology", refers to technologies that are new to their potential implementation area at Volvo and do not have to be new in traditional sense of the word. The type process technology that is considered ranges from automated machines to digital work instructions, but is limited to technologies related to the actual assembly process. Technologies related to logistics will therefore not be considered. The technical aspects of the process technologies are not in focus, but rather the organizational aspects of approaching new process technology. Furthermore, the economic aspects of the approach will not be covered in its entirety. Rather, this is subject to further research where investment costs and quantifying criteria such as improved ergonomics and safety etc. should be considered.

The empirical part of the study will be limited to the production plant at Tuve. The standard that is created will not be implemented or validated within the frame of this thesis project. Moreover, the thesis will not review what departments or positions within Volvo that should be responsible for the different aspects of the approach to new process technology. In other words, the standard will only consider what methods should be utilized and how and not organize who will do what.

1.6 Report Outline

The first chapter (1 Introduction) introduced the reader to the study and provided the background necessary to read and follow the rest of the report. In addition, the purpose, research questions, scope and delimitations were presented. The coming chapter presents the theoretical framework, divided into three areas; *Identify*, *Evaluate* and *Implement* new production technologies. Following the theoretical chapter, the research method, strategy and design are presented. The next chapter (4 Findings and analysis) presents and explains the cases and the findings that were made during the analysis. The analysis is divided into two parts; within-case analysis and cross-case analysis. The proposed standard is presented in chapter 5. Following comes the discussion chapter where discussions and reflections regarding the project outcome are presented. Also, the answers to the research questions are presented as well as suggestions for further research. The concluding chapter sums up the thesis.

2 Theoretical Framework

The purpose of the literature review was both to provide an answer to RQ2, i.e. to find out what has been published regarding how to effectively identify, evaluate and implement new process technology, and to create a theoretical framework for the project at large. Literature that considers the entire process, from identification to implementation, is scarce and the only mentioning of the entire process that was found in academic literature was from Dengler et al. (2017), who states that "a proactive technology management approach is characterized by continuously assessing established production technologies as well as identifying, evaluating and acquiring alternatives and capabilities in advance of needs". For that reason, the review was structured so that literature relating to each of the three main subprocesses, i.e. 'identify', 'evaluate' and 'implement', was reviewed separately. There seems to be good potential for synthesizing literature about these three activities into an effective standard, since the theories related to each of the subprocesses are mostly created in the same or similar contexts, namely the manufacturing industry. In other words, compatibility issues as a result of stringing together separate theories into a continuous process should be negligible. Some of the literature does not reference production or process technology specifically but is still considered relevant.

The majority of the literature on the identifying part is based on what could be described like predictive methods. Namely, how to anticipate what advancements to expect in process technology and why it is important to do so. The literature on how to evaluate process technology consists of many different aspects, such as readiness level, technology maturity and what could be considered as commonly used evaluation criteria. The literature used in the report on the implementation process exclusively relates to the organizational aspects of technology implementation and therefore largely consists of literature on change management.

2.1 Identification theory

There is a plethora of terms and concepts related to identifying new process technologies. Sometimes the difference among terms is simply semantic, related to the authors' differences in definitions and terminology, whereas the content is largely the same. What various publications dealing with the subject all have in common is that they fall under the umbrella of what is usually called technology management or technology intelligence. Among these terms are technology forecasting, technology scanning and technology monitoring or scouting, which are the concepts most relevant to this thesis. In simple terms, these processes serve the same purpose, to gather information on process technology that can benefit the company's overall competitiveness. Some of the concepts also contain theory on how to absorb this information efficiently into the organization. However, how to absorb the information is outside of the scope of this report, rather the focus is on how to obtain it. The differences between the technology management methods are of two dimensions: the scope of the search (how specified the search is in terms of what type of technology is being sought after) and whether or not it is of predictive nature or simply a matter of investigating what existing technologies are out there.

2.1.1 The importance of technology management

In his article "managing manufacturing process innovation", Schrettle (2013) says that many studies have been made, stressing the positive impacts of new process technologies. However, there is little information "available regarding how companies gather relevant information about new manufacturing technologies and trends" (Schrettle, 2013, p. 65). It is important to notice, according to Schrettle (2013), that new manufacturing technologies don't necessarily create advantages per se, but rather opportunities. In order to be able to take those opportunities and turn them into competitive advantages, adequate identification of relevant technologies is required (Schrettle, 2013). Having superior manufacturing competence is, according to Schrettle (2013) considered to be a central part of having a competitive advantage on the market. In today's ever-changing technological world, rapid changes and fast shifting customer needs forces companies to stay on top of their technological advancements. Schrettle (2013) argues that systematic technology scanning plays a crucial role when identifying new technology.

2.1.2 Technology forecasting, scouting and scanning techniques

According to Quinn (1967), technology forecasting is the process of evaluating the significance of possible future technological developments and the impact they might have on a company. That way, managers can make the right decisions on whether or not to adapt certain technologies. Quinn (1967) further states that technological forecasts are similar to other forecasts like economic-, market- and financial forecasts in the sense that the predictions are not exact, rather they reflect an idea of what can be expected in terms of future technological capabilities. Quinn (1967) also states that similarly to all other forecasting methodologies, careful analysis and observations of trends and collected data lay as a basis for technological forecasting. This means that it is, just like any other forecasts, subject to "data errors and natural limitations of its human interpreters" (Quinn, 1967).

Quinn (1967) presents some widespread technological forecasting techniques and how the information they produce influence management decisions. Perhaps the most relevant of these techniques is the *demand assessment*. Recent studies have shown that "clearly perceived demand tends to be the primary force stimulating technological change" (Quinn, 1967). Technology is actually only utilized if it responds to a need, and generally developers of new technology tend to want to create technologies that are utilized. Consequently, identifying a need of a technological solution for a problem gives a good indication of where technology will advance.

Schuh et al. (2016) says that companies are facing challenges with identifying disruptive technologies. New technology trends are both great opportunities but also threats to a company's business model, as it is hard to foresee the long and short-term impacts that the technology will have (Schuh et al., 2016). According to Schuh et al. (2016) one way to go about identifying new technologies is with technology scanning. This deals with technologies from outside the company's context that turns out to be relevant to the company. Technology scanning deals with trends and signals within certain research fields that may be of interest to implement in the company (Schuh et al., 2016). Furthermore, technology scanning is, according to Schuh et al. (2016, p. 891) future-oriented and can therefore be "classified to be part of the strategic foresight functions of a company", thereby making it quite similar to technology forecasting as described by Quinn (1967), at least in terms of its purpose.

Schuh et al. (2016, p. 901) state that “as technology scanning delivers information on subjects outside the scope of the organization, it can only rely on openly available information or on information coming from a network of experts”. The reason for this is “as the organization by definition lacks competences in the analyzed fields, otherwise this would be a task for technology monitoring or scouting” (Schuh et al., 2016, p. 901). In other words, Schuh et al. (2016) view technology scanning as undirected search for technology, i.e. outside of the scientific field of the company in question. The important message here is to rely on external expertise when scanning for technologies in a broad scientific scope, as to make sure the assessment of it is done effectively. Schuh et al. (2016, p. 902) also state that “studies show that in order to get timely information on relevant signals and trends involvement of employees and bottom-up input collection channels are success factors.

Brenner (1996, p. 20) states that “superior technology is often a source of considerable competitive advantage, making intelligence about competitive technologies essential”. He goes on to say that “understanding a competitor’s product quality, environmental concerns, or process flexibility to produce a variety of performance grades can lead to opportunities for creating advantages in the marketplace” (Brenner, 1996, p. 20). Thus, explaining the importance of effective technology intelligence. Brenner's (1996) primary focus is on technology scouting, which he describes, similarly to Schrettle (2013) and Schuh et al. (2016), as consisting of interpreting external signals of technology development. Brenner (1996) describes three levels of signals to be aware of, and through what sources they might appear. The first, and weakest signals appear in “grey literature” or in technical discussions etc. These signals can be difficult to relate to concrete consequences in technological development but is according to Brenner (1996) important to gather and assess. The second type of signal includes scientific publications and occurs, according to Brenner (1996), after the first signal. The third and strongest signals occur when the technology is fully developed, and typically comes from product announcements or product sales (in the context of this report: from process technology suppliers). This type of signal is what might be regarded as being the result of scanning for *existing* technologies at competitors, suppliers or in patents etc.

Brenner (1996, p. 25) puts emphasis on adopting technologies in its early stages of development, stating that “we have all watched the development of a new technology and not taken action until it was fully commercial, severely affecting profits”.

2.2 Evaluation theory

Evaluating process technology effectively is a prerequisite for making strategically sound decisions regarding what technologies to implement (Dengler et al., 2017). With today’s rate of technological change, this statement has never been more true (Kurzweil, 2005). Failing to react to changes in technology development can mean having a less efficient production system, and thus a less competitive company. Knowing the manufacturing capabilities of a production system as well as the performance of potential substituting technologies enables making incremental improvements to a production system when opportunities arise. However, there are a lot of aspects to consider when evaluating process technology and failing to account for those can result in the company ending up in a worse situation than the previous one.

2.2.1 Important technological dimensions to consider during evaluation

Starting from the beginning, Peters (2015) emphasizes the importance of assessing the readiness level of new process technologies for industrial decision making. Peters (2015) presents an assessment model for determining the readiness of a specific technology based on two main criteria: Quality/stability and flexibility. The quality aspect relates to how stable the process of the new technology is, i.e. can it reliably and consistently achieve the required result. The flexibility aspect refers to the technology's flexibility in terms of production volume, variants, product modification and routes.

Building on the theory of readiness level, there is the aspect of when to acquire a new process technology. Given that the stability and flexibility of a new process technology, as described by Peters (2015), are adequate, the next question becomes whether or not it is a good investment from a financial and competitive point of view. Lumen Learnings describes four phases of the technological life cycle that all new technology go through. These are, in chronological order, the *research and development phase*, the *ascent phase*, the *maturity phase* and the *decline phase* (see Figure 1 The technology life cycle path). Assessing in which of these phases a certain technology is can determine whether or not an acquisition is a good idea (Lumen Learnings). For instance, in the research and development phase, the risk associated with acquiring a technology may be substantial, as the technology is not yet proven to be effective. However, it may offer a considerable competitive advantage against competitors whose process technology might be of inferior sophistication. The ascent phase seems to be the sweet spot for technology acquisition as it offers both a competitive advantage and that "out-of-pocket costs are fully recovered". At the same time, in this phase, technologies are generally more reliable. The maturity phase is a safe bet in terms of effective technology, but doesn't offer much in terms of competitive advantage as most competitors likely use the same or better technology already. Needless to say, acquiring process technology in the decline phase is not a competitive technology management strategy.

