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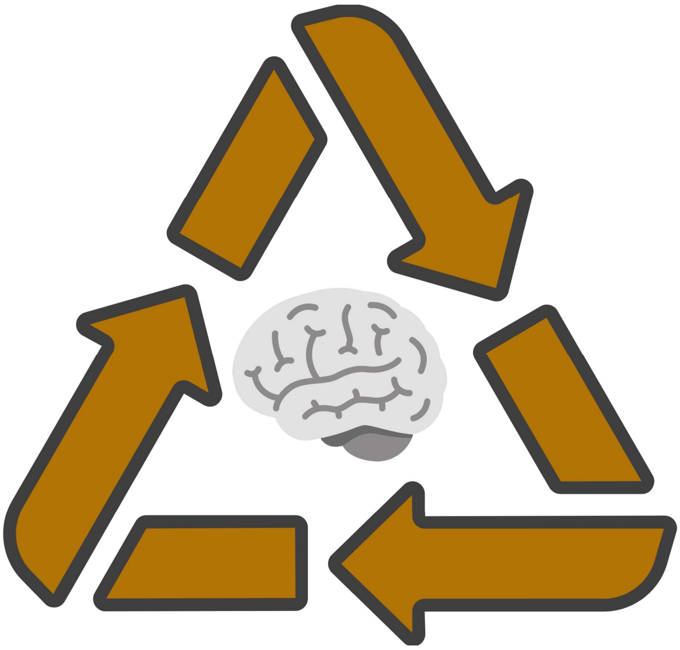

Respecting the power of knowledge

Reducing design weaknesses in factory equipment by facilitating knowledge reuse, with a maintenance perspective

Master's Thesis in Product Development

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

Earlier research, at the company this thesis has been carried out, has shown that design weakness is a major contributor to machine breakdowns, and struggles with knowledge re-use is believed to be a cause for this. Therefore, this thesis covers two areas: (1) To try to find if there is a correlation between breakdown losses and the project documentation, and (2) Find a solution to improve the existing acquisition process in the aspect of knowledge management.

The analysis of project documentation was conducted in a manual and qualitative manner, which leaves room for improvement. In the end, it did not give clear evidence for a correlation, but a few indications, such as delays and lacking documentation for testing, seemed to cause more breakdowns.

To improve lessons learned, a tool was developed which served to replace the existing method which had been deemed too cumbersome and not a worthwhile task from earlier research at the company. This tool consists of an app created in Power Apps, connected to a database of lessons, which is believed to improve several aspects of lessons learned as well as eliminate existing pitfalls the existing method had fallen into relating to lessons learned.

It is recommended to continue exploring the reasons for poor machine performance, as this thesis could not conclude with certainty that documentation is the root-cause. Furthermore, the analysis-process could be improved greatly as there was no predefined way of conducting it, and conducting it in a more systematic manner could yield better results. Finally, lessons learned within the case company can be further improved in the future by involving elements from industry 4.0 by, for example implementing direct connections to the machines to increase the amount of data; increasing automatic communications between softwares; using machine learning to automatically create lessons and ultimately make decisions based on these lessons. Following through with these improvements, and other as well, for increased knowledge re-use can be incredibly beneficial for any company as less resources will have to be put into reinventing the wheel and helps avoid making mistakes over and over again.

Keywords: Knowledge Management, Factory Equipment, Early Equipment Management, Industry 4.0, Maintenance, Acquisition, Design Thinking, Lessons Learned.

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Thank you to our examiner Dag Bergsjö for contributing with knowledge and ideas on how to develop our tool, especially during the COVID-19 outbreak.

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1
Introduction

This report aims to describe the work done in the masters thesis Design of intelligent support for engineering knowledge management *conducted. This first chapter introduces the reader to the subject and its importance. It also presents the purpose and research questions the report aims to answer along with the considered delimitations.*

1.1 Short background to the project

The industry in the world today has begun it's fourth revolution, this revolution is called Industry 4.0 and is described as enabling the usage of internet of things to have more collaboration between machines, but also with other software like maintenance help and databases for knowledge management. As robots and other production machines become more advanced the implication is that manual labour will be automated to a higher extent in industry which leads to more machines in total. This gives an even higher demand for quality of the machines and an aspiration for zero breakdowns (Thoben, Wiesner, & Wuest, 2017). In line with the increased digitalisation and new ways of working in global organisations and supply chains, new demands emerge regarding customer and supplier interactions. Prior research within this topic show that the process of acquiring these machines can be improved, according to (Blomberg & Håkansson, 2019), and that there is a need for better handling of the knowledge in these projects, this together with the data that Industry 4.0 have the potential to provide is where this thesis begins.

This thesis is sprung out of a research project from Vinnova called MALEKC which is short for Machine Learning for Engineering Knowledge Capture. The project aims to use machine learning to make knowledge within companies more accessible and correct. The technology is promising, but how and when in processes it can be used is left to find. This master thesis wants to help identify this by analysing data from a case company's knowledge transfer methods, comparing it to the end results of projects connected to this knowledge and eventually try to find how this research could help improve its processes.

1.2 Prior research on the topic of knowledge reuse in equipment acquisition

This project will be largely based on the findings by Malin Hane Hagström, PhD-student at Chalmers University of Technology and her colleagues from two earlier papers: *"Reducing professional maintenance losses in production by efficient knowledge management in machine acquisitions"* (2019) and *"Visualising wastes and losses in automotive production flows (across multiple plants and organisations) for increased accuracy in improvement prioritisations"* (2019). Where the main losses occur have thus already been studied, and this thesis is based on that work.

1.3 Purpose of this thesis

The purpose of the project is to highlight the industrial problem that exists today regarding knowledge re-use in acquisition of factory equipment. Root cause analyses show that a large portion of machine breakdowns happen because of a design weakness (Hagström, Bergsjö, Blomberg, & Håkansson, 2019, p. 1). The design of the machine is created in the acquisition process, and design weaknesses can only be dealt with efficiently in the same. Further, it is believed that information being overlooked or not readily available can be connected to these design weaknesses (Blomberg & Håkansson, 2019).

If this knowledge can be used in the right way, it can lead to reduced waste, in time, costs and material. It will also aim to create a more sustainable working environment for not only the people involved in the design process by improving their tools, it can also help the safety of operators by reducing downtime and failure associated with the machines. Lastly as Industry 4.0 is approaching, there is a need for more effective ways to use the amount of data that will be available from these machines. Otherwise just collecting all this data can also be considered a waste.

The overall objective is to reduce breakdowns in machines to zero. Both to increase productivity and profitability from being able to reduce the number of stops in production and lowering maintenance costs for repairing the machines.

1.4 Research Questions

To narrow down the research, and to concretise the goals of the project, its purpose is developed in to three research questions:

1. **Is there a correlation between breakdown losses and project documentation?**

2. **How can the existing acquisition process be improved in the aspect of knowledge management?** Based on the findings from Blomberg and Håkansson (2019), how can these improvements be implemented in practice.

As mentioned, this project is loosely based on a project called MALEKC, whose aim is *"To create conditions to effectively identify and reuse knowledge by utilising machine-learning algorithms on engineering change reports (ECR)"* (Vinnova, 2019).

The project is also connected to another Vinnova-project called KIDSAM, *This project aims at creating a greater understanding of the industry´s need to run collaborative projects where people play a key role in knowledge creation and problem solving*(Vinnova, 2018).

1.5 Delimitations

The project is conducted at Volvo Group and is limited to one or a few plants. No other companies will be investigated nor part of this report other than conclusions from other reports or works.

The project is limited to 20 working weeks to equal 30 ECTS.

This thesis is a continuation of the work done by Blomberg and Håkansson (2019), and will be the base for how to improve the acquisition process.

This project was carried out partly during the COVID-19 outbreak, where all employees at the case company got temporarily furloughed. This affected our ability to get in touch with employees at the most crucial time; when we needed user testing for the development of a tool to facilitate knowledge reuse, explained in chapter 4. This hindered our ability to refine the prototype as much as we initially intended.

1.6 Describing the Case Company

The company comprises of ten business areas and 100 000 employees across the world, with factories in 18 countries. Their portfolio consists of several brands and vehicles, from excavators to buses and trucks. The organisation this thesis covers is based in Sweden and the plant which most of the work is based on mainly works with manufacturing of engines and transmission.

2

Theory

This chapter contains the basics behind many of the terms and theories used in this project. Throughout the project, the principles of Design Thinking *have been used. The purpose of this was two-fold: firstly it offers a framework on how to develop an eventual product with the human in mind; it also serves the purpose of testing a concept from product development in the domain of acquisition which in this case company have a significant number of similarities with a "traditional" product development project. These similarities are found in how there are requirement specifications for the machine; "concept-generations" in the form of exploring multiple suppliers and solutions; and a project plan similar to a* Stage-Gate Process*, a linear development process in contrast to the iterative process of Design Thinking. Potentially finding how principles from Design Thinking can be implemented in the very robust and linear acquisition process can provide interesting input for the report.*

2.1 Approach to defining the research topic

To decide on what areas to look in to and find relevant research connected to the topic a venn diagram shown in figure 2.1 was created to easier see where connections could be found between the topics. The topics themselves were chosen since they were deemed to cover enough information to answer both research questions. This theory chapter is divided in to these areas and presents them broadly to create a foundation for understanding the rest of the report. The study was carried out by utilising Scopus, Chalmers Library's search engine, Google Scholar, and similar tools to find relevant articles and literature. Relevant information gathered from the literature was summarised and made available for use in later stages of the project. The literature was also compiled in Mendeley for easy overview and collaboration, as well as allow for easy referencing for this paper.

As a part of the importance of visualisation mentioned later in section *2.3 Design-Thinking*, another tool that was used for this part was *Lucidchart* to create a chart with post-its visualising the areas that the literature brings up and also the key take-aways from each article or book. This was done to get a better feel of where further information was needed throughout the project. The final chart can be seen in Appendix A, figure A.1 showing a part of the chart as well as the legend, and figure A.2 that shows the chart as a whole. The last figure is not meant to be legible,

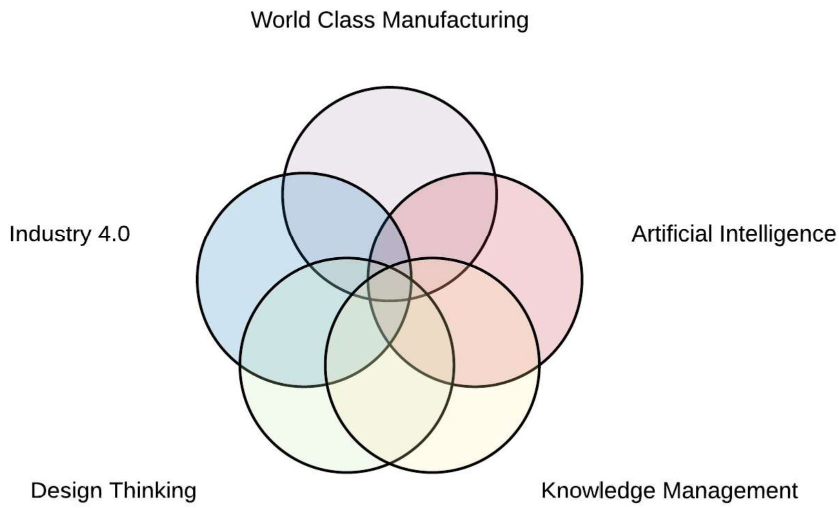

Figure 2.1: Venn diagram of research topics

but is used to get an overview of the topics covered in the literature.

2.2 Analysis of earlier research using Scopus

An analysis of earlier research on the topic of knowledge management and lessons learned was conducted; and more specifically focused on the area of acquisition which is the primary focus for this report. Scopus was used to search and Excel to compile the findings. A reduced table with search strings and resulting hits can be found in table 2.1, the full table with all search strings used can be found in appendix G. When using Scopus, wrapping the search term in *TITLE-ABS-KEY* refers to limiting the search to title, abstract and keywords, and using *W/10* means that the following search term needs to be within 10 words of the preceding.

Finding relevant articles on the topic of knowledge management within acquisition was found to be a difficult task; most results would cover the area of merging, acquisition of a company to another, or simply "knowledge acquisition", meaning the capture of knowledge which is a common term in knowledge management which resulted in many irrelevant results. Excluding that term mostly only made articles on merging more prevalent.

Searching for *purchasing* gave zero hits on-topic and many articles did not include both search terms in the abstract. The results mostly included articles on purchasing behaviours of consumers or were related to procurement, which is explained below.

Using *procurement* in the search string was more rewarding, although the number of results were significantly lower. The majority of articles covered public procurement or purchasing in terms of consumer and payments in regard to consumers. A few covered handling and purchasing of material. However, it resulted in finding four interesting articles that were more or less on-topic, although not a perfect fit and none of which had been cited much either, with eleven citations at most. The only perfect fit was a Master's Thesis by Bouwmans (2003) which was found on Google Scholar. This thesis covers case studies of purchasing knowledge management in six large companies, along with barriers to knowledge management within purchasing.

The area of *lessons learned* within acquisition was also investigated, with little success. The goal was to find articles on how lessons learned are captured and used, and more specifically when applied to an acquisition process. But once again, this topic is difficult to find many relevant articles on, possibly due to *lessons learned* being a popular term for articles discussing actual lessons learned from case studies or literature studies etc. And that is what is found when searching, little to no articles bring up the actual procedure of a lessons learned session within this domain, although there are plenty of articles in the results. Utilising keywords such as session, method and process did give more results on the process of conducting lessons learned sessions or the capturing and re-use of lessons learned but again, nothing specifically on purchasing.

In an effort to find more specific literature within the area of industry, other searches were conducted. Again, it yielded little reward with very few hits. Including Total Productive Maintenance (TPM) or *early management*, referring to the pillar from TPM, resulted in only one article which actually used early management, but applied to human resources so it was essentially not relevant. The other results usually used early management in the literal term, such as how to manage a disease early and similar terms. Including *industrial engineering* as a search term mostly resulted in articles regarding education, both when using *lessons learned* and *project review* as accompanying search terms.

From this analysis, it is concluded that this area is not particularly researched at the moment. Knowledge management and lessons learned, or how to capture earlier experiences and reuse what was learned, are topics which have been researched to great lengths but not when applied to this domain.

2.3 Design thinking

In design thinking, multiple authors emphasise the designers mindset as more important than the tools used and that design thinking puts an emphasis on a human-centric design as well as the importance of prototypes for development (Brenner, Uebernickel, & Abrell, 2016, p. 8;Dolata & Schwabe, 2016, p. 71). Lindberg, Meinel, & Wagne, 2011, p. 13 discusses how exploration of both problem and solution space is important. Usually the focus is put on exploring solutions to a given problem but with design thinking, the problem itself also needs further investigation, mostly through observing use cases or scenarios. The solution space is explored by continuous ideation and prototyping, and exploration of both spaces are iterated over and over throughout the project. This helps the design to be problem-relevant and to further refine and revise the solution. Brenner et al. (2016, p. 11) explains the steps

Table 2.1: Table of search string used and number of results of each document type. The search strings were all wrapped in TITLE-ABS-KEY but omitted in this table to ease reading.

Search String	Total Results	Article	Conf. Paper	Book Ch.	Book
”Knowledge management” W/10 (Purchasing OR Acquisition)	413	200	162	18	4
”Knowledge management” W/10 (Purchasing OR Acquisition) AND NOT (”Knowledge acquisition”)	138	73	49	7	2
”Knowledge management” AND Acquisition AND NOT ”Knowledge acquisition”	1 524	557	825	49	15
”Knowledge management” AND Procurement	234	95	113	6	4
”Knowledge management” AND procurement	234	95	113	6	4
”Lessons learned” AND Procurement	504	187	251	11	4
”Lessons learned” AND (”TPM” OR ”Total Productive Maintenance”)	5	2	3	-	-
”Lessons learned” AND (Procurement OR Acquisition) AND Automotive	14	1	12	1	-
”Knowledge management” AND ”Early management”	2	2	-	-	-
”Lessons learned” AND ”Early management”	10	6	1	-	-
”Lessons learned” AND ”Industrial engineering”	196	43	138	10	2

in a Design-Thinking-micro process as constisting of *Define the problem*, *Needfinding & Synthesis*, to understand the user, *Ideate*, *Prototype*, *Test*, and back to *Redefining the problem*, iterating the loop again. Brenner et al. (2016, p. 8) further explains the important principles in design thinking, a couple of them are: *Combining divergent and convergent thinking*, *Fail often and early*, *Build Prototypes that can be experienced* and *design never ends*.

When prototyping, the media used during the process is important to facilitate exploration of solutions according to Edelman and Currano (2011, p. 78). They further describe how so called *resolution* and *abstraction* are important aspects to creating shared models among design engineers. Resolution refers to the refinement that can be observed, for example, a rough sketch has a lower resolution than a CAD-model. Abstraction refers to putting certain characteristics out of context, to make something familiar into something unfamiliar. It is divided into the four classes *material, formal*, for example shape or appearance, *functions* and *mathematical*, for example dimensions. As a simple example, a rough sketch has a higher level of abstraction than a physical prototype.