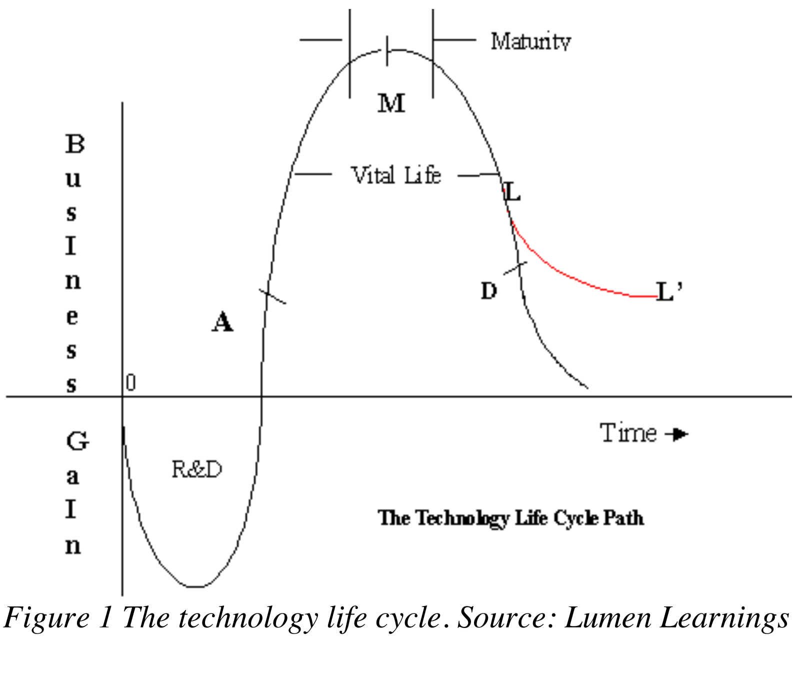

Figure 1 The technology life cycle. Source: Lumen Learnings

2.2.2 Evaluation methods

Having dealt with aspects that more or less just qualifies a process technology for consideration, i.e. assessing the readiness level etc., the logical next step is a more hands on technology evaluation method. Dengler et al. (2017) have developed a methodology for evaluating production technology in the context of the production cycle, i.e. from *ramp up*, to *high volume production*, to *low volume production*, to *removal*. Dengler et al. (2017) states that effective technology management is necessary in the continuously changing technology environment. “A proactive technology management approach is characterized by continuously assessing established production technologies as well as identifying, evaluating and acquiring alternatives and capabilities in advance of needs”. Dengler et al. (2017) lists what have been some of the most commonly used criteria for evaluating production technology during the past decades and pick those they consider to be most important for evaluating production technology. These criteria are cost, quality, volume flexibility, sustainability, product feasibility, dependability and interconnectivity. Technologies are given a grade, either “requirement exceeded”, “requirement fulfilled” or “requirement not fulfilled”, in each criterion and in each phase of the production cycle. The result is then illustrated graphically in order to analyze of how the technology performs as well as facilitating comparisons between different technologies.

Apart from Dengler's et al. (2017) method for evaluating and comparing process technologies, no additional methods specifically aimed at addressing process technologies were found. However, there are plenty of more generic methods for evaluating and selecting an option out of an option set. The thesis is not primarily concerned with determining what the best methods for different process steps within the standard are, but rather to create a structure of what type of methods it should contain and how best to sequence those. Therefore, one of the most commonly used methods for making engineering decisions, the Pugh matrix, will serve as a representative for these decision-making methods and no additional similar methods will be reviewed.

The Pugh matrix, also known as a decision matrix, was created by Stuart Pugh in 1981. The matrix is a qualitative method for ranking different options in an option set and is mostly used for design decisions in engineering. However, the method is applicable in any decision area where a systematic approach to discern among options is needed. There are many variations of the method but the general idea is to select important criteria and to compare the different options in relation to how they perform in those areas. Examples could be cost, esthetics, simplicity and so on, it really depends on the situation.

The comparison is an iterative process were the different options each acts as reference for the other options one time. For every iteration, the objective is to determine whether or not the options perform better, equal or worse than the reference option. In the case the option performs better than the reference option in a criterion it is given a “+”, equal a “0” and worse a “-”. After assessing the performance for each of the criteria, the score is summarized. A positive score means that it is overall better than the reference and a negative means is worse. Having done all iterations, the result should start to converge towards the option that performs best overall.

In case there is considerable difference in terms of the relative importance of the criteria, weighting can be introduced. In that case the result of the comparison, i.e. “+”, “-” or “0”, is multiplied with a number corresponding to the importance of the criteria, where the higher the number the higher the importance. Figure 2 Example of a Pugh matrix, illustrates how a Pugh matrix can be used for comparing options in different criteria.

Criteria	Weight	Option 1 (reference)	Option 2	Option 3
A	1	0	+	0
B	3	0	+	-
C	2	0	-	+
	SCORE	0	2	-1

Figure 2 Example of a Pugh matrix.

2.3 Implementation theory

Although having structured methods for identifying and evaluating new technologies is very important, not being able to effectively and efficiently implement those technologies into the production system means all that hard work was for nothing.

2.3.1 Important considerations for technology implementation

Being aware of to what extent the current situation has to change in order for the new technology to be successfully integrated is a good start to any implementation. Leonard (2014) describes different types of implementation situations based on two dimensions: source of technology (whether or not the technology is developed in-house or acquired "off-the-shelf") and technology fit (how well the technology fits into the existing production system; how much change is needed). The following theory presented by Leonard (2014) relates to the situation where the technology is acquired from an external source and requires substantial change of the existing production system. First, the authors states that uncertainty, defined as "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization", can be reduced by making sure that knowledge gained from previous implementations is used in each succeeding one. Reducing the uncertainty makes for smoother implementations. Second, Leonard (2014) states that according to their research, the use of local user-experts (a designated person whose task it is to "teach" the new behavior) has made for the most successful implementation sites. Third, they state the pioneering sites, i.e. the first site out in a multiple site implementation project, should be selected on the merits of representativeness rather than reasons such as receptivity or special needs. This makes the knowledge gained from the implementation at the pioneering site as relevant as possible for the succeeding ones, as similar effects can be expected also there.

2.3.2 Psychosocial aspects of technology implementation

Jones (2017) proposes a team and teamwork-oriented approach towards implementation of new technology. Jones (2017) uses the balance theory as presented by M. J. Smith and P. Carayon-Sainfort in 1989 as an underlying theoretical framework for describing what factors are involved in technology implementation. These factors are new technology characteristics, organization structure, task factors, environmental characteristics, and the individual human factors involved. Jones (2017) stresses the psychosocial aspects of an implementation process as the most important. He states that "it is recommended to utilize a cooperative team-oriented approach to new technology implementation, which relies heavily on obtaining employee inputs and participation throughout the entire process" (Jones, 2017, p. 3). Moreover, Jones (2017) says that employee participation during implementations raises motivation and increases acceptance of the future technology. Laumer et al. (2016) adds to this, stating that the perception of future work routines has an even a greater impact than perception of the new technology itself. In other words, it's important not only to create a positive perception of the new technology, but also of how the future work routines will look like.

Kotter (2017) presents an eight-step model that is highly relevant in terms of the psychosocial aspect of technology implementation. The model is intended for extensive organizational transformations, rather than small to medium size changes in production systems. Even so, some of its aspects are still relevant within the scope of this thesis, namely its first four steps. The first step is to create a sense of urgency for change, communicating the relevance of the change either by describing its potential benefits or by showing that the current order of things is unsustainable. The second step consists of creating a powerful change coalition, i.e. a group of people responsible for advocating for the change and carrying it through. The third and fourth step is to create and communicate a clear and concise vision for the change.

2.4 Answer to research question 2

The division of the literature review into searching for methods for the different subprocesses separately resulted in finding quite a large body of literature. However, some aspects were covered more than others. Beginning with the topic of identifying new process technology, the focus in literature is almost exclusively on predicting emerging technologies. A number of different methods are presented for doing this. Quinn (1967) suggests that one of the most powerful methods for predicting technological advancement is by assessing demand. Although the logic of this reasoning is sound, getting an accurate assessment of what type of technology actually is in demand can be challenging. However, when there is a proven demand for a not yet existing technology, that information should be taken into account when making decisions regarding acquiring new process technology. Demand assessment can arguably be regarded as a first line of defense towards making untimely process technology acquisitions and should therefore be a part of a manufacturing company's technology management arsenal. Another perhaps more concrete method is Brenner's (1996) interpretation of external signals. This method provides a more hands on approach for staying on top of emerging technologies, as he presents what specific sources (including academic literature, patents, sales statistics etc.) to review in order to collect valuable information. This method, coupled with Schuh's et al. (2016) suggestion of having a broad search for technologies also outside of the company's immediate scientific field, might be regarded as the second line of defense.

Very rarely emphasis is put on methods for identify *existing* technologies. The only real example of such a method that was found during the literature review was in Brenner's (1996) method of interpreting external signals, where the third and final signal he presents relates to product announcement and product sales, which in most cases at least should concern existing technologies.

Regarding the topic of evaluating process technology, a number of important aspects to consider are brought forward in literature. Technology readiness level as presented by Peters (2015) is one such aspect. When, during the technology's life cycle, to acquire the technology is another (Lumen Learnings). Lastly, Dengler et al. (2017) presents some of the most commonly used, and arguably most important, evaluation criteria to consider when evaluating process technologies.

As for methods related to actually performing the evaluation, the literature is scarce. Dengler et al. (2017) presents one method, which similarly to the decision matrix (Pugh matrix), is based on making comparisons between different process technologies rather than objectively evaluating them. This does present an issue in those instances when the "new" technology is not replacing an "old" technology. However, as the scope of this thesis concerns the topic of continually improving production systems, the majority of the situations will revolve around replacing or improving an already existing function within the production system. Thus, an evaluation method based on comparisons should be sufficient.

Literature on the implementation aspect of approaching new process technology mostly consists of communicational aspects and how to manage the information flow. Leonard (2014) emphasizes the importance of learning from mistakes and to continually improve the implementation process. He also states that user experts (also referred to as key persons or change owners) have a positive effect on the implementation process, something that is closely related to Kotter's (2017) second step; creating a powerful change coalition. Furthermore, informing all stakeholder about the change, why it's necessary, its benefits and how operators' work routines will change as a result of it, are aspects that are heavily emphasized in literature (Kotter, 2017; Jones, 2017; Laumer et al., 2016).

Apart from this, Leonard (2014) also discusses technology fit, i.e. assessing how the surrounding production system has to change to accommodate for the new technology, and presents an appropriate strategy for selecting a pioneering sites (also referred to as pilot areas).

To conclude, academic literature contains a considerable amount of methods and other important aspects to consider when approaching new production technologies and provides a good starting point for achieving the purpose of this thesis. However, some areas are lacking and additional research is likely needed in order to enable synthesizing a complete approach towards new production technologies.

3 Method

This chapter presents the method of how the research was conducted. It includes the research framework, literature study, research strategy, data collection, data analysis and a description of how the standard was created. Following these sections, the methods are discussed.

3.1 Research framework

The thesis can be categorized as applied research, meaning that it aims to solve a specific problem rather than produce universal scientific principles. However, the finished product, i.e. a standard for approaching new production technologies at Volvo Trucks, is created with the aim of containing all important aspects of approaching new process technologies and should be applicable in other similar manufacturing companies. In other words, the external validity in regards to applying the standard outside of Volvo Trucks can be considered reasonably high (Voss et al., 2002).

The nature of the research is mostly exploratory, aiming to uncover, through observation and interviews, what Volvo Trucks' procedure for approaching new production technologies consists of. However, in order to create a new procedure for approaching new production technologies some conclusions regarding *how* and *why* certain things are as they are must be drawn. Consequently, some measure of descriptive and explanatory research is also necessary.

The research approach can be categorized as inductive, as the main objective is to collect qualitative data and use that to create applicable theory for Volvo Trucks. However, in order to be able to collect and analyze the data adequately, a theoretical framework of established theories related to the topic was used. These theories were studied prior to, and meanwhile, the data collection and analysis were performed. The methods used for collecting data were exclusively qualitative as that best suits an inductive research approach (Bryman and Bell, 2011). Semi- and unstructured interviews together with informal conversation and Gemba walks were used to triangulate the information to the extent it was possible, increasing the construct validity of the research. Construct validity refers to how effective the research framework is at actually researching what it is intended to research (Voss et al., 2002).

3.2 Literature Study

After the research questions were defined, the next step in the project was to search for existing literature on the topic of technology management. This is, according to Bryman and Bell (2011) a necessary step as it provides the basis for answering the research questions and creating the research design. The literature study was divided into three topics; how to identify, evaluate and implement production technologies. With this division, it was easier to search for and find relevant sources within each subtopic. Web-based search engines were used to find literature on the topics. To get as reliable sources as possible each piece of literature found was evaluated based on author, number of citations, publication site and publishing year (Bryman and Bell, 2011). The following search engines were used: Scopus, IEEE, Google Scholar, Science Direct and Chalmers Library. The following are examples of search strings that were used to find literature within the project's scope: "identifying new technology", "evaluating new technology", implementing new technology", "new production technology", "change management" "disruptive technologies" and "emerging technologies". The abstract of each piece of literature found was screened for relevance based on the scope of the thesis and the decision on whether or not to include the source in the study was made. A comprehensive list of all sources was created and each source was carefully read and summarized. In order to get a holistic view on the entire body of literature, the relationship between the articles and how their contents relate to each other was also studied. This was done by searching for similarities and differences in the theories.