With this framework, Edelman and Currano (2011, p. 65) found that a low level of resolution and high levels of abstraction helps designers think in new ways, and is associated with divergent conversations and paradigmatic shifts; and consequently, low levels of abstraction and high levels of resolution often resulted in convergent conservations and incremental changes.

2.4 Knowledge management

To better understand the concepts on how to improve knowledge sharing some basic concepts around knowledge management is needed. One distinction that is usually made, is one between data, information and knowledge where they are at different abstraction levels. **Data** is raw numbers and text that can exist in for example a database of some sort, **information** is this data processed somehow to put in some context and **knowledge** is this information processed by a mind and put in to relation to everything this mind knows (Dretske, 1983, p. 58; Vance, 1997, p. 2). There are different kinds of knowledge as well, they are usually divided in to three categories (Tryon, 2016, p. 34).

Explicit knowledge is any form of knowledge that has been captured or recorded using a formal physical mechanism.

Tacit knowledge is something that cannot be written down in numbers and words, easiest described as intuition.

Implicit knowledge can be described as something in between the latter categories, or as tacit knowledge that can be converted to explicit knowledge by using the correct processes.

Or as described in the flowchart in figure 2.2 below by Diugwu (2011, p. 106).

2.4.1 The Knowledge Value Chain

One tool used to both evaluate and to help reason about knowledge in organisations is the Knowledge Value Chain (KVC) (M. C. Lee, 2016, p. 217). The KVC is adopted from the business value chain model by Porter (1985) which is describing how value is created and contributing to competitive advantage for corporations.

The Knowledge Value Chain, as discussed by C. C. Lee and Yang (2000, p. 786), describes the process of knowledge management in 5 activities:

1. Knowledge Acquisition - To find information. This can be done in different ways. Either to actively search for it through some form of knowledge management infrastructure or through creating a "learning organisation", as

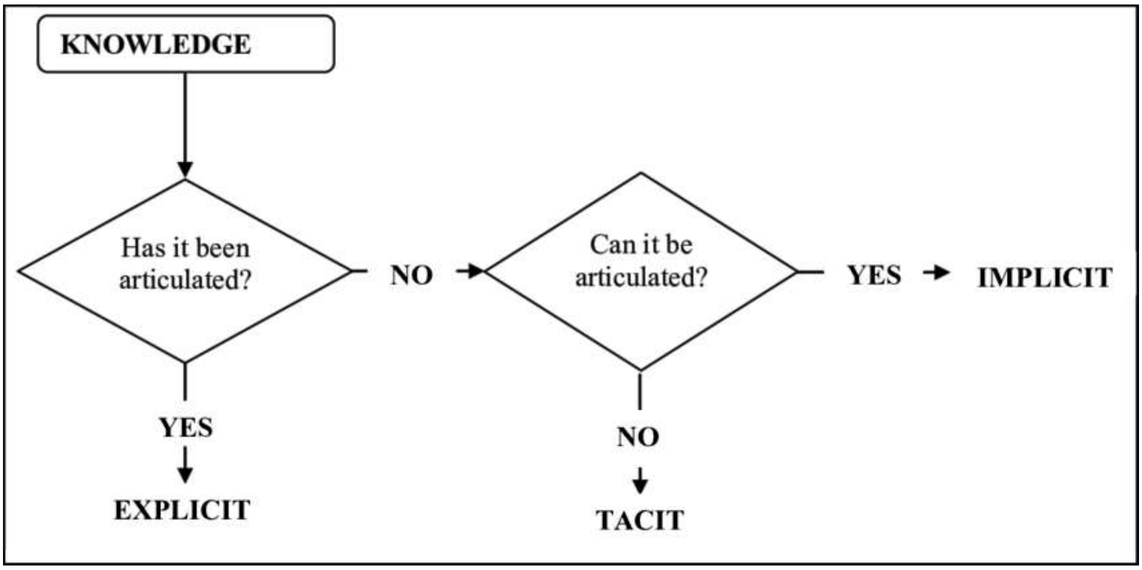

Figure 2.2: A flowchart describing the differences between explicit, tacit and implicit knowledge, from *Building Competitive Advantage of Small and Medium Sized Enterprises through Knowledge Acquisition and Sharing*, by Diugwu, I., 2011

proposed by Senge (1990, p. 7), with the first one usually connected to explicit knowledge and the latter to tacit knowledge.

2. Knowledge Innovation - This is the process of individuals creating knowledge through 4 different modes of knowledge conversion, from C. C. Lee and Yang (2000, p. 789):

    (a) from tacit knowledge to tacit knowledge, which is called socialisation;

    (b) from tacit knowledge to explicit knowledge, which is called externalisation;

    (c) from explicit knowledge to explicit knowledge, which is called combining; and

    (d) from explicit knowledge to tacit knowledge, which is called internalisation."

3. Knowledge Protection - Is the process of dealing with Intellectual Property Rights (IPR) like patents and copyrights. Also things like cybersecurity and what information which employees should have access to falls under this segment.

4. Knowledge Integration - Is the activity of putting the knowledge in to practice in the respective company's business context.

5. Knowledge Dissemination - Basically spreading information. Can be done in a number of different ways but one important thing to bring up is that "Dissemination of knowledge is a social process " and explicit knowledge is

something that can be shared through an IT-system.

These activities are then supported by 4 components of the knowledge management infrastructure. These can be seen in the visual representation of the whole Knowledge Value Chain in figure 2.3 below.

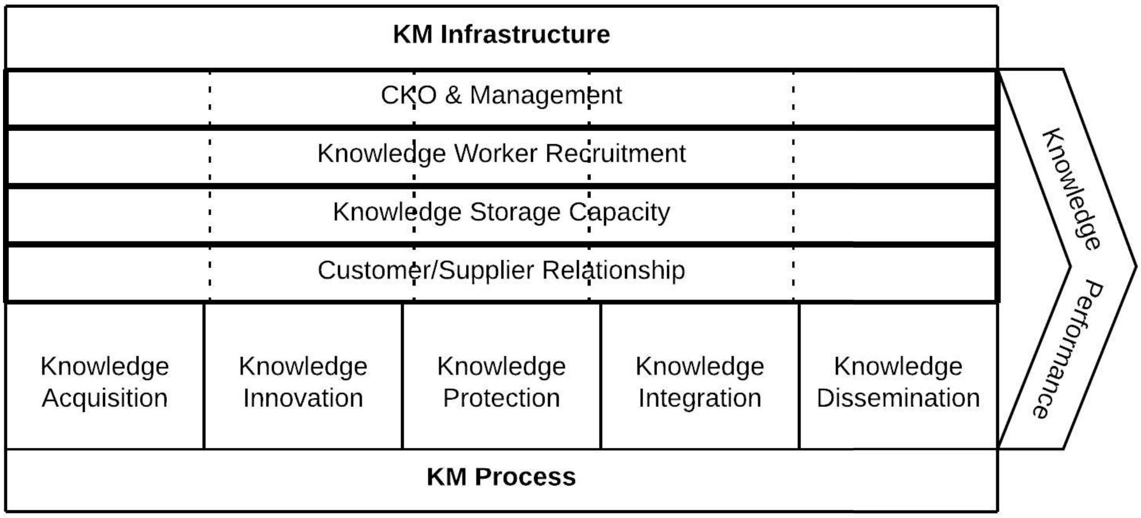

Figure 2.3: A visual representation of the Knowledge Value Chain. Adapted from *Knowledge Value Chain*, by Lee, C. and Yang, J., 2003

A supporting knowledge management infrastructure together with a well-working process is what creates knowledge value for businesses, which is important for their competitiveness in todays market (M. C. Lee, 2016, p. 213). The Knowledge Value Chain will be used to evaluate where in the case-company's process there is the most need for improvement, since "a chain is only as strong as its weakest link", according to Reid (1785, p. 41).

2.4.2 Barriers to Knowledge Management

Bouwmans (2003, p. 26) discusses barriers to knowledge management in the area of purchasing, and are found in table 2.2. It should be mentioned that table 2.2 is related to specifically purchasing rather than organisation-wide studies which other articles covers. Furthermore, what is true when studying purchasers, might not necessarily translate to engineers. Unfortunately, as studies regarding knowledge management or knowledge reuse within purchasing or acquisition-related domains are rare, some of the barriers brought up in this section will be more general as the studies in question do not generally cover specific areas in an organisation. Therefore, the following section will discuss general barriers and how they agree or disagree with the ones Bouwmans (2003, p. 26) found.

Table 2.2: Barriers to Purchasing Knowledge Management

1.	**No clear definition of knowledge** – Purchasing and purchasing managers are not aware of what knowledge is and thus what and why knowledge should be shared.
2.	**Purchasers are unaware of who owns what knowledge** – One reason why knowledge is not shared within organisation is simply that purchasers do now know each other or are not aware of the knowledge a colleague owns.
3.	**No incentive to share knowledge ("What's in it for me")** – Sharing knowledge is assumed only to be time consuming and no incentives are in place to motivate the purchaser to share its knowledge.
4.	**Geographically dispersed** – Because departments and groups of large companies are often physically and geographically dispersed, purchasers argue it is difficult to share knowledge.
5.	**Systems are no available or user-friendly** – Purchasers argue the available systems are not available, adequate or user-friendly.
6.	**The content of systems is not up-to-date** – Information is often not available in systems. Second, the information and knowledge is often not up-to-date or ambiguous.
7.	**Purchasers do not have the skills to use the systems** – Some claim they or their colleagues do not possess the skills to use the systems correctly. This concerns having the administrative skills as well as understanding what data should be entered in the systems and how.
8.	**No time is available to share knowledge** – Purchasers have no time available or do not take the time to share knowledge. Documenting their knowledge if often avoided because it is time consuming.
9.	**Transparency is threatening** – Transparency in processes, contracts and supplier relations means that some flaws may be revealed. Purchasers are afraid to be punished or criticised for these flaws.
10.	**Risk of becoming redundant** – By sharing knowledge, purchasers are afraid to become redundant and therefor lose their jobs.
11.	**Knowledge is regarded as power** – Knowledge gives an individual or a group a certain position in the organisation. Individuals are respected for their unique knowledge and groups gain benefits that other groups within the organisation cannot achieve.
12.	**Lack of respect for colleagues and their knowledge** – A lack of respect results in less communication, interaction and openness and thus in less knowledge sharing.
13.	**Knowledge is assumed to be unique** – Purchasers argue that projects they are involved in are unique. Sharing knowledge concerning these projects would be useless.
14.	**Knowledge is sensitive and confidential** – Purchasers have the perception that their knowledge is sensitive and confidential. Contracts and relation with suppliers for example can as a result not be shared.

Note: Adapted from *Purchasing Knowledge: Key to Purchasing Performance*, by Bouwmans, P., 2003

Many of the barriers brought up are mentioned by other authors as well, outside of the purchasing area. For example, there are multiple authors claiming trust and respect is essential for knowledge reuse, such as McNichols (2010, p. 34), who covers the perspective of cross-generation communication, specifically between baby boomers and generation X and Davenport and Prusak (1998, p. 24), who covers the topic of learning organisations. However, this is questioned by Schacht and Maedche (2016, p. 27-28), arguing that earlier research results on trust are outdated and trust is much less of a barrier than before, partly due to the growth of the internet. Seeing as the former two articles are either old or conducted on an older generation, the conclusions may be correct in each corresponding time and domain.

On a similar topic, that people assume knowledge is unique or regarded as power, Ardichvili, Page, and Wentling (2003, p. 69) argues that a reason for "hoarding" information is not because of selfish reasons, such as being the sole source of a certain knowledge to assert the organisation needs you; but rather due to a fear of contributing with information which is inaccurate or not important, and that fear of ridicule or criticism is a barrier for posting information on an organisation-wide system.

Further, problems with IT-systems are brought up by Chinowsky and Carrillo (2007, p. 128), arguing for the difficulties that come from utilising an IT-system which was not developed for the right purpose. So even though knowledge management and learning are not direct IT-issues, IT is essential to provide an infrastructure that allows for sharing and accessing knowledge.

Another barrier mentioned by other authors is the lack of time for knowledge sharing (Davenport & Prusak, 1998, p. 97; Wilkesmann & Wilkesmann, 2011, p. 106). Both articles also mention *space*, which can refer to both physical spaces as well as digital spaces such as e-learning systems, as a crucial component to successful knowledge transfer. Slack time is also reiterated by Haas (2006, p .1181) as an important factor towards superior knowledge gathering and ultimately superior project performance.

2.4.3 Lessons Learned

A definition of lessons learned, according to Project Management Institute, Inc. (2017, p. 709), is: "The knowledge gained during a project which shows how project events were addressed or should be addressed in the future for the purpose of improving future performance."

Another definition for lessons learned, brought up by Weber, Aha, and Becerra-Fernandez (2001, p. 18), is used by the American, European and Japanese Space agencies goes as follows:

> A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or

> decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result.

A similar definition comes from (Walden, 2011, p. 161):

> Results from an evaluation or observation of an implemented corrective action that contributed to improved performance or increased capability. A lesson learned also results from an evaluation or observation of a positive finding that did not necessarily require corrective action other than sustainment.

The two latter also putting focus on the need to acquiring lessons learned in the form of best practices; to not only look where the project went wrong but also finding positive results which can be applied to other projects.

Dülgerler and Negri (2016) describes how the process for developing lessons learned traditionally involves the three steps *Collection*, identifying and analysing lessons, *Documentation*, codifying and archiving lessons and lastly *Communication*, where lessons are spread to people who would need it. They discuss further how this is insufficient and requires two other phases: you need to *prioritise* the lessons before they are documented, and they need to be *assimilated*, that is, actually use the database. They further describe a couple of common traps:

- Finding experiences can be difficult as people might not want to share their own failures
- The form in which recommendations are written often become too general and "non-actionable", with no relevant instruction on how to implement the lesson. Another point which is also elaborated by Milton (2010, p. 177) and (Walden, 2011, p. 162) who argues advice should be specific and avoid phrases that are too general without clear results, as they are mostly not valuable.
- The vast amount of lessons can create a database which is too time-consuming to navigate to find lessons relevant to the task at hand.
- Unless it is practised thoroughly or as part of the tasks needed to be conducted, checking for earlier lessons learned can often be neglected at the start of a project or task, which deems all previous actions to collect them pretty much useless.

Regarding the last part of a traditional process, communication, it is similar to the KVC-step of dissemination, which is discussed in regards to lessons learned by Weber et al. (2001, p. 22). They bring up different types of dissemination and typical characteristics of each:

- Active Dissemination - The system dynamically notifies the user when it notifies a relevant lesson in context to the active process.

- Passive Dissemination - Users need to actively search for info while the system itself remains passive.
- Proactive Dissemination - Similar to active, but builds a model of the user's interface to predict when to notify the user with relevant lesson
- Reactive Dissemination - Similar to a helpdesk, or a help system.
- Active Casting - Lessons are sent to profiles which could potentially use it.
- Broadcasting - An example of this are bulletins which are sent to everyone in the organisation.

Milton (2010, p. 27-31) discusses two fundamental choices that impact how a lessons learned system will be designed: deciding the degree of formal/informal system and whether the focus is on connecting people or collecting lessons. This creates four approaches, which are illustrated with examples in figure 2.4, each with different strengths and weaknesses. For example, a *formal collect* system can often be difficult to fill with content but easy to retrieve, while an *informal collect* in a wiki-based manner may make it easier to enter basic content, it can also cause lessons to missed; either from ever getting into the system or from finding their way to the user that needs them. A *formal connect* approach can be favourable in an environment where problems are always changing but are less appropriate when it comes to standardised procedures and the lessons can be used in general guidelines or standards. Finally, the approach of *informal connect* is exemplified by social medias; where it is incredibly easy to find discussions, questions and answers that might be beneficial for the organisation. However, it can also be difficult to distinguish gossip from lessons, making it an approach which is not appropriate for systematic knowledge sharing.

In summary, having a "blended approach" is recommended by Milton (2010, p. 31), where the system utilises both connect and collect qualities. When it comes to formal and informal approaches, there needs to be a balance rather than a blend; as a formal system running in parallel to an informal system can cause confusion if the same lesson differ in the two systems. This is a point also argued by Powell (2001, p. 6), where informal knowledge exchange should be encouraged.

The connect/collect dimension is connected to the major decision of whether the author should be anonymous or not; Weber et al. (2001, p. 25) mentions anonymity as a way to find more realistic lessons as there is less risk of consequences by sharing negative experiences. However, there are benefits to disclose the author according to Milton (2010, p. 178), as that enables the reader to connect with the author if additional information on the topic is needed. And as previously mentioned, utilising both connect and collect approaches is recommended, which requires an author to each lesson. Thus, it needs to be carefully evaluated whether the authors identity should be disclosed or not.