3.3 Research Strategy: Case research

The research strategy selected for the thesis was case research. According to Voss et al. (2002), case research can lead to new insights and ideas and is suitable for developing new theory. Case research allows for questions such as "why, what and how together with a relatively full understanding of the nature and complexity" of the entire situation (Voss et al., 2002, p. 197). Furthermore, Voss et al. (2002) states that case research enables early exploratory investigations with a starting point of limited understanding of the phenomena. And since these particular circumstances matches those of this project and the aim of the thesis is to create new theory in the form of a standard for how Volvo Trucks approach new production technology, case research was considered the most relevant research strategy.

Voss et al. (2002) presents two types of case research designs, single- and multiple case study. Single case studies have limitations in terms of generalizability of the drawn conclusions, i.e. the conclusions and resulting theory might not be applicable elsewhere than in the context of the studied case, thus reducing the external validity. Furthermore, there is a risk of misjudging a single event and the available data (Voss et al., 2002). This risk applies to all case research but is somewhat mitigated when comparing data and events across multiple cases. The upside of a single case study is the level of detail and depth that can be achieved by only focusing on one case. Doing a multiple case study allows for more generalized conclusions and since generalizability is of higher importance than case depth in this project, due to the general nature of RQ1 and RQ2, a multiple case study was deemed most suitable for the thesis (Voss et al., 2002). Throughout the project, ideas and impressions were documented as they appeared. This ensured that no ideas got lost during the project (Voss et al., 2002).

3.3.1 Case criteria

Firstly, boundaries defining what type of projects would be considered cases were set. Cases were defined as projects where Volvo Trucks replaced or added a new process technology to their production system (see 1.4 Scope and delimitations for definition on "new process technology").

In terms of what criteria the cases needed to fulfill to be regarded as relevant, they had to be within the scope of production technologies and cover the entire process from identification to implementation. In order for that to be possible within timeframe of the thesis, only retrospective cases were considered. Studying cases where only part of the process had been performed would have made the analysis harder as the outcome would not yet be definite. According to Voss et al. (2002), studying retrospective cases allows for reflection on whether the process was a success or failure, which is important in creating new theory. Another criterion was that the cases preferably needed to be relatively recent in terms of time frame. The reason for this was that it would be easier to get valid data from respondents, due to less post-rationalization and higher recollection clarity (Voss et al., 2002). Another important reason was that it to some degree ensured that the studied cases were representative of Volvo's *current* approach to new production technologies.

Case selection criteria:

- Within the scope of process technology
- Retrospective cases where the entire process had been performed
- Relatively recent in terms of time frame

3.3.2 Finding and selecting cases

When getting started with the case research, a senior employee within the company was used to get in contact with principle informants for potential cases. A Principle informant is according to Voss et al. (2002) the person that is best informed about the data being researched.

The principle informants for each case were contacted and unstructured interviews were conducted in order to get basic information about the respective cases. During these interviews, the relevance of the case in question was assessed based on the criteria presented above. If the case was selected to be part of the study, the principle informant was then asked to suggest employees to be interviewed, to gather the data needed for each case. As the principle informant had worked with the case closely, it was considered that he/she had the best and most valid suggestions on who to contact for data gathering. It was communicated to the principle informant that the goal of the interviews was to get an objective view of the cases, and that preferably all relevant stakeholders (such as operators, managers etc.) should be included in the study.

There was also the issue of how *many* cases to study. According to Bryman and Bell (2011), in the situation in which the case population to be studied is homogenous, as within one single company, the sample size can remain quite small. In this thesis, a sample size of four cases was chosen as that was considered enough to achieve sufficient generalizability, external validity within Volvo Trucks, to enable answering RQ1 (Voss et al. 2002). Having said that, if convergence of the results did not appear during the analysis, additional cases would have been added. During the selection process, a literal replication technique was applied (Voss et al. 2002). Meaning that although all cases needed to fulfill the same basic criteria, the process technology for the respective cases had to be different, i.e. the varying variable. This was done in order to get width in the research, increasing the generalizability of the conclusions and ensuring that the findings were relevant for a broad scope of process technologies. The selected cases ranged from concerning software programs for line balancing, 3D printing, digital work instructions and electric screwdrivers.

3.3.3 Data collection

The primary source of data for the case study was semi-structured interviews. In accordance with the theory presented by Voss et al. (2002) on research instruments and protocols, these were also backed up with unstructured interviews and interactions. To further strengthen the information gathered, Gemba walks were done in order to go and see what and where each of the cases took place. These functioned as a form of direct observation in terms of data collection. To assure the internal validity and reliability of the case research, a well-designed and detailed research protocol was created (see Appendix A and Appendix B) (Voss et al., 2002). Internal validity refers to how well causal relationship between different events can be proven. In this thesis, all causal relationships have been described and explained by the interviewees themselves and the information is regarded as being of relatively high validity. The reliability of research refers to if the research can be repeated again with the same result. Although the research framework is very detailed and structured and therefore easily repeated, the method of gathering data with interviews is inherently unreliable as there is no way of assuring that an interviewee will give the same answer twice. However, since multiple interviews were conducted for each case that was to some extent mitigated (Voss et al., 2002). The core of the research protocol consisted of a set of questions to be answered by the interviewees. The questions were created with the aim of answering RQ1; "How do Volvo Trucks identify, evaluate and implement new production technologies in the production system?" and to provide input to RQ3**;** "What can an effective standard for identifying, evaluating and implementing new production technologies in Volvo Trucks' production system look like?". However, the questions were not formulated to address all of the specific aspects found in literature, but rather to get a general idea for how the three subprocesses had been performed. For that reason, the questions were kept quite generic. This was done to generate the interviewees' own explanations of how the processes had been performed instead of getting "yes"- or "no"-answers relating to if they had used specific methods or not. The interview questions were divided into three categories corresponding to the subprocesses previously mentioned (identify, evaluate and implement).

In line with Voss et al. (2002) recommendations, prior to starting the interview round, a pilot interview was conducted to assure that the questions in the interview protocol were clear and that the questions were interpreted as intended. Adjustments to the interview protocol were made according to the pilot respondent's suggestions. Prior to conducting each interview, the interviewee was provided with the questions along with a short presentation of the project's aim. This was done to provide context and to convey the purpose of the interview. The respondents also received a short case description of the specific case the interview concerned, as to ensure that they were well understood with the topic of the interview. Providing this information beforehand allowed the interviewees to prepare and think about the subject prior to the actual interview, which is beneficial for data validity (Voss et al., 2002).

It was decided to ask all questions to all interviewees, regardless of their position within the company. The reason was to facilitate the subsequent analysis and to increase the reliability of the research, as the issue of determining who would receive what questions was eliminated. Presuming to know what knowledge as certain respondent has on the basis of their position introduces researcher bias and reduces reliability (Voss et al., 2002). Instead, in the case a respondent could not answer a certain question, the lack of an answer was documented and regarded as potentially valuable information to consider during the analysis, i.e. what people were kept in the loop during the case.

As the interview questions covered all relevant aspects of the three subprocesses, it was assumed that no one respondent could give thorough answers to all questions. However, they main goal was to at least get input on all questions.

3.3.4 Conducting interviews

With the research protocols as a basis, semi-structured interviews were performed with the chosen interviewees for each case. Semi-structured interviews were chosen as it allows for more flexibility than structured interviews, both in terms of the questions asked and the answers the interviewee give (Bryman and Bell, 2011, p. 467). The interviews were conducted with two investigators, which according to Voss et al. (2002) allows for a great creative potential. Convergence in understanding between the investigators also increases confidence in the findings, i.e. inter-rater reliability (Voss et al., 2002). During the interviews, one investigator took notes while the other conducted the interview. This allowed for effectiveness as thorough notes were taken as the interview proceeded. In addition, the interviews were recorded to enable listening to the interviews again for clarification purposes. However, the recordings were not transcribed, as the exact phrasing of the answers was not in focus. Immediately after the interview, the answers were summarized and what was considered the most relevant information was documented. This can be regarded as coding and the first part of the analysis, as the investigators actively had to determine what was valuable input and what wasn't. One important aspect when coding the data is to do it as soon as possible after the interview (Bryman and Bell, 2011).

After conducting all interviews in each case, a summary in flow-text form was written. The summary was sent back to each respondent within each of the cases. This allowed for getting feedback to ensure that the investigators' understanding were accurate (Voss et al., 2002). After having received feedback and adjusted the case descriptions accordingly, the collected data was considered valid.

3.3.5 Analysis

The analysis of the data was performed in two steps, within-case analysis and cross-case analysis. The general idea of the within-case analysis was to get a clear view of the events that took place and to demonstrate causality among them. This was done by referencing the literature and by considering the interviewees' own explanations. The cross-case analysis was performed in order to identify what similarities and differences existed among the different cases. The main goal of the cross-case analysis was to get a general idea of Volvo's current approach to new process technology, thus answering RQ1.

Within-case analysis

The coded and summarized interview responses were structured in arrays, displaying the answers from each interviewee for each question. Coding is an effective way to structure and analyze answers from a qualitative study (Bryman and Bell, 2011). According to Voss et al. (2002) this method allows for easy visualization of answers and detecting possible patterns. The next step was to analyze the patterns of the data collected within the cases, i.e. the exploratory part of understanding what events took place during each of the cases (Voss et al., 2002). In order to understand the patterns, references from literature along with the interviewees own explanations were used to prove causality of events. The within-case analysis also provided depth in the understanding of the cases independently, which is crucial in order to be able to do the cross-case analysis successfully (Voss et al., 2002). The focus of the within-case analysis was also to determine what worked and what didn't work during each of the cases, providing input towards the future standard.

Cross-case analysis

The main purpose of the cross-case analysis was to answer RQ1. In other words, to compare the events of a variety of cases within Volvo Trucks, to determine how they typically approach new process technology and whether or not they seem to have a standardized approach. Another important aspect of the cross-case analysis was to see if similar patterns of causalities emerged in the different cases. Identifying similar successes or failures in more than one of the cases helps to prove the causality of those events (internal validity), further substantiating the recommendations of the standard and increasing the construct validity of the research (Voss et al., 2002).

The cross-case analysis followed a similar methodology to the within-case analysis. However, instead of having all interviewee answers in the arrays, summaries of the answers for each case were compared for each question.

3.4 Creating the standard

Since creating a standard for how Volvo Trucks should approach new production technologies is the main objective of this project, the reasoning behind the choices of what to include in the standard was of paramount importance. The content of the standard was based on input from three sources. Firstly, academic literature, which throughout the creation of the standard stood highest in hierarchy in terms of input value. The second most important source was the findings from the analysis and input from employees at Volvo Trucks (see Appendix B). Tertiary in the input hierarchy, came the authors' own ideas.

Similarly to the data collection and to a large degree also the analysis, the standard was divided into the three subprocesses. Methods, recommendations and ideas were listed for each of the process categories and coded according to its respective source ("LIT" for literature, "VT" for Volvo employee input and "A" for authors' ideas). After the coding it became evident what inputs were most important to include in the standard. Inputs that were coded as having support from both Volvo Trucks and literature were regarded as top priority, and the rest followed the hierarchy presented above. Having decided on what inputs to include in the standard, a creative process of structuring each of the subprocesses began. In other words, the different methods and ideas were stringed together into a coherent process.

3.5 Method discussion

As stated above, the objective with the interviews was to interview representatives from all relevant stakeholders. However, this was not always possible due to non-responses (Bryman and Bell, 2011). The non-response persons contacted did not want to cooperate or could for some reason not provide the data required. Considering this aspect, the result was that at least two respondents with different positions were interviewed for each of the cases. Having more than one position interviewed for each case gave the data some width as the interviewees had experienced the cases from different points of view. Whereas the managers were more involved in the *identifying* and *evaluating* phase, assembly workers played a greater role in the *implementation* phase. Interviewing employees of different background and positions within the company also exposed some discrepancies of how each of the phases within the cases had been performed. Having several different perspectives on how Volvo Trucks is working today was considered enough to be able to answer RQ1 and get some input on how the different positions would like it to be done in the future (RQ3).