Further, Milton (2010, p. 175-184) presents a long list of tips on how lessons learned should be conducted efficiently, many of which are already discussed but here are

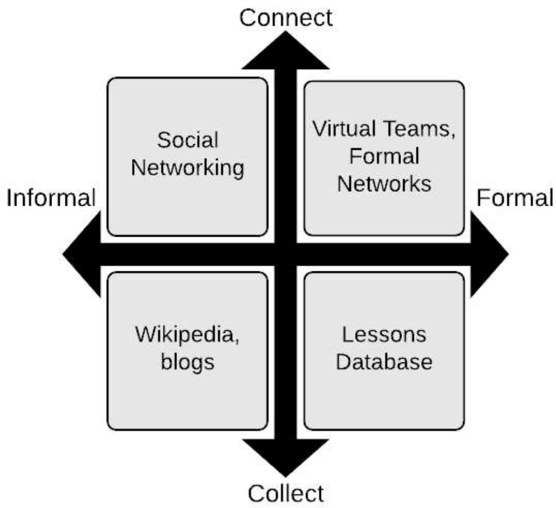

Figure 2.4: The four quadrants of learning approaches. Adapted from *The lessons learned handbook : Practical approaches to learning from experience*, by Milton, N., 2010

a few of them: Have scheduled lessons learned at regular intervals throughout the project, use a moderator to let input from everyone but ensure to stay on the topic, write lessons with the reader in mind and ensure that documentation is easily accessible.

When it comes to maintaining a lessons database, multiple authors mention the importance of verifying the lessons that goes into the system. (Dülgerler & Negri, 2016) argues that the amount of lessons can become overwhelming as every stakeholder thinks lessons that improve the process within their area are more important than other; causing a mess of ambiguous lessons that does not focus on the actual root-cause problems unless prioritised correctly. This is elaborated further by Milton (2010, p. 178) and (Walden, 2011, p. 166), where a quality assurance or review of the lessons learned database is necessary. Also (Weber et al., 2001, p. 21) note the importance of validating the lessons for redundancy, relevancy and correctness. Unless the database is maintained, you run the risk of making it become a case of finding the "needle in a haystack" again, which can cause employees to be less inclined to use it. This in turn lessens the motivation of putting relevant content into the database, making it even harder to find the relevant lessons.

2.4.4 Engineering Checksheet

A tool used to capture and transfer knowledge is an Engineering Checksheet (ECS), as discussed by Stenholm, Catic, and Bergsjö (2019, p. 8), which is in essence a checklist of actionable and experience-based knowledge elements which consist of one or several Know-what's, often accompanied by *Know-how's* and *Know-why's* which details how to perform an action and during which circumstances to apply them. It is also beneficial to include references to other documents or people when needed. An ESC should also strive towards quality over quantity and make it as condensed as possible, as overly detailed descriptions can be confusing and difficult to assess. As for merits of using ECS, Stenholm et al. (2019, p. 26) found that inexperienced engineers in particular benefits from using it, but found that it can be tedious to go through the documentation. It is also beneficial for experienced engineers, however slightly less, but acts more as stress-relief as they can make sure all actions have been taken rather than relying on memory. It is also easier for an experienced engineer to go through an ECS as they usually only need to glance at the ”know-what” to get a sufficient overview.

Table 2.3: Evaluation Factors of a knowledge management system

Step	Evaluation factor
Acquire	Findability – Knowledge is found with minimal effort and time
	Understandability – Content and rationale is understandable with minimal effort and time
Assess	Validity and Reliability – Knowledge is trustworthy and replicable
	Evaluability – The knowledge is easily assessed based on its value in current context
Apply	Applicability – The knowledge is reused in a current context
	Actual value/Problem Solved – Applying knowledge leads to bringing development forward
Create	Knowledge Gap identification – A knowledge gap is easily identified between existing knowledge and the necessary knowledge required
	Expandability – Possibility to build upon existing knowledge
Identify	Identifiability – New knowledge is easily identified
	Extractability – New knowledge is easily separated from existing codified knowledge
Refine	Createability of new records – New knowledge is easily codified
	Manageability – Existing knowledge record is easily updated and managed
Disseminate	Shareability – The knowledge can easily be prepared for availability and accessibility to an arbitrary receiver
	Transferability – The knowledge can easily be transferred to a specified receiver

Note: Adapted from *”Knowledge reuse in industrial practice: evaluation from implementing engineering checksheets in industry”*, by Stenholm, D., Catic, A., Bergsjö, D., 2019, *Design Science*, 5(15), p.8

Further, Stenholm et al. (2019, p. 7) describes the steps of a knowledge management cycle: *acquire, assess, apply, create, identify, refine,* and *disseminate*, as well as factors which are important to achieve to valuable flow of knowledge. The factors are connected to a step in the KM cycle and are summarised in table 2.3.

Another important aspect of knowledge sharing is brought up by Powell (2001, p. 6) as the importance of *informal exchange* of knowledge. For example running in to someone in the hall or talking by the watercooler. This gives people a chance to let someone know of a small update they did to something or possibly what went horribly wrong in their latest big project.

2.5 Industry 4.0

Industry 4.0 is described as the fourth industrial revolution, the first being the invention of the steam engine, the second came with the invention of electrical motors and the third when computers and the internet came in to our lives. The fourth industrial revolution comes with automation and computers coming together with ”The internet of things” and big data analysis (Boone, 2019). This will presumably lead to an increased amount of automation in factories, together with information about everything from quality of products to what maintenance might be needed for the machines (Li, Fast-Berglund, & Paulin, 2019, p. 3291), to name a few examples. To accomplish this, the first part is to have everything within the factory digitised as can be seen in figure 2.5.

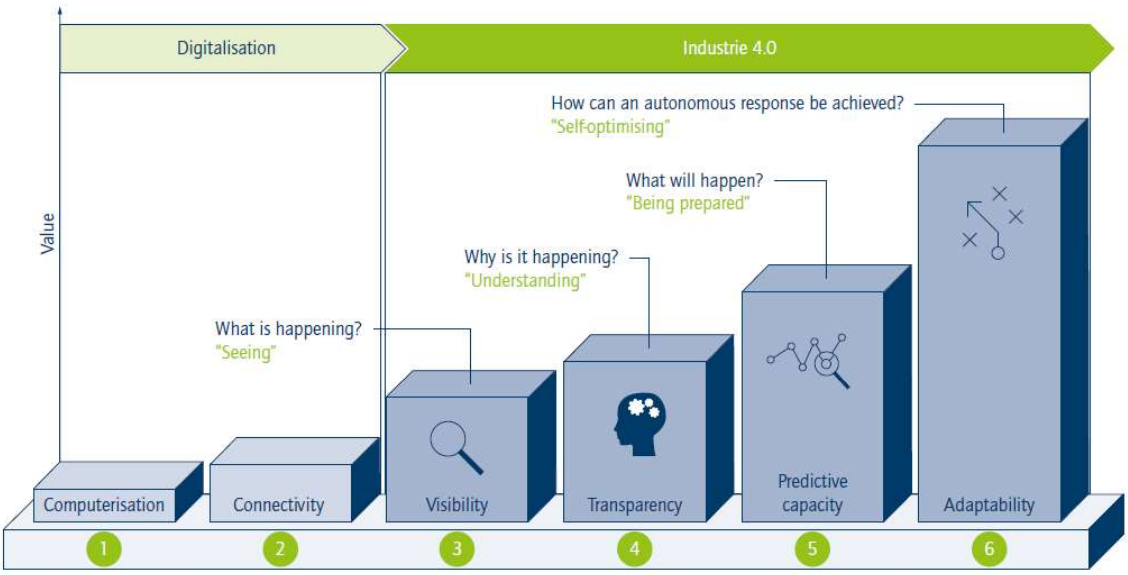

Figure 2.5: The levels of maturity in Industry 4.0, reprinted from *Industrie 4.0 Maturity Index - Managing the Digital Transformation of Companies*, by Schuh, G., Anderl, R., Gausemeier, J., ten Hompel, M., Wahlster, W., 2017

Adopting towards Industry 4.0 and higher levels of automation will relieve more time for value adding work for engineers and other employees to use the full potential of their knowledge. It will also let the companies deal with more variation in products and more customisation.(Thoben et al., 2017, p. 4)

The case company defines the areas of Industry 4.0 as shown in figure 2.6.

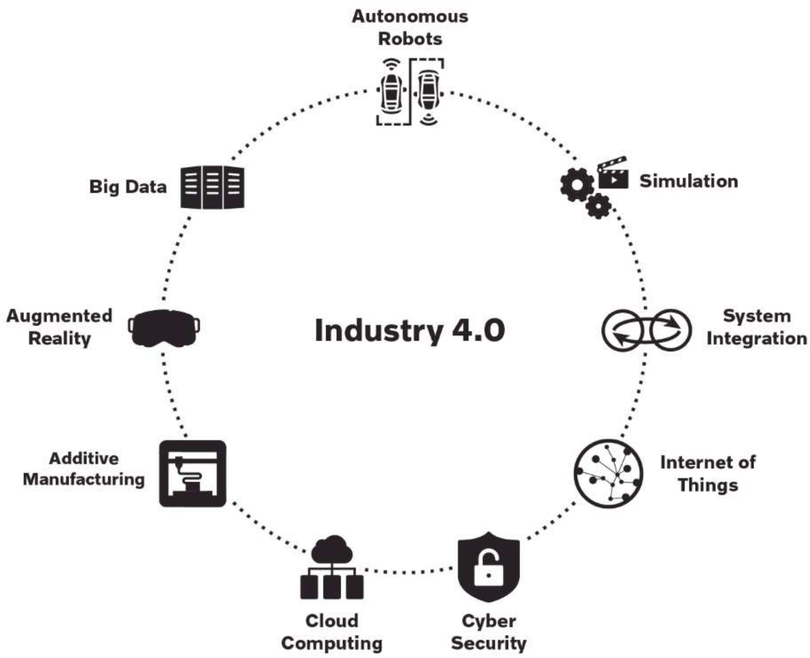

Figure 2.6: Illustration of the areas of Industry 4.0 as thought by the case company

The following sections will shortly describe the areas most relevant to this thesis.

- Big data - Can in many ways be seen as kind of the heart of Industry 4.0 (Marr, 2015, p. 9). By "Big Data" many mean that with more digitisation anything that happens will leave some form of digital footprint or "data". This data can then be used to gain important commercial insights for companies but also help everything from crucial scientific research to smaller tasks in managing your home, reference. Managing bit data usually involves standardising data to be able to draw better and more reliable conclusions.

- Internet of Things - Much as our computers and cellphones are connected today via the internet, the future proposes that almost anything can be connected to the "The internet of Things", connected to each other and therefore being able to communicate and take in to consideration what other things are doing. E.g two machines connected to each other dealing with a faulty piece in the same way (Thoben et al., 2017, p. 9).

- System Integration - Means that the current systems that are in place today in many companies, for example a maintenance system or a resource planning system. By integrating these systems they are able to communicate and allow users to access data between systems, allowing for better and more effective data analysis (Schuh, Anderl, Gausemeier, ten Hompel, & Wahlster, 2017, p. 26).

2.6 Artificial intelligence

Another important subject within Industry 4.0 that isn't covered by the case company is that of Artifical Intelligence.

Artificial intelligence or AI can be described as trying to make machines think like humans (Wodecki, 2019, p. 86). One reason for this is to help humans process large amounts of data that otherwise would take far too long for humans to deal with, to gain new insights and even to make decisions for us in various processes, which is why AI is interesting to this thesis.

2.6.1 Information sharing and Artificial Intelligence

One particular field in which this is interesting to this thesis is connected to the before mentioned Industry 4.0, explained in section 2.5, where the idea is that with the emerging connectivity and data collection, factories will be able to process data and make decisions on their own even without human interaction (Li et al., 2019, p. 3953). As Li et al. (2019, p. 3951) describes *"Technologies which enable the emerging phenomenon of Industry 4.0 have the possibility to simplify the sharing of information and knowledge among people at work"*. Some different kinds of systems that can do this are as follows.

Knowledge based expert systems

These range back from the early 1980s and the general idea behind them are that facts and rules are created in a "Expert system" that other users later can ask questions and get answers to them, very simplified. This works by an inference engine that performs the logical manipulation and deduction of responses, the full structure can be seen in figure 2.7.

Neural Networks

Neural networks are comprised of numerous nodes that are similar to the axons of the biological brain, these are connected through weighted information links as the dendrites of the brain(Fowler, 2000). The idea is that these systems are trained with given data from decisions taken previously, provide all the inputs any human was given and the decision that was made from this. From this the weightings of the links between inputs are changed progressively to adjust toward the "ideal solution". When this has been done the network should be able to deal with similar decision making given any inputs and can be useful for recurring decision making problems where the input data is quite similar. These differ greatly from the more knowledge based systems where facts and rules are put in to the system, but rather a *set of assumed empirically derived relationships between data.* (Fowler, 2000, p. 112).

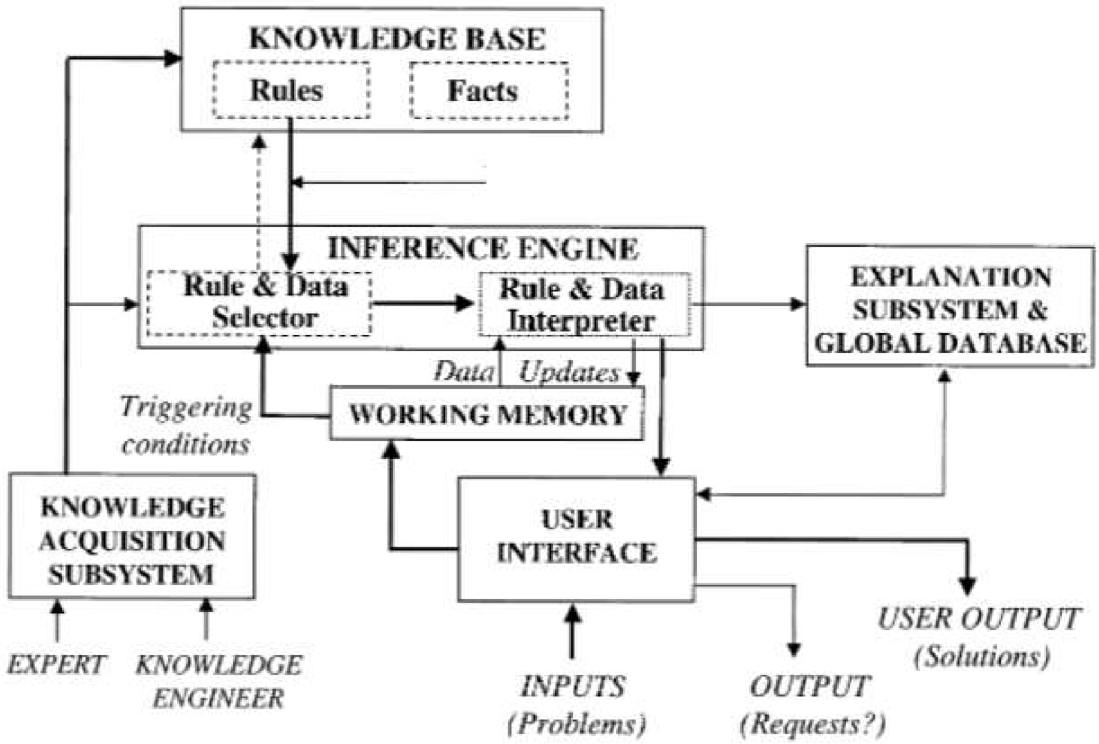

Figure 2.7: Systematic view of how knowledge based expert systems work, reprinted from *The role of AI-based technology in support of the knowledge management value activity cycle*, by Fowler, A., 2000

Case-based reasoning

This system is similar to Neural Networks in that it takes raw data from past cases and solutions, but rather than finding relationships between inputs it only tries to find relevant cases to what the user is looking for to solve. What the user found and how they used the data can then be appended back to the system for future use and thus creating new knowledge for the system to display (Fowler, 2000, p. 113).

To be able to use these systems as efficiently and accurately as possible the quality of the data collected is very important. As this data is processed through computational power it is easier to determine correlations and patterns if the data is uniform and standardised (Wodecki, 2019, p. 77). For example, if someone refers to ”project phase A” at one place and ”projectphaseA” in another, it requires more effort to tell that these mean the same thing rather than having them both be ”project phase A” from the beginning.

2.6.2 Natural Language Processing

Within the field of Artificial Intelligence and Data Analytics a subfield called Natural Language Processing (NLP) exists. In short this is a way to interpret text written by humans. It accomplishes this by a variation of algorithms and rules to recognise different patterns in the text and translate it to different analyses based on what patterns to look for provided by users (Manning & Schütze, 1999). This can be used, for example to categorise lessons learned based on free-text answers. There are also software available that can search through large amount of documentation to try and find important lessons and other data relevant to business analytics, for example *MAANA* and *Sparkcognition*.

2.7 World Class Manufacturing

The overall processes and thinking regarding the production system that is used by the case company and what this report is largely based on is called World Class Manufacturing, developed by Yamashina (2000). The basis for thinking in WCM is this temple, reliant on a foundation of *Management Criteria* with eleven pillars of focus areas on which the total of World Class Manufacturing (WCM) is supported by, this can be seen in figure 2.8. WCM is coming from the basis of lean manufacturing which has been a largely adopted way of thinking and working for a long time in industry.