As mentioned previously, only retrospective cases were selected, as the ambition was to study Volvo's approach to new process technology from start to finish. Another way of achieving this would have been by performing longitudinal case research, i.e. studying a process as it occurs. Studying a case as it occurs mitigates the effect of data distortion in form of post-rationalization of interview respondents (Voss et al., 2002). However, longitudinal case research is far too time consuming for the project timeframe. Also, the amount of longitudinal cases needed for creating an adequate multiple case study is unlikely to be found at one company in the same timeframe.

One negative aspect of only studying retrospective cases (that covered the entire *approach*) is that it to some extent excludes cases that would be considered failures. In other words, cases that for some reason were terminated before they were finished. Information about such cases could have provided additional valuable input to the standard. However, getting in depth understanding of a larger sample of cases for only partial information would have been too labor intensive. Furthermore, acquiring information on failed cases might have been challenging, as that type of information arguably would have been considered more sensitive by Volvo employees.

4 Findings and within-case analysis

In the following sections, each of the cases that were studied will be presented, in no particular order. First, a short description of the case is given, which is followed up by more detailed texts for each of the three subprocesses. These texts represents the data gathered from the interviewees and the authors general impressions gathered from Gemba walks and informal conversations. The intention was to present that data as objectively as possible. Following the sections on each of the subprocesses is the analysis, which is presented case by case. The analysis contains the authors' own thoughts, the interviewees' thoughts and relevant aspects from literature. In some instances, recommendations for how to improve certain aspects are presented. However, the recommendations will be covered in more detail in chapter 5. Proposed standard. Lastly, the findings from the cross-case analysis are presented.

4.1 3D Printer

In the past, Volvo Trucks have manufactured fixtures and other small components using milling. A lot of times, these components have been ordered from outside of the company. This resulted in long lead times and high costs, which were the underlying reasons for considering buying a FDM 3D printer. The initial initiative for obtaining a printer came in 2015 from individuals at Volvo who had personal experience with the technology. However, the machine wasn't installed and ready for use until 2017. Since then, the machine has pretty much been used to its full capacity and the weight of printed components amounted to 150 kg in the first year.

4.1.1 Identify - 3D Printer

There were no outspoken issues with the previous process (ordering milled parts from third party suppliers) that initiated the search for a technology to replace it. Rather, the 3D printer purchase was a result of Volvo's strive for continuous improvement and being at the forefront in process technology. However, the technology was not found as a part of an organized and standardized search for new process technology at Volvo Trucks. Rather, the initiative came from Volvo employees that were enthusiastic about 3D printing and had experience with it in their personal life. The potential for improvements, both in terms of cost and component lead time, by investing in this technology was apparent for these individuals and brought forward to the company. Different 3D printing techniques were considered, but only one, FDM, fulfilled the conditions of being both operational around the clock and intuitive.

4.1.2 Evaluate - 3D Printer

No particular standard or guidelines were followed when evaluating the 3D printing technology. Moreover, no concrete evaluation procedure was performed except for a business case comparing it to the previous process of ordering components from third party suppliers. To some extent the technology was already considered to be "evaluated", namely by the individuals who had previous experience with it. When determining what actual 3D printer to purchase, components printed with the printer of interest were ordered from outside of the company to ensure that component quality was satisfactory. All the *obvious* stakeholders were consulted as a part of the evaluation, namely the initiators themselves. However, the operators that would use the printed components were not consulted. The reasoning behind this was that from an operator perspective it doesn't matter were the components come from as long as they are of the same or better quality than before.

4.1.3 Implement - 3D Printer

The implementation process more or less only consisted of installing the machine and starting to print what would otherwise be ordered. No particular standard or guidelines were used to guide the implementation. The reasoning behind this was that since the number of people affected by the change were so few, there was no need to follow any standardized implementation process from an organizational perspective, as would have been the case in a bigger change. Furthermore, in case things didn't function smoothly, there was always the option of ordering milled parts, same as before. The only people involved in the implementation process were the initiators.

The immediate effects of the implementation were decreased lead time, component weight and cost and increased creativity and flexibility in prototype (component) design. One effect of the change that was not expected was how the tool designers' work routine had to change as a result of the new type of models/drawings that was needed for the 3D-printer. Another aspect that wasn't taken into account before acquiring the machine was the amount of reconstruction that was needed to the room that would house the 3D-printer, making the cost of the implementation higher than expected. This cost wasn't accounted for in the initial business case. Also, the high demand for printed parts from "customers" in-house, was underestimated and resulted in a shortage of printing material.

All in all, the implementation was considered to be successful according to the respondents and they mentioned a few aspects as the reason for this. Firstly, the fact that Volvo Trucks did not cheap out on the machine and bought a relatively expensive one was a factor that facilitated the subsequent implementation process and for future service. Another aspect that was mentioned as an important factor for the success was that there was an engaged and knowledgeable "change person" involved from start to finish.

4.1.4 Analysis - 3D printer

Having driven employees that spontaneously take initiative for how to improve the production system with new technologies can be very beneficial, as has become evident in this case. Not only are these employees many times the people who best know the ins and outs of the current process, but they are also very suitable for taking on the roll as a change owner as they have personal connection to the change (Leonard, 2014). However, relying on employee initiative requires having driven employees, often with an interest in what could be considered relevant technology in their personal life, and that might not always be the case. Having a systematic, standardized and, in the work description, integrated approach for identifying possible technological upgrades will make sure these types of initiative are made regardless of the *hiring process* "succeeding" or not. Of course, a combination of both is preferable. Also, having a clear sense of the shortcomings of the currently used technology was a prerequisite for finding relevant technologies to replace it. To clarify, in this case Volvo Trucks knew that the lead time and cost of the ordered components were high and therefore searched for technologies that could improve those metrics specifically.

During the evaluation phase, the strategy of ordering components printed by the same model machine that Volvo considered buying, was good way of ensuring its functionality without investing a significant amount of resources. Whenever such a strategy is possible Volvo Trucks should consider applying it. However, some aspects were not considered during the evaluation. Firstly, no operators were consulted, resulting in not taking into account potentially valuable input. As stated in 4.1.2 Evaluate - 3D Printer, the reasoning behind this was that it wouldn't matter for the operators where the components came from. However, that reasoning might be post-rationalization and operators may perhaps not have been considered at all during the evaluation process. Although operator consultation comes at an administrative cost, giving all stakeholders a chance to influence decisions like these, apart from with potentially valuable input, it can also create a positive company culture. Secondly, not considering the added installation cost of the reconstruction needed for the printer room could in different circumstances have meant making an unprofitable investment. Taking all relevant aspects into consideration when evaluating the technology is thus very important. Considering what possible cascade effects that can be expected is especially important. This also became evident is during the implementation phase were the adjustments needed to the tool designers' work procedure came as a surprise and caused some confusion.

Having the opportunity to "go back" to the previous technology (ordering milled components) during the initial phase of the implementation in case things didn't work out can be considered a good safety measure. Such a strategy can smoothen the bumps during implementation of new technology and should be applied if possible. Lastly, not trying to save money in the short term by purchasing one of the cheapest printer options likely saved money in the long run.

4.2 Paperless Cabtrim

The Cabtrim stations, where the cab assembled, have previously worked with paper to give the assemblers task instructions. Due to several reasons such as cost, environment and lead time they have considered to eliminate the papers completely at the stations. Another contributing factor, and what made the transition even more urgent, was that the leasing contract of printers was coming to an end. Digital displays have now replaced the paper instructions at some of the stations in cab trim. The long-term ambition is to make the entire factory paperless.

4.2.1 Identify - Paperless Cabtrim

Identifying the new technology was done without using any formal standard or guidelines. The reason for searching for new technology was that the contract on previously used printers was running out. Another reason was that Volvo Trucks want to stay on top of modern technology and want customers to see that they are a high-tech company. Furthermore, the environmental impact that printing paper has is far worse than working with digital screens. Printed work instructions are also unnecessarily costly.

The format of the work instructions was kept the same, i.e. presented in a text format. However, some rationalizations of the instructions were made prior to uploading it to digital form. This was done to make the instructions more user friendly and relevant for the operators. Finding what *hardware* to use to display the instruction became the primary objective of the project. When deciding which technology to implement, dialogue and communication with operators was key and the maturity level of the technology was one aspect that was considered important. When evaluating what technology to implement, tablets and screens were considered to be the only relevant options.

4.2.2 Evaluate - Paperless Cabtrim

Evaluating the new technology was done without following a formal evaluation standard. When looking at whether or not an evaluation of the technology was made prior to implementation, there are some disagreements among the respondents. While one manager stated that the technology was tested and evaluated with pilot tests, the others say that the technology was not evaluated other than with a business case.

While doing the evaluation, all stakeholders were informed and asked about their thoughts and ideas for the new technology. The communication and dialogue with the operators played a key role in this stage. The operators were even involved in making some decisions. The evaluation process considered two technology options, tablets and screens. Functionality and ergonomic evaluations were done for the two options, as well as economic calculations. However, tablets were never really an option as they would have changed the work process and the software Volvo already had did not support this.

4.2.3 Implement - Paperless Cabtrim

No standard or formal guidelines were used when implementing the screens in the production system. Implementing the screens required some pre-work and once that was done a "trial and error" mindset was applied. The system was implemented and questions or issues were dealt with as they arose. During the implementation process, both operators and employees in managerial positions had the power to influence how things were done.

During the implementation, the collaboration and communication between the different parties worked well. However, some people have expressed frustration regarding not getting the screens physically in place. There were many intermediators involved in this process, making it very slow. Furthermore, the information regarding *why* the change was done was perceived as vague by operators. Some of the operators experienced the change as difficult and the manager for these operators were responsible for addressing such concerns.

Looking at the effects of going paperless, cost and environmental impact are the most commonly mentioned. Less paperwork and maintenance of the printers are mentioned as some of the upsides of going paperless. One unexpected cascade effect of the transition was that the operators could no longer go back and look at previously built trucks in an easy way.

After the implementation, managers have been at the assembly stations to answer questions and concerns regarding the new technology. However, once all stations at Cabtrim have gone paperless, a workshop will be organized to go back and evaluate the entire implementation process and what can be done to improve in upcoming projects. So far, the change has been perceived as positive by the employees overall.

4.2.4 Analysis - Paperless Cabtrim

Analyzing the *paperless* case, it is evident that it was quite successful. When identifying what new technology to implement, Volvo chose to look within the company to see what types of technologies already existed. In this case, this was a good approach since the time frame for the project was quite short and it saved a lot of time as opposed to searching outside of the company for new technologies. However, it should be kept in mind that always utilizing such an approach can harm the possibilities of staying on top of new technologies. By not looking at other companies and suppliers one might run the risk of missing out on important new technologies that exist on the market (Brenner, 1996).

Throughout the process, communication and dialogue with all parties played a key role. This is an important aspect as it allows for everyone to be a part of the change and everyone can contribute with thoughts and ideas regarding the new technology (Kotter, 2017). It also makes the transformation process smoother, as assembly workers will know what and why the implementation is happening and that minimizes the risk of resistance. The only missing part in the communication was that the information on *why* the change was happening was not clear. This can potentially lead to assembly workers being negative about the change as they do not know why it is happening and why the new way of working is better than the previous one (Kotter, 2017). However, one risk of thoroughly involving everyone in a change is that it may turn out to be very time consuming. At one point, the project leader will have to make final decisions in order for the project to move forward.

No thorough evaluation was done before the screens were implemented as Volvo Trucks had previous experience with the technology. However, comparisons to the old technology were done prior to implementing it. This is an important aspect, as it must be assured that the new technology yields a return on investment and is profitable. The approach when implementing the screens was "trial and error". This is a quick way to implement new technologies and is effective if successful, as in this case. However, it should be noted that it can be risky to implement a new technology if there is lacking knowledge and understanding of how it works and how it will impact the rest of the production line.