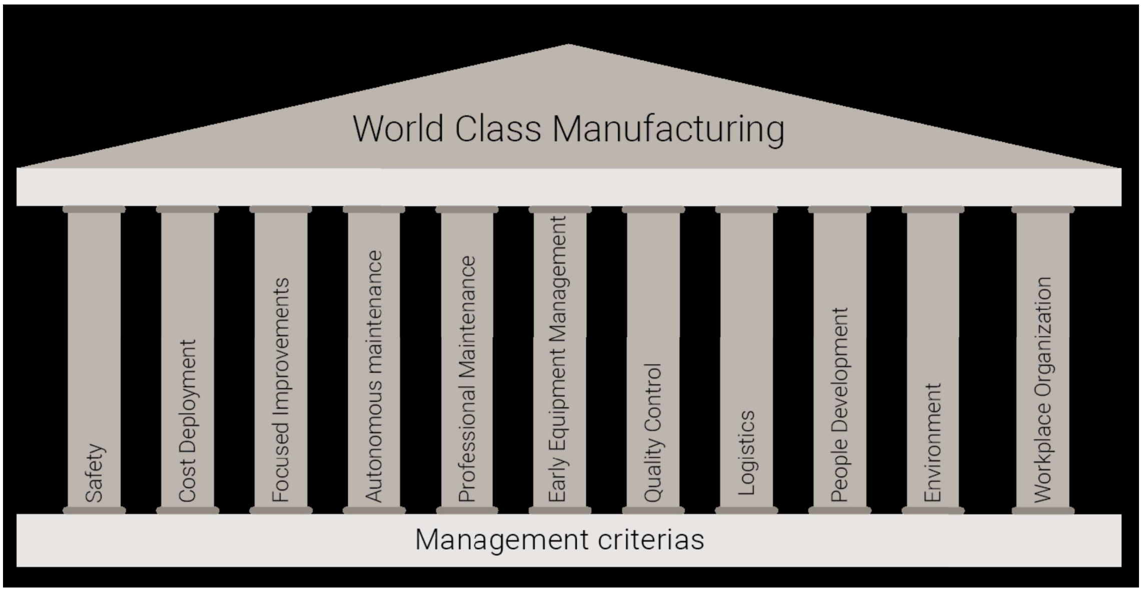

Figure 2.8: Illustration of the temple of World Class Manufacturing (WCM). Adapted from *Challenge to world-class manufacturing*, by Yamashina, H., 2000

All plants within the case company that adopt this way of working are evaluated on these focus areas together with the management criteria to get a score on how well they are performing.

2.7.1 Early Equipment Management

This report will not go in to detail of each focus area, but will be mainly focused on Early Equipment Management (EEM), which is the process for acquiring new machines to factories and how to get the most out of them by aiming for zero breakdowns.

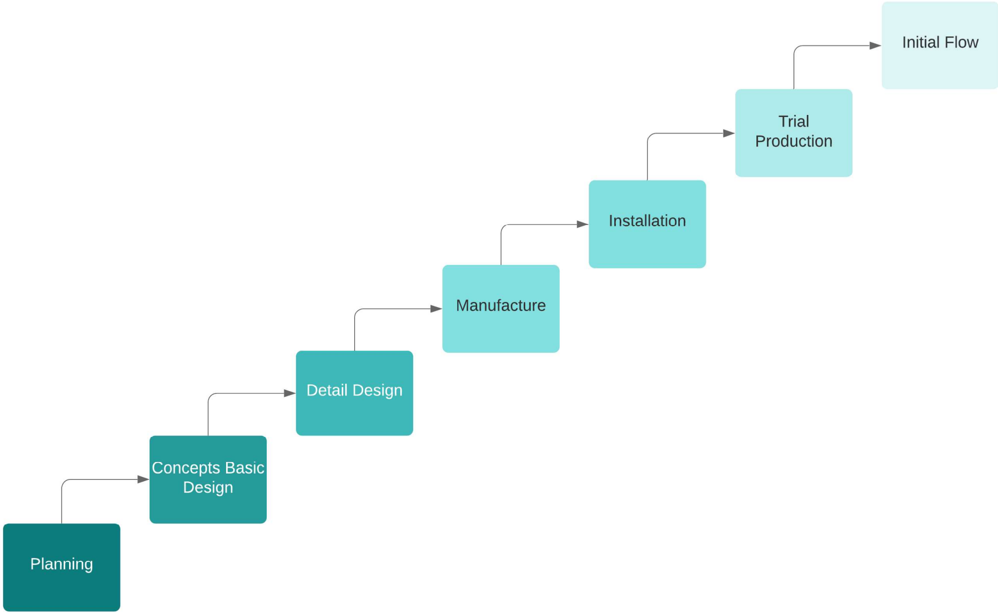

Figure 2.9: Illutrations of the 7 steps of EEM

EEM is described as a closed loop where the start is to understand the current situation and what problems to close with the new equipment. As it is defined, there are 7 Steps of this process as can be seen in figure 2.9. Each of these steps consists of a number of different actions that the project group working with this particular acquisition are to perform. These actions form the process and are largely connected to different document templates and specific deliverables for each task. The process model is a stage-gate process which means that after every step in the process the project is evaluated and determined if it will keep going or not. To evaluate how well different plants are adopting the production system there are 7 levels of maturity for EEM as can be seen in figure 2.10.

To be more resource-efficient, front-loading information gathering and knowledge

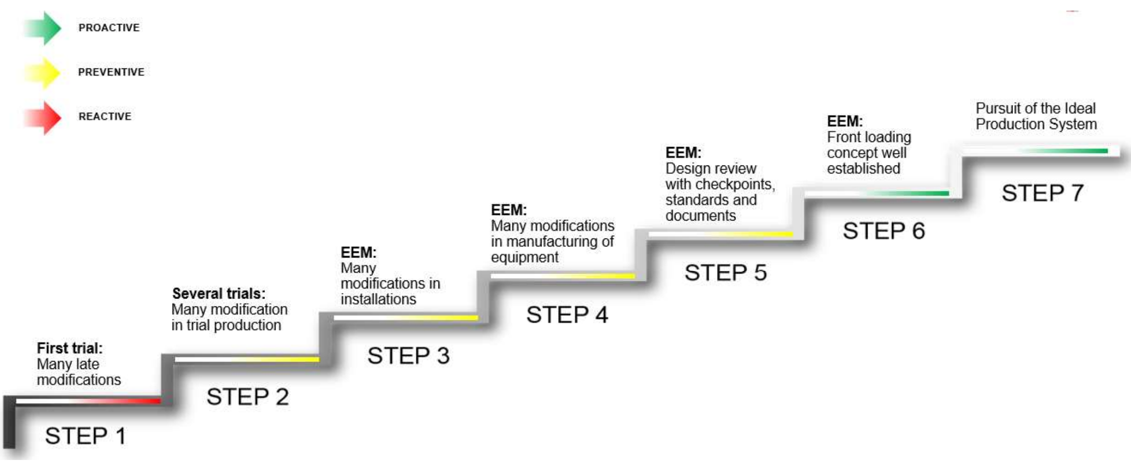

Figure 2.10: Illustration of the 7 levels of maturity of EEM

transfer in a project is preferred. The later problems arise in a project, the more expensive they are to handle, as the cost of design changes increase rapidly when made late in the development process (Folkestad & Johnson, 2001, p. 3).

2.7.2 Documents in EEM

There are up to 40 different types of documents that can be found for EEM-projects at the case company, not counting CAD-drawings and other similar necessary things, more closely connected to the machine itself rather than the project. Since this report focuses on finding points that could differ and improve between projects, the documents presented below are the ones that could contain the most of this information.

Acceptance Record and Handover Record

These records are documents that are supposed to follow the process of acquiring new machines. Acceptance Record (AR) is between the supplier and the purchaser and is used to monitor the progress of the purchase through the gates of the EEM-process and to illustrate any aspects of the machine which does not fulfil the requirements so any shortcomings can be dealt with by the supplier. Examples, and a more detailed explanation, of the different parts of an AR can be found in appendix B – F.

The handover is essentially the same document as AR but between the project-team and the line organisation that is taking over the machine at the end of the project.

Meeting Minutes

Meeting minutes are protocols from meetings between the buyer and the supplier and this is where agreements that differ from the *Technical Specification* and the *Scope of Supply* are recorded. For example changes to the design/demands of the machine or changes to the time-plan.

Technical Specification

The Technical Specification is a document of around 400 requirements that apply to all machines bought by the case company, these are general requirements that are updated once a year to try to be up to date with what the plants need from their machines.