Instead of removing the paper instructions and moving to screens over one day, it was decided to keep both technologies in parallel in the beginning to make sure everything worked as intended. This minimizes the risks of complications during the initial phase of the implementation and the assembly workers also get some time to adjust to the new way of working. One manager said that pilot testing was done prior to implementing the screens. In this case, the pilot area was not chosen on basis of being representative of the entire factory. Instead, it was chosen for convenience reasons (Leonard, 2014). One reason being receptivity, i.e. the operators at the station were young and most likely open to adopting the new technology. The second reason for choosing this station was *special needs;* the contract of the printers was running out and they had to be replaced by new technologies. According to Leonard (2014), it is not suggested to choose a pilot area on the basis of receptivity or special needs; rather the pilot area should be representable for the rest implementation areas. Such an approach ensures that the lessons that are learnt also are applicable in subsequent implementations.

4.3 AVIX - Line balancing

Volvo Trucks in Tuve has previously worked the program CSO to do line balancing in the factory. CSO produced reports showing the workloads of each truck and operator, both three weeks ahead and in a retrospective. It was not possible to get further details about the workload. With the introduction of AVIX, a more detailed analysis was available, both in retrospective and three weeks ahead. AVIX allows for easy simulations of different line balances and the effects before they are implemented in the production system. This was previously done with pen and paper by hand on a board.

4.3.1 Identify - AVIX

There is an ambition to continuously improve production efficiency at Volvo Trucks and having better line balancing was considered one way of achieving that. Attention was turned towards Volvo Group itself to find technology that could enable this. No particular standard or guidelines were used to perform the search, but Scania's performance in terms of balancing was used as a benchmark for the new technology. The most important aspect of the new technology, apart from it enabling better balancing and utilization of workers, was that it had to be compatible with the existing production system at Tuve. The only software that met that criterion was AVIX, hence it was the only technology that was considered relevant.

4.3.2 Evaluate - AVIX

AVIX had been evaluated within Volvo Group prior to the implementation at Tuve, so no factory specific evaluation before implementing it at Tuve was considered necessary. Apart from making sure AVIX was compatible with Tuve's current system, the only form of evaluation was brief testing and "playing around" with the software. Regarding the question on whether or not everybody was consulted for their opinions during the evaluation phase, there are mixed opinions. According to management, everybody had their say and were given information prior to the implementation. However, according to one operator, they were only notified when the implementation happened and had consequently no part in any evaluation process that occurred. In terms of comparing AVIX to the previous system, CSO, some metrics that were considered relevant were used to ensure that AVIX performed superiorly. Another aspect that was taken into consideration was that all the functions that had been previously available in CSO, was also available in AVIX.

4.3.3 Implement - AVIX

The implementation process followed the PSM standard (project structured management). This is more of a standard for how to execute projects, rather than a standard specifically aimed at implementation processes. As a first step of the implementation, both management and operators were trained in using AVIX. Everybody involved considered the training sessions very helpful and intelligible. The implementation started in a small pilot area and during this phase, important lessons for how to implement AVIX in the rest of the factory were learnt. This was done by establishing a change request list for the software and the implementation process. In other words, keeping track of issues that surfaced during the pilot implementation. Thanks to this, adjustments could be made making subsequent implementations run more smoothly. During the implementation, people that were knowledgeable about AVIX were present to help operators to adjust to the change. Of the stakeholders involved in the project, everybody except the operators had the chance to influence the implementation process, something that the operator respondent perceived as discouraging. The operator respondent would have preferred if they were at least informed about the transition earlier, as according to him, operators had no prior information of AVIX before the actual implementation started.

The immediate effects of the implementation of AVIX were higher utilization of workers as a result of better balancing and according to the operators it also resulted in better ergonomics. One unexpected cascade effect arose, namely that preparation of the information that had previously been compatible with the old software, CSO, had to be reformatted for AVIX.

The respondents highlighted the pilot area approach and the training sessions as what worked well during the implementation. However, the training sessions were held for all the people that would eventually be affected by the change at the same time, something that resulted in the time between training and using the software in some instances became rather long. This was mentioned as one of the mistakes that were made. No follow up, except for ensuring efficiency increases was made, at least not from an organizational perspective.

4.3.4 Analysis - AVIX

Starting the search for new process technologies looking at what existed within Volvo Group, was a time efficient strategy. In general, it also means that some of the evaluation procedure and preparatory work has already been carried out (Leonard, 2014). However, it is important to assess the validity of that evaluation and preparatory work to ensure that it also applies in the new application area. Furthermore, if the time frame allows for it, looking outside of the company, at fairs and in literature etc., will undoubtedly give a more complete picture of what potential technology options exists and thus ensuring that no opportunities fall through the cracks. Benchmarking against Scania, one of Volvo's top competitors, was a good way of making sure that the performance of the new technology was adequate. Furthermore, having clear criteria such as system compatibility and the existence of certain functions waas a good way checking the relevance of new technology (Dengler et al., 2017).

During the evaluation phase, a concrete comparison between AVIX and CSO was performed, considering the most important metrics. This ensured that the new technology was actually an improvement, something that of course is essential in all technology changes. However, not consulting the operators (if that indeed was the case) as a part of the evaluation might have resulted in missing out on important input, especially as the operators are the closest to the process.

Starting the implementation in a small pilot area was a good way of making small scale mistakes early on to learn from rather than having to deal with them in full scale (Leonard, 2014). Establishing a change request list seemed to be an effective way of tweaking the implementation process and the software to facilitate for the subsequent implementation areas. However, the training sessions that were held should perhaps have been portioned out during the spread of the software so that the time between training and actually having to use the technology was shorter, minimizing the need for additional training.

Inadequate information about AVIX to the operators prior to the implementation can have resulted in them being less inclined to accept the change. Keeping all stakeholders in the loop is important for having a smooth implementation (Jones, 2017). Although it should be noted that having knowledgeable people around during the implementation that dealt with questions and complaints from the operators, helped ease their concerns (Leonard, 2014).

The lack of a follow up on the implementation from an organizational perspective meant that some of the mistakes that were made are likely to be repeated in similar implementations later down the line (Leonard, 2014).

4.4 Electric screwdriver

In 2012, Volvo Trucks installed electric screwdrivers at the preliminary workstation to the mufflers. The electrical screwdrivers replaced the air pressure machines that were previously used at the station. The reason for the replacement was that the work tasks at the station required varying torques and caps. This lead to a quite cumbersome work situation where 7-8 machines had to be used within one work cycle. With the new electric screwdrivers, the torque is automatically adjusted and the cap is easily replaced to fit the different operations.

4.4.1 Identify - Electric screwdriver

In the identifying phase of this case, catalogues were used to search for the new technologies. The reason for searching for new technology was to improve the work situation for the assembly workers. They were previously working in a noisy, inflexible environment with a large amount of air hoses on the station. A formal standard (820-001) was used to assure the capacity and requirements of the new machines. The electric screwdrivers were already being used at other stations so the company had previous experience of their benefits and they were considered to be the most relevant technology for this station.

4.4.2 Evaluate - Electric screwdriver

In the evaluating phase, no standard was followed. As the technology already existed on the production line, no particular evaluation was done in this case and no other technology was evaluated. Before the implementation, all stakeholders were consulted for their opinions. Their thoughts and ideas were considered when making decisions regarding the new technology. Before making the decision on whether or not to implement the electric screwdrivers, a business case comparing the air pressure machines to the electric screwdrivers was performed. The business case addressed financial calculations, the work environment and noise levels etc.

4.4.3 Implement - Electric screwdriver

Although, the implementation process did not follow any particular standard, it was carefully prepared for and information to the assembly workers was sent out prior to the implementation. Everyone who would work with the new tools had the opportunity to influence the implementation. The implementation worked well and there was good and thorough communication between the parties. The careful preparatory work allowed for a smooth implementation process. Although the reactions to the new screwdrivers was very positive, the operator respondent stated that it could have been made clearer how the operators' work routines would change as a result of the implementation. The new technology was popular with the assembly workers, apart from a small group that in the beginning had a hard time adapting to the new system and kept working according to their old work routines. They were, however, positive and satisfied after working in the new environment for a while.

Looking at the effects of the implementation, the flexibility increased, the work environment became better and the quality of the screw joints increased. After the implementation, the tooling group followed up on that the machines worked as intended. No follow up from an organizational perspective was performed.

4.4.4 Analysis - Electric screwdrivers

Identifying the new technology was done using catalogues that Volvo Trucks receives from their supplier. This is an effective way of searching for what the supplier can offer and the different opportunities they have. However, it should be noted that searching for technology from only one supplier may lead to missing out of new production technologies that are available on the market but that the specific supplier for some reason has not yet adopted (Brenner, 1996). Searching at only one supplier also increases the risks of overpaying for the technology, as there might be suppliers with equally good products for less money. Furthermore, expanding the search scope to look for technologies also in sources other than suppliers can be additionally beneficial in terms of not missing out on opportunities.

Throughout the entire process, both project leaders, group leaders and assembly workers had the opportunity to come with thoughts and ideas for what technology to choose and how to implement it. This allowed everyone to be a part of the change, which makes the workers less likely to be negative about the technology once in place (Kotter, 2017). Involving assembly workers in the change process is, according to Jones (2017), a crucial factor for successful implementation projects. Communicating the reasons for the change was also successfully done in the case. This helped the assembly workers to understand *why* the new technology was superior to the old one and how the implementation would lead to a better work situation (Laumer et al., 2016). The only situation where the communication and information lacked, was when explaining how the new technology would change the assembly workers' work routines. Such information should be clear and thoroughly communicated to assure that the workers receive it. It is ultimately their daily work that gets transformed and if they are not fully informed about the changes that will occur they are likely to be resistant and to have a negative attitude towards the implementation (Laumer et al., 2016).

The implementation was considered very successful and everyone involved was satisfied with the outcome. One of the key reasons for the success was the careful planning and preparatory work that was done prior to the implementation process. The careful planning resulted in people perceiving the project as serious and well thought through. Furthermore, it ensured that no unwelcome surprises arose.

5 Cross-case analysis

Judging by the answers to the concrete questions on whether or not they used a standard or guidelines for the subprocesses during the cases (see Appendix A - Interview protocol), the answer is almost exclusively no. And although the consistency of those answers seems to indicate that no standard is used all by its own, there is still a possibility that Volvo indeed follows an unspoken standard that they're simply not aware of. Nevertheless, looking at the answers to the more specific questions on each of the subprocesses, it is evident that that is not the case. Having compared the gathered data from each of the cases, it becomes clear that the differences largely outweigh the similarities. Therefore, the answer to RQ1 is that Volvo Trucks does not follow a standard for approaching new process technology, a conclusion that strengthens the relevance of this thesis. Other important patterns and problem areas found during the cross-case analysis are presented below.

5.1 Identify

Doing the cross-case analysis, it became apparent that Volvo Trucks consistently only utilized one source when looking for new process technology. All the cases resulted in identifying a technology that already existed within the company, i.e. in-house. It is effective and quick to search for technology that is already used at the company, however it should be noted that doing this can result in missing out important new technologies. Moreover, none of the cases displayed an effort of assessing what emerging technologies that could be relevant. Not considering this aspect can result in making acquisition decisions that soon turn out to be unwise.

Assessing a technology's relevance for Volvo has been done differently in all four cases. While some technologies were assessed based on compatibility, others have been evaluated based on a dialogue with operators. It should be noted that as long as no technologies are being eliminated during the identification phase for unjustified reasons, it is fine to keep them to the evaluation process where the evaluation process is more thorough. Looking at the four cases together, it can be concluded that there was only one or a few technologies that were considered to be relevant for each case. This could be a result of having a narrow search scope or because it had already been decided on what technology to adopt before looking at the available alternatives. Either way, Volvo Trucks should strive to have an open mind towards all different technology sources and try to avoid getting "fixated" with one certain technology.

5.2 Evaluate

Looking at the evaluation process, Volvo Trucks does not follow a standardized process. In some of the cases, the new technology was evaluated while in others the process was implemented without doing any prior significant evaluation. Although implementing a new technology without prior evaluation can indeed be successful, it is associated with much risk. Furthermore, it doesn't offer the learning opportunities a structured evaluation process would, as it's hard to know the reasons behind its success. Only in some of the cases, all stakeholders were consulted for their opinion prior to making decisions on which new technology to implement. The involvement of operators early in the process is very important for the success rate of the implementation (Jones, 2017).

In all cases, comparisons with the previously used technology were performed. This is a good method as it helps ensure that the new technology is “better” than the old one. Most often, a business case has been used to justify the transformation. However other criteria such as ergonomics, noise levels and work processes have in some instances been evaluated as well.

5.3 Implement

The implementation process was different for all cases. This is natural as the cases per se are very different and require different approaches. However, having some segments being the same in all implementation processes could be beneficial, for example preparatory work and follow up. This was not the situation in some of the studied cases. Always including important segments would ease the implementation process as the change owners of each project that is carried out can share their successes and failures with the rest of the company and thus the implementation can continuously be improved.

Everyone had the chance to influence the implementation, except for in one case where the operators were not listened to. Not including the operators in the transformation process can make them feel excluded, making them less inclined to accept the change (Jones, 2017). Looking at all the cases, it becomes apparent that the information given to the operators is sometimes vague. Reasons for *why* the implementation is happening are often left out. Furthermore, the operators are often not informed as to how their work routines will change as a result of the new technology.

Overall, the projects have been perceived as successful and most employees are satisfied with the changes. However, there is always some opposition from a number of workers. When this happens at Volvo Trucks, dialogue between the workers and their managers has been key to solving such issues.

All cases have experienced some sort of cascade effect which have had a negative effect on the project. These effects can be prevented by taking them into consideration when planning for and setting up the change. In order to try to eliminate the cascade effects completely, careful predictions and calculations of possible effects should be performed.

Very rarely are the cases followed up after the implementation is finished. From an organizational perspective this can lead to missing out on important learnings from previous cases and the risk of repeating mistakes increases. It will also be more difficult to improve the implementation process if previous cases are not analyzed and evaluated (Leonard, 2014).

6 Proposed standard

The standard was divided in the same way as before and consequently the methods chosen for each of subprocesses are presented separately. The standard is tailored towards Volvo's specific situation in the way that Volvo employee input was considered to a great extent. Furthermore, most of the problems that are addressed in the standard stem from the findings from the within –and cross-case analysis.

6.1 Identify

The identifying part of the standard was structured into two separate processes, unfocused search and problem oriented search. After these processes are discussed, the entire identification part of the standard is illustrated in the form of a flow chart in Figure 3.

6.1.1 Unfocused search

The first aspect of the identifying part of the standard is what is called the unfocused search for new process technology. This search is characterized by not aiming to find solutions for particular production related problems, but rather to review appropriate technology sources in order to find what could be opportunities for improvement. This aspect of the standard is meant to be an ongoing process at Volvo, meaning that there is no point in time at which the unfocused search should be discontinued. The unfocused search consists of two types of activities. The first activity is what could be classified as the predictive part of the identifying standard and it serves the purpose of avoiding untimely decisions on what technologies to acquire. Judging by the cases, that is an activity that Volvo don't seem to consider. Volvo Trucks should utilize Brenner's (1996) methods for technology scouting, interpretation of external signals, and Quinn's (1967) method for technology forecasting, demand assessment (see 2.1 Identification theory).

The second part of the unfocused search consists of reviewing more concrete technology sources, such as fairs, employee suggestions, suppliers and competitors, which in part is mentioned by Brenner (1996) regarding the third external signal. All of the findings from the different sources, including both existing technologies as well as predictions on future technological advancements, should be collected in a "technology bank". Before entering the "technology bank", a simple feasibility assessment of the technologies is suitable, this could be done by having recurrent tech watches where new technologies are presented and discussed. Even though the unfocused search is not intended to solve particular problems, getting a comprehensive overview of what process technologies exist and future predictions, can facilitate spotting potential improvement areas within the production system. Thus triggering a problem formulation, relevant for the second aspect of the standard (see 5.1.2 Problem oriented search).

6.1.2 Problem oriented search

The second aspect of the identifying part of the standard is when there is a particular problem in the production system that needs to be solved with new process technology. The first step of that process consists of clearly defining the problem in order to clarify what general performance areas the new technology needs to improve upon for it to be an option. Not having as a top priority to ensure that a technology actually solves the problem that exists, might lead to implementing new technologies for the wrong reasons, such as enthusiasm over new "cool" technologies etc.

With the objective of solving a specific problem as a starting point, time also becomes a factor. Depending on how urgent the change is, the extent to which the technology sources are reviewed for options, might have to differ. However, Volvo Trucks should *strive* to review all technology sources, something that currently is not done. Nevertheless, in the case of a very urgent change, the first step should be to look in-house at Tuve or within Volvo Group for technology that might be applicable. In most cases this will mean that some of the evaluation process has already been performed as well as important implementation lessons learnt. This saves time and money further down the line. Implementing technology that already exists within the company also facilitates support, maintenance and training. However, whenever there is time, a more thorough search should be conducted, including reviewing the technology bank and, if necessary, go through the previously mentioned other technology sources with a more problem oriented and focused approach. Additionally, given enough time to solve a problem, Volvo Trucks can turn to its suppliers with problem descriptions and have them develop possible solutions (see Appendix C for Volvo Trucks employee input).

Having identified possible options for new process technology to solve a specific problem, an initial assessment should be carried out to ensure that each of the technologies are relevant and suitable to be evaluated further. During this assessment, four different aspects should be considered; system compatibility, technology readiness, technology life cycle, and future proofing. The first aspect of system compatibility simply means ensuring that the new technology fits with the system around it. Obviously, changes can be made, however the cost of those changes needs to be taken into account. The second aspect, technology readiness, refers to assessing the stability and flexibility of the technology as described by Peters (2015) (see 2.2 Evaluation). The third aspect is technology maturity and relates to assessing were the technology is in its life cycle (see 2.2 Evaluation). The fourth aspect, future proofing, is closely related to the information gathered from the predictive methods. The term itself relates to how long the technology can be expected to remain relevant. How future proof a technology is depends on two factors. The first factor is compatibility to other parts of the system that might change. As an example, there is no point in investing in a new printer when having a vision of going paperless in the near future. The second factor relates to the technology itself and assessing whether or not a functionally equivalent, but more efficient technology is about to emerge. As an example, investing in a mechanical calculator, knowing that a digital equivalent is being developed would not be considered future proof. The assessment related to technology maturity can also provide relevant input here.

Having done the initial assessment, the remaining technology options will be evaluated further in the evaluation part of the standard.

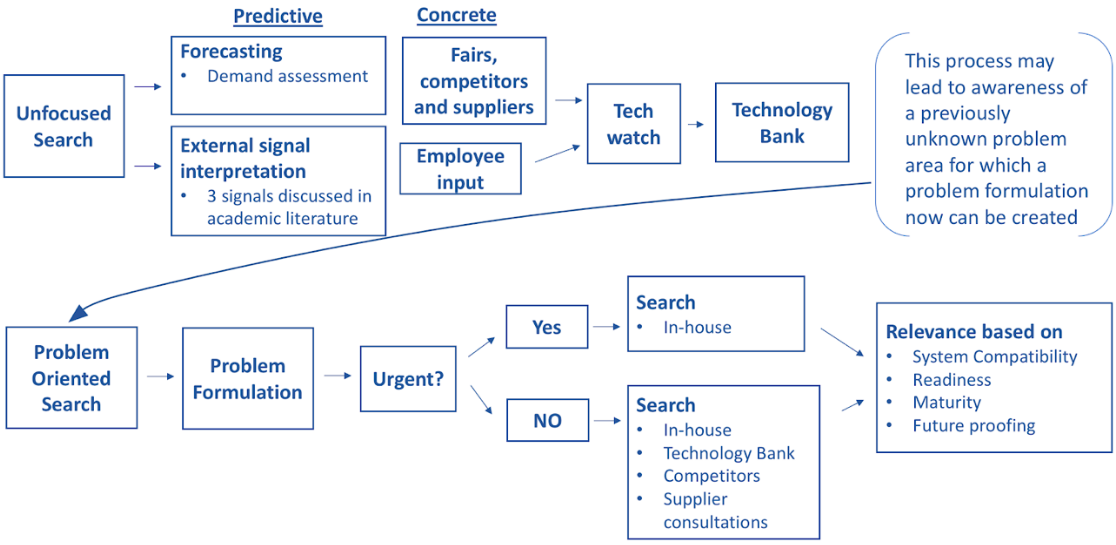

Figure 3 Flow chart illustrating the identification part of the standard.

6.2 Evaluate

The Initial step of the evaluation phase might arguably be to make an assessment of the profitability of the investment. This can be done with a business case. However, how this is performed is outside of the scope of this thesis and the evaluation methods presented in the following section focuses more on other aspects of the evaluation and does not take for instance investment cost into consideration. Other than that, some overlapping between the function of a business case and the evaluation part of the standard is likely to exist.

The first step of the evaluation phase is to determine what criteria to use when evaluating the technologies. The standard suggests six basic criteria, which should always be included in the evaluation. The basic criteria are quality, extent of change needed, safety, operating cost, dependability and sustainability (Dengler et al., 2017). The reasons for always including the basic criteria are both because of their inherent importance and the fact that they should be relevant regardless of what technology is considered. In addition to the basic criteria, more circumstantial ones may also be defined. The circumstantial criteria do not warrant being a part of the evaluation in every approach to new process technology but should, in situations when they are considered relevant, be included in the evaluation. For instance, when implementing fully automated technology, ergonomics is likely not a criterion that needs consideration. However, it most certainly is when evaluating process technology related to manual assembly. Other examples of what could be considered circumstantial criteria are volume flexibility, functional flexibility, intuitiveness, interconnectivity and maintenance etc. The circumstantial criteria are not limited to the ones mentioned here, nor do they all need to be included for the sake of one, rather what circumstantial criteria to include depends entirely on the situation.

The second step of the evaluation part of the standard is to weight the criteria in accordance to their relative importance. Our suggestion is that each criterion is given a grade from 1 to 3, where a higher number corresponds to higher importance. There are no objective guidelines for what grade a criterion should get depending on the situation, rather an internal comparison among the chosen criteria should be the starting point. In other words, the grade of a criterion depends more on its importance relative to the other criteria than its actual importance.

Having selected suitable criteria and their relative importance, the next step is to perform the evaluation. There are two possibilities here, either a virtual evaluation or a physical evaluation. It should be noted that during this phase of the evaluation, and preferably even earlier, operator consultation is advised regardless of what method is chosen. The operator consultation fulfills three purposes. Firstly, they might have valuable insight as to what criteria to select and how to weight them, as they often have in depth knowledge about the process and its issues. Secondly, operators can be helpful when assessing the performance of the different technologies in each criterion, especially so if physical tests have been performed were the operators were involved. The third and perhaps most important aspect is that involving the operators as early as in the evaluation phase will likely have a positive impact on the subsequent implementation process. Volvo Trucks had instances in all of the studied cases were the operators in some way or another were neglected, why including operator consultation as a part of the standard is warranted.

6.2.1 Virtual evaluation

The virtual evaluation method utilizes a weighted Pugh matrix (see 2.2 Evaluate for more details.) The advantages of this method are that it is very cost and time efficient. Its drawback is that it can be difficult to know how a technology performs in certain areas without having conducted physical tests. Meaning that this method can sometimes be inaccurate.

6.2.2 Physical evaluation

The physical evaluation consists of testing the technology in an environment as similar to its intended application area as possible. Either this can be done in Volvo's pilot plant or directly on the production line. For obvious reasons, testing the technology directly on the production line might not always be possible. However, the conclusions of such tests are arguably the most valid. One strategy that can be utilized to enable testing online is running parallel technologies (more details about this can be found in 5.3 Implement). In situations where online testing is deemed impossible or inconvenient, the pilot plant can be used. In those cases it is important to try to recreate the actual application site as accurately as possible. Furthermore, operators that are affected by the change should if possible also be involved during this testing.

One great benefit of running physical tests is that benchmarking is possible, meaning that the technology options can be compared accurately based on how they perform in a live setting. In the benchmarking, the previously selected criteria can still be used similarly to in the virtual evaluation. The only difference is that the accuracy of the input data is much better and that a quantitative approach is possible. An example of which could be percentage comparisons between the technologies, which are then multiplied according to criteria weighting.

In the case that many different technologies need evaluating, a first step could be utilizing the virtual evaluation method in order to make an initial distinction and narrow down the selection and then perform more accurate physical tests. It all depends on available time and resources.

After the evaluation has been performed it should be obvious which of the technology options (including the already existing one) that should be implemented. Figure 4 illustrates the evaluation part of the standard in the form of a flow chart.

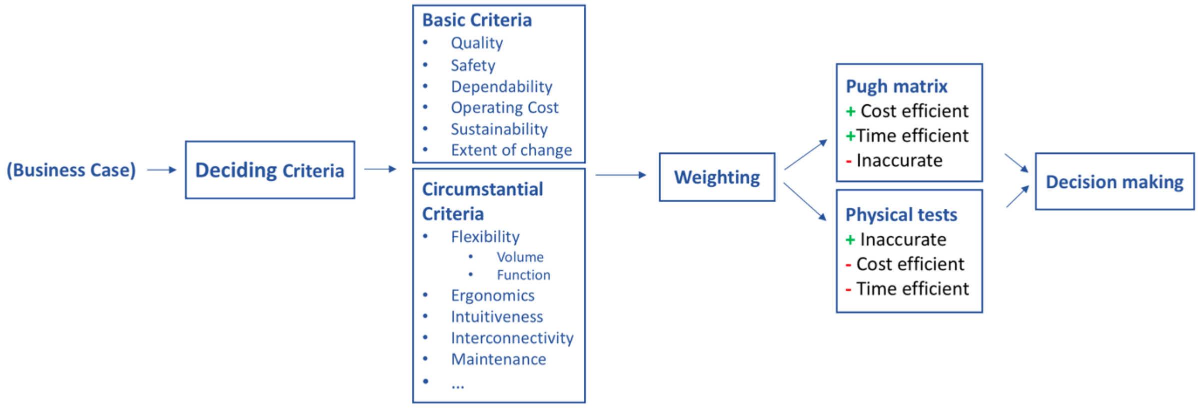

Figure 4 Flow chart illustrating the evaluation part of the standard.

6.3 Implement

The final part of the standard is the implementation. At this stage, all necessary decisions regarding the technology have been made and the remaining step is to actually implement it in the production system. This part of the standard can be divided into three processes: preparatory work, execution and follow up. The first and highly important part is the preparatory work. This involves going out with thorough information about the change to all employees affected by the implementation. This information should be clear and there should be room for the workers to ask questions about the new technology. It is important to communicate the benefits that will come with the new production technology. It is also of high importance to explain *why* the implementation will happen and the positive aspects it will bring. This will ease the process of accepting the transformation for the operators (Jones, 2017). Also, if the technology requires a change in the operators' work routines, this should be thoroughly explained and demonstrated (Laumer et al., 2016). Judging by the cases, most of these communicational aspects are not addressed fully by Volvo Trucks during implementations.

Furthermore, the preparatory work involves assessing what changes will occur as a result of the implementation. As an example, in the paperless Cabtrim case, the hardware needed to mount the screens had not been acquired prior to the implementation resulting in delays. According to Leonard (2014), preparatory work is crucial to have a successful implementation. Doing this in the preparatory phase minimizes the risk of having unplanned stops and obstacle further down the line during the implementation. Finally, the last part of the preparatory work consists of appointing a change owner and other key persons. They should be chosen on the basis of how knowledgeable they are and will be responsible for communication and overall handling problems that arise during the implementation.

The second part of the transformation process is the execution. If the technology is intended to be implemented in a large area of the factory, Volvo Trucks should utilize a pilot area strategy. This is done to keep the scale of the problems as small as possible but still allow important lessons to be learnt. The pilot area should be chosen based on how representative it is of the rest of the stations where the technology later will be implemented (Leonard, 2014). Choosing the pilot area out of convenience will result in complications further down line, since the change might not be received similarly by other workers. The paperless Cabtrim case is an example were Volvo Trucks picked the pilot area based on receptivity instead of representability, as the pilot station was chosen due to the operators being young and therefore more likely to accept the change. Although, the effects of that decision were not entirely clear, this is an important aspect for Volvo to consider. During the pilot area phase, a change request list should be created in order to document tweaks needed to the implementation process and thus ensuring that mistakes are not repeated in the subsequent implementation areas.

Before replacing the old technology with the new, a good method to make the transition smooth is to use parallel technologies for a period of time. This is a good safety measure and allows the operators and managers to learn and see how the new system works without having to stress. This way, unexpected stops or other obstacles will not be as critical. Once all people involved feel comfortable with the new system, the old technology should be removed. Having parallel technologies for a period of time was a strategy that Volvo Trucks successfully utilized in two of the studied cases.

Third in the implementation process comes the follow up. This step is very important as it allows for continuous improvement of the implementation process. Volvo Trucks currently lacks a consistent process for following up their implementations resulting in them repeating mistakes from one implementation to another.

The follow up should reflect on the events and actions that went well during the implementation, and that should be repeated in future implementations. It should also reflect on the failures or complaints that arose during the implementation. It should be noted how those failures were dealt with and what actions were taken to solve them. If complaints arose, one should ask how those were dealt with and what should be kept and changed for future implementation processes. Furthermore, the follow up should assure that the technology functions properly and that it is being used as intended by the operators. Relating to the technology being used as intended and why that is an important aspect, operators during the screwdriver case continued with their previous more inefficient work routines for a period of time before actually performing the tasks as they were designed. Figure 5 illustrates the implementation part of the standard in the form of a flow chart.

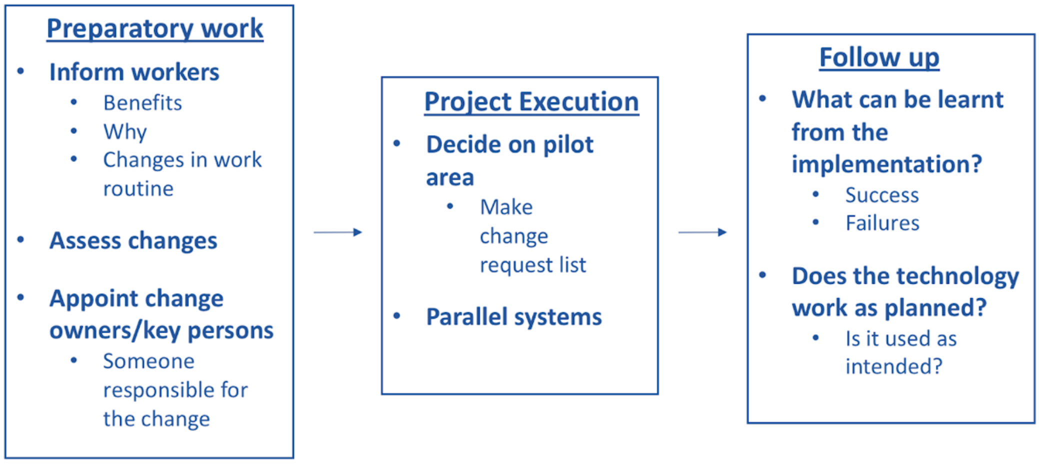

Figure 5 Flow chart illustrating the implementation part of the standard.

7 Discussion

This chapter discusses the research questions and the theoretical contribution of the project. Furthermore, the practical contribution is presented. Economic-, social- and environmental sustainability are also addressed.

7.1 Addressing the research questions

The answer to RQ1 provided an overview of the problems that Volvo Trucks experience when approaching new process technology. Thus, providing necessary insight into what problems a future standard need to address. Overall, answering RQ1 was a crucial part of fulfilling the purpose of the thesis. Many of the problems that were found at Volvo Trucks were recurring in all of the studied cases and corresponded well to the theories found in literature. However, those problems almost exclusively revolved around the organizational and psychosocial aspects of approaching new process technologies. Regarding the identification and evaluation of new process technologies, Volvo's current approach included very little of the theories presented in literature.

Regarding RQ2, there is extensive literature on the different subprocesses, although arguably some areas are lacking. One surprising discovery was that there was close to no literature on how to search for *existing* process technologies during the identification phase. Rather the focus seemed to be on predictive methods and gathering knowledge about emerging technologies. That is a very important aspect, especially so in relation to disruptive technologies. However, emerging technologies are in most cases not ready for implementation, meaning that during a problem oriented technology search they don't hold value. In those cases, proven technologies are needed and thus more concrete technology sources are of interest. Another aspect was that the lack of literature describing the entire process of approaching new process technology, i.e. from identification to evaluation to implementation. Although the importance of the entire process is brought forward by Dengler et al. (2017), who states that "a proactive technology management approach is characterized by continuously assessing established production technologies as well as identifying, evaluating and acquiring alternatives and capabilities in advance of needs", a continuous string of methods to achieve this is not presented.

Regarding RQ3 and the proposed standard; although it is created with the aim of addressing Volvo's specific problems, it contains what the authors determined to be all necessary aspects for having a comprehensive approach towards new process technologies. Consequently, it should be applicable in all manufacturing companies similar to Volvo Trucks. To begin with, introducing (to Volvo Trucks) the concept of predicting future technological advancement, as a part of technology management ensures not making untimely decisions in regards to what technologies to acquire. Furthermore, it is perhaps the most important aspect when detecting disruptive technologies. The standard also presents a broad range of technology sources to review for finding potentially useful technologies, thus minimizing the risk of missed opportunity. In regards to evaluating the identified technologies, the standard provides a structured way of approaching problems and ensures that a technology is chosen based on its potential to solve the problem rather than something else. Moreover, the standard contains both what aspects to consider during the evaluation as well as actual methods to do so. The implementation part of the standard, similarly to the identification and evaluation, consists of a step by step process. It addresses both important communicational and psychosocial aspects as well more technical strategies for how to successfully implement the technologies. In addition to this it also presents the most crucial aspects to consider during the follow up.

7.2 Theoretical contribution

The theoretical contribution of this thesis mostly consists of synthesizing different relevant methods into a comprehensive overview that includes the entire string of processes needed for effectively approaching new process technology in a manufacturing company. As a side effect of this, each subprocess has also been structured independently. Looking at literature, rarely are the subprocesses discussed in their entirety but instead more specific concepts within in the processes are in focus. This thesis provides a more holistic view of the subprocesses than what can be obtained in current literature.

The thesis also provides information about what concrete technology sources to review during the identification phase. The selection of which is based on suggestions from Volvo's employees as well as the authors' own ideas. A more thorough research to sort out what are relevant concrete technology sources would increase the validity of such a selection. The concept of using parallel technologies during the initial phases of the implementation process was not discussed in literature and can therefore be considered a theoretical contribution. It should be noted however that the effectiveness of that method has not been validated during this thesis. Lastly, the research also provides insight into some of the problems that can be expected as a result of not having a standardized process for approaching new technology.

7.3 Practical contribution

The practical contribution of the thesis, i.e. the contribution to Volvo Trucks, is that of pointing out recurring problems that arise within their company during the process of approaching new production technology. That in of itself can be regarded as valuable input for Volvo, regardless of them implementing the proposed standard or not. Nevertheless, the proposed standard addresses all their communicational problems, lack of operator involvement, their often quite narrow technology identification method, inconsistent evaluation methods as well as their lack of preparation and follow up during implementations. However, the most substantial contribution that the standard provides is that of being a standardized work procedure. Thus, providing basis for continuous improvement of the processes since continuity in how they are performed can be ensured.

7.4 Sustainability

Sustainability has become an important part of companies' strategic plans and actions (Gunasekarana and Spalanzani, 2012). Sustainability is often divided into three categories; social, economic and environmental. From a social perspective, the standard might increase the motivation for the operators as they will be better informed about technological changes. They will also have the possibility to contribute with thoughts and ideas about changes, making them feel more involved and listened to (Liker and Hoseus, 2008). The involvement will lead to increased work motivation and a greater understanding of the importance of the changes. Moreover, giving and receiving constructive feedback is key for a good social sustainability (Liker and Convis, 2012).

Looking at the economic sustainability, the standard will enable Volvo Trucks to sustain and expand their economic growth as they will stay on top of new production technologies (Gunasekarana and Spalanzani, 2012). It will also, to some extent, help them analyze and eliminate those technologies that are not economically viable anymore. The standard will help Volvo to identify what new technology to implement and thus contribute to assuring that it will remain a successful business.

Lastly, looking at the environmental perspective, the standard might help Volvo Trucks to search for environmentally friendly technologies (Gunasekarana and Spalanzani, 2012). The future standard supports ecological sustainability by having sustainability as one of the basic criteria for evaluation. However, how Volvo chooses to address this will not be discussed in this thesis.

7.5 Recommendations and future research

Additional research regarding what concrete technology sources to consider when identifying new process technology is needed. Questions such as "what are the most potent technology sources?" and "what are the possible effects of not considering *all* technology sources when identifying new process technology?" can be a good starting point. Another aspect that should be further investigated is if the standard, or a similar framework, can be applied outside of the scope of process technology, such as within product development etc. Further research is also needed, to more in depth, assess what financial aspects to consider during a technology evaluation. This research should concern aspects such as return on investment and profitability of the technologies. Research for how to accurately quantify the traditionally non-monetary criteria might also be needed.

This thesis has provided Volvo Trucks with a standard that constitutes a structured and improved method for approaching new production technologies. The standard should however be considered as a basis for further development. Moreover, the standard's effectiveness needs to be validated before implementation.

8 Conclusion

Since approaching new process technology in an effective and efficient way becomes more and more relevant as technology development accelerates, failing to do so constitutes a growing threat to manufacturing companies. Volvo's primary problem is that they don’t have a standardized approach that is continuously improved upon, resulting in limited learning and unwanted variation in the processes. The thesis aims to solve that problem by analyzing Volvo's current approach with a multiple case study, gathering improvement suggestions from employees at the company and in combination with established methods from literature create an effective standard for approaching new production technology.

Three research questions were formulated to support that aim. The first question was “How do Volvo Trucks identify, evaluate and implement new production technologies in the production system?” and after the case analysis it became evident that Volvo do not utilize a standardized approach. Furthermore, aspects such as lack of overall communication, inconsistent technology evaluations and insufficient technology identification methods were identified as problem areas. The second question was “What methods for identifying, evaluating and implementing new production technologies in a production system can be found in literature?”, to which the answer consisted of a collection of effective methods on topics like technology forecasting and scouting, evaluation criteria, decision matrices and important organizational aspects to consider during the implementation process. The third question was “What can an effective standard for identifying, evaluating and implementing new production technologies in Volvo Trucks’ production system look like?”. The standard was created based on the findings from RQ2, suggestions from Volvo employees and the authors’ own ideas. The standard is intended to be an overview of important aspects to consider when approaching new process technology in general but is especially aimed at addressing Volvo’s specific problems as found by answering RQ1. However, the standard is arguably applicable also outside of the context of Volvo Trucks.

The thesis presents an overview of potentially useful technology sources for finding existing technologies, something that is hardly mentioned in current academic literature. Furthermore, it provides an idea for how different methods related to identifying, evaluating and implementing new technology can be stringed together for an overall effective approach towards new process technology. The Proposed standard should be regarded as a basis for further development of a more concrete and streamlined standard for the environment where it is used. Nevertheless, the standard is structured in a step by step manner for ease of use and Volvo trucks can expect a more effective approach towards new production technologies by utilizing it.

References

Brenner MB, 1996. Technology intelligence and technology scouting. *Wiley online library*, [Online]. Volume 7, Issue 3, 20-27. Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1002/cir.3880070306 [Accessed 20 February 2018].

Bryman, Bell, A., 2011. *Business Research Methods*. 3rd ed. United States: Oxford University Press Inc., New York.

Christensen C., 2011. *The Innovator's Dilemma*. 3rd ed. United States: Harvard Business School Press.

Dengler Schönmann, Lohmann, Reinhart, CD, AS, BL, GR, (2017). Cycle-oriented Evaluation of Production Technologies: Extending the Model of the Production Cycle. *In The 24th CIRP Conference of Life Cycle Engineering*. Kamakura, Japan, 8-10 March 2017. Elsevier B.V.. 493-497.

Gunasekarana, A. and Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics*, November.

Jones DRJ, (2017). Psychosocial Aspects of New Technology Implementation. *In International Conference on Applied Human Factors and Ergonomics*. Los Angeles, CA, USA, 17-21 July. Springer, Cham. pp. 3-8.

Kotter J.P. 2017, "Leading change why transformation efforts fail", *Accountancy SA,* , pp. 19-29

Laumer S., Maier, C., Eckhardt, A. & Weitzel, T. 2016, "Work routines as an object of resistance during information systems implementations: theoretical foundation and empirical evidence", *European Journal of Information Systems,* vol. 25, no. 4, pp. 317-343.

Leonard, DA 2014, Managing Knowledge Assets, Creativity and Innovation: Selected Works by Dorothy a Leonard (2014), *World Scientific Publishing* Co Pte Ltd, Singapore. Available from: ProQuest Ebook Central. pp 449-479 [27 Feb 2018].

Liker, J., Hoseus, M. and Organizations, C. (2008). *Toyota Culture*. 3rd ed. New York: McGraw-Hill Publishing.

Liker, J. and Convis, G. (2012). *The Toyota way to lean leadership*. 2nd ed. New York (N.Y.): McGraw-Hill. Lumen Learnings. *Technology and Innovation*. [ONLINE] Available at: https://courses.lumenlearning.com/boundless-management/chapter/technology-and-innovation/. [Accessed 16 May 2018].

Peters, S., 2015. *A readiness level model for new manufacturing technologies*. 9th ed. Germany: Springer Berlin Heidelberg.

Pugh S. (1981) Concept selection: a method that works. In: Hubka, V. (ed.), Review of design methodology. Proceedings international conference on engineering design, March 1981, Rome. Zürich: Heurista, 1981, blz. 497 – 506.

Quinn J. B., 1967. Technological Forecasting. *Harvard Business Review*, March.

Schuh; Kabasci; Drescher; Ryschka; Wetterney, GS, PK, TD, SR, TW, (2016). Identifying and evaluating disruptive technologies using technology scanning. *In International Association for Management of Technology, IAMOT 2016 Conference*. Orlando, Florida, 15-19 May 2016. Germany. pp 888-905

Schrettle, SS, 2013. *Managing manufacturing process innovation – New manufacturing technology adoption as a dynamic capability*. Germany: University of St.Gallen.

Voss Tsikriktsis, Frohlich, CV, NT, MF, (2002) "Case research in operations management", *International Journal of Operations & Production Management*, Vol. 22 Issue: 2, pp.195-219, https://doi.org/10.1108/01443570210414329

APPENDIX A - Interview protocol

Hi, we are two students from Chalmers University of Technology in Gothenburg that are writing our thesis project at Volvo Trucks in Tuve. We are looking at how Volvo adapts new production technologies. The goal of the study is to understand how production technologies are identified, evaluated and implemented in the production system. To do this, we have decided to do a multiple case study where we look at previous examples of when Volvo Trucks has introduced new production technologies. We want to get a clear picture of the process and understand what went well and what didn't go so well. With this, we aim to create a standard for how this process should be performed in an effective way.

The interview will take about 30 minutes and will with your permission be recorded. After the interview, we might contact you again for clarification purposes. Attached in this document are the questions we aim to ask during the interview. If you have time, we would appreciate if you read through them once before the time of the interview. In case you feel that you cannot answer all questions, just answer the ones you feel comfortable with.

Case description:
(short presentation of the case in question)

Identify

1. Did you follow a standard or guidelines to identify the new technology
2. Why did you search for new technology?
3. What sources were used to find the technology? (e.g. tech fairs, academic literature, brochures, tech watch, technology catalogues, existing technologies etc.)
4. How did you search through each of the sources?
5. Where did you find the new technology (what source)?
6. How did you decide which technologies were relevant and not?
7. Where there more than one technology that was relevant? if so, how many?
8. Do you have any suggestions on how the identification process should be done?

Evaluate

1. Did you follow a standard or guidelines to evaluate the new technology?
2. Were the new technology evaluated before it was implemented?
    a. if so, how what this done? (testing, criterium, comparison of technologies etc.)
    b. if not, why was it not evaluated?
3. Were all stakeholders consulted as a part of the evaluation?
4. Was more than one technology evaluated?
5. Were any comparisons done with the existing technology before the implementation? if so, how was this done?
6. Do you have any suggestions on how the evaluation process should be done?

Implementation

1. Did you follow a standard or guidelines to implement the new technology?
2. What did the implementation process look like?

3. Who had the possibility to influence the implementation process? (assembly workers, group leaders etc.)
4. How and when were you informed about the implementation?
5. What worked well during the implementation process?
6. What did not work well during the implementation process?
7. Were there any complaints from employees after the implementation?
   a. if so, how were these complaints dealt with?
8. What effects occurred as a result of the implementation?
   a. Direct effects (effects on the place where the implementation occurred)
   b. Cascade effects (effects in other areas that occurred as a result of the implementation)
   c. where any of these effects unexpected?
9. How did you follow up on the implementation?
10. How did the employees experience the implementation?
11. Do you have any suggestions on how the implementation process should be done?

Other

1. Are there any documentation from the case that we can take part of?

APPENDIX B - Research protocol

- Multiple cases, retrospective: Study ends when RQs can be answered
- Data gathering methods/Sources: Interviews, documents, Gemba, observation, informal conversation.

Case criteria:

- Within production technology.
- Preferably all three subprocesses (phases) are included in the case.
- Time frame, the newer the better (to mitigate post-rationalisation) and increase accessibility of information.
- Extent of the change (perhaps not cases regarding very small changes)

Guidelines:

- Pilot testing of Interview protocol.
- Feedback and checking of information after it has been collected for verification.
- Record ideas and conclusions as we go.
- When confronted with differing views and opinions, we must challenge and seek other sources of data for clarification.
- Be as objective as possible, be wary of our own bias.
- Summary of interviews should be done soon after for clarity of recollection.
- Record interview to enable returning to the source of information.
- Reliability: Using established methods and a detailed research protocol.
- Make within-case analysis first, and only when a thorough understanding of each individual case is reached proceed with cross-case analysis.
- Interview length under 30 min.

APPENDIX C - Employee suggestions

During the interviews, one questions per subprocess was aimed at collecting input from the interviewees regarding what aspects they think are important for each subprocess. The answers to those questions have been summarized and listed below and were used to great extent when creating the standard.

Identify:

- Start by asking the people that will use the technology and see how the technology can be integrated with the existing system.
- Communication with the people that will use the technology (the customer) to see what they know and what they want.
- Look within the company and within Volvo group, as its cheaper than reviewing other sources.
- Aiming to have similar technology in different areas to facilitate support, maintenance and training.
- Consulting suppliers with problems and letting them develop solutions.
- Keep doors open to all sources of input and not hindering creativity.
- Go to technology fairs.
- Encourage supplier manufacturing companies to display their process technology at Volvo Trucks.

Evaluate

- Important to perform live tests online or in pilot plant. Technology can be rented or borrowed from supplier.
- Important criteria to consider: attractive workplace, quality, cost, environmental sustainability, planning ahead (future proofing).
- Communication and dialogue with the end user, for instance assembly workers.
- Benchmarking important metrics.
- Business case.
- Evaluating based on functionality and compatibility.
- Having a structured evaluation method that is intuitive and simple to use.

Implement

- Small allows for more freedom.
- Thorough preparatory work and pre study should be performed. What can be expected from the change?
- Go to the end user for feedback.
- Spreading the word about the new technology that have been implemented to facilitate implementation in other areas of the production system.
- Initial pilot area/pioneering area to make dealing with problems easier and subsequent implementations more smooth.
- Appointing change owner and key person that have lots of knowledge that can support the implementation.
- Communicating the benefits of the change
- Inform as early as possible
- Prepare the installation and make sure that all the hardware is available and that the installation is physically possible.

- Talk to all stakeholders about how the will be affected and why.
- Follow up to review the result.