Scope of Supply

The Scope of Supply is a list of requirements that are specific to each machine. This means that the Scope together with the Technical specification makes up the total list of requirements put on these machines. The Scope consists of around 400 points.

Whitebook

The Whitebook is a document where everyone that has been involved in a project can contribute with what went bad and what was good with each project. This can then be used to improve the next project. It can be found in the form of a single whitebook that is continuously updated after each project, thus consisting of multiple projects, or as a separate whitebook for each project with lessons learned from that project.

3

Correlation between project documentation and breakdown data

This chapter covers methodology and results in the search for connections and correlations between project performance and machine performance. As such, it is mainly covering the first research question, Is there a correlation between breakdown data and project documentation.

3.1 Approach to first research question

As this project began, it was recommended by the case company to start off the project by looking at Acceptance and Handover records as these were thought to contain very relevant information to how an acquisition project performed, and follows the project throughout the whole process. Earlier work within this area as mentioned in section 1.2 revealed that some machines cause major issues in the production and a lot of these issues are problems that should be able to avoid as early as in the acquisition process. To find an answer to why this is, everything that could point to why some machines perform so much worse than others needs to be found.

3.2 Acceptance and handover records

To find an answer to RQ1, work was needed to clean up and summarise the data that was given. The handover records did not seem to contain much of interest relative to AR and was therefore ignored, to focus on the AR instead. The AR, which are explained in section 2.7.2, has some interesting data and the number of problems found when going over the machine were chosen as the main focus as it represents what might have been possible to prevent by fixing it earlier. All entries from the action page were transferred into a separate sheet and summarised; a small part of the sheet can be found in 3.1. For the breakdown data, help was given from employees at one of the plants and the most interesting statistics were given directly in sheets provided by them. This sheet provided a list of machines, bought between

Part nr	Tagged (Y)	Tag Type	Started Date	Started (person)	From which point under status	Equipment ID	Subject	Description
8536193 - OP30-2.2			[illegible]	[illegible]	2.1	Automation	Mechanical	Seperate air pressure check for the glasscales
8536193 - OP30-2.2				[illegible]		Op132-2 (8536194)		Seperate air pressure check for the glasscales
8536193 - OP30-2.2			[illegible]	[illegible]		All machines		Why is Password needed for toolchange
8536192 OP30-2.3			[illegible]	[illegible]	2.1	All machines	Mechanical	Seperate air pressure check for the glasscales
8536192 OP30-2.3			[illegible]	[illegible]				
8536192 OP30-2.3			[illegible]	[illegible]				
8536194 - OP132-2			[illegible]	[illegible]	2.1	All machines	Mechanical	Seperate air pressure check for the glasscales
8536194 - OP132-2			[illegible]	[illegible]		Op132-2 (8536194)		Head for drilling holes . Coolant in the head Nr 3
8536194 - OP132-2			[illegible]	[illegible]				Head for drilling holes . Op130 Coolant in the head Nr 2and 4
8536197 - OP210-2			[illegible]	[illegible]	2.1	All machines	Mechanical	Seperate air pressure check for the glasscales

Figure 3.1: Excerpt from the AR-summary. Not all columns are shown, nor all rows, but the full sheet included the same columns as the original AR template.

2014 and 2019, with various information for each, such as function, acquisition cost and year installed. There is also a column for supplier, but it is not used. From the provided information, it was possible to see which machines had cost the most to maintain, how much they cost to acquire and much more.

When summarising the AR, the lack of standardisation was a clear problem. A lot of them were missing information regarding which machine/machines it covered; actions was often missing some information, be it ”Tag Type”, ”Subject”, ”Equipment ID’ or most notably ”OK Contractor”. It was also concluded that the AR did not bring enough information about the whole EEM-project to conclude what might have caused a high number of breakdowns and maintenance for the worse performing machines.

Therefore, another strategy was needed and it was decided that **all** project information/documentation from the better performing and the worse performing machines would be needed to further investigate if a correlation could be found between project performance and machine performance. High machine performance in this case would be referring to few breakdowns and low maintenance cost.

3.3 Comparing remaining project documentation of a select few projects

To further investigate the correlation, it was deemed too difficult and cumbersome to compare documentation from all machines in the plant, not to mention the difficulties of finding the documentation in the first place. Therefore it was decided to narrow it down to just a few machines.

3.3.1 Using Power BI and Excel to find appropriate projects

To find suitable machines to compare, data from multiple excel sheets were used. These include a register of all machines in use with their acquisition value, data from all EWO’s on these machines and the corresponding maintenance costs. The data was compiled in Power BI and the total maintenance cost and total number of EWO’s for each machine was calculated. The machines in question were installed between 2014 and 2019. This was then used to filter the machines, omitting extreme outliers in terms of acquisition value, as conclusions from an abnormally costly, or an abnormally cheap, project most likely can not be applied to an arbitrary project. Another filter was applied; namely the function it is belonging to. In the plant in question, there are three main functions, two of which were deemed inappropriate, the first function due to being too simplistic and the second due to the complexity and large intervals between purchases of new machines.

Lastly, the remaining machines were compared in terms of maintenance cost and number of EWO’s, short for Emergency Work Order which is issued every time a machine breaks down, per year in use, to find suitable projects to look up. The machines used in this comparison can be found in figure 3.2. The colours were

Object	Year installed	Purchasing cost	Maintenance Cost	Maintenance Cost / year	No of EWO	No of EWO / year	No of maintenance cost entries / year
Machine 1	2015	3526310,52	170161,65	34032,33	127	25,40	125,00
Machine 2.1	2015	2558730,30	236812,72	47362,54	42	8,40	51,00
Machine 2.2	2015	2665231,19	336679,95	67335,99	82	16,40	86,00
Machine 3	2015	2068259,74	311793,38	62358,68	95	19,00	110,00
Machine 4	2016	3706459,53	300229,17	75057,29	85	21,25	159,00
Machine 5	2019	4038154,41	112098,36	112098,36	87	87,00	286,00
Machine 6	2019	4057833,29	71675,59	71675,59	44	44,00	154,00
Machine 7	2015	2456665,35	112278,36	22455,67	49	9,80	56,00
Machine 8	2018	933127,03	84909,47	42454,74	35	17,50	86,00
Machine 9	2018	594753,00	7668,14	3834,07	6	3,00	14,00
Machine 10	2015	1090823,45	28492,95	5698,59	16	3,20	11,00
Machine 11.1	2016	2406034,19	51345,84	12836,46	30	7,50	40,00
Machine 11.2	2016	2387309,19	41786,50	10446,63	21	5,25	27,00

Figure 3.2: A table of machines chosen for intermediate analysis of maintenance cost and EWO data, which was then used to select a few for further analysis.

formatted using a 3-scaled "Conditional Formatting" with the average of each parameter acting as middle-point. The average in this case is still the average from all machines in machining, not solely the ones used in this comparison. The colouring was used to visualise and make it easier to process the information. It was noted that Machine 2.1 and Machine 2.2 were identical machines, as is Machine 11.1 and Machine 11.2. Further, it was noted that all four share the same supplier but had widely different statistics, with the more costly pair, Machine 2.1 and 2.2, costing the company seven times more in maintenance than Machine 11.1 and 11.2. Another note was how Machine 2.1 and 2.2 varied significantly as well, with Machine 2.2 causing two times as many EWO's as its counterpart.

Therefore, these four were deemed the most interesting to analyse further, along with Machine 5 which have a staggering amount of EWO's considering it has only been in use since 2019. Lastly, Machine 10 was chosen for further analysis since it had relatively low maintenance as well as number of EWO's. The reason to disregard Machine 9 although it had the best record of the machines was due to it being a robotcell, a type of machine which overall was relatively unproblematic. This resulted in six chosen machines, three on the worst end of the spectra and three on the best end.

3.3.2 In depth analysis of four similar projects

Some of the projects chosen were quite similar and thus seemed very good to look at. Their acquisition cost were approximately the same and took roughly the same amount of time to complete. The case company also bought two of each of these machines. One set of machines has not caused a significant amount of maintenance cost whereas the other set has caused a lot of costs.

There are a lot of documents connected to these projects. Many of these are only machine-details like drawings etc. These were not looked through as they are unlikely to contain information about what the case-company did correctly and incorrectly during these projects that might have led to the respective performance of these machines.

An overview of all the documents, what type they are, what they contain and if they are specific for each machine or if they are connected to a project that involves multiple machines can be found in appendix H.

All documents were gone through thoroughly and put next to each other to compare if there were any major differences in the projects and in the documentation. This was done mainly by a qualitative review where the text was read through and getting an idea of how the project went and what might have gone wrong. Some quantitative research was done as well by comparing sheer numbers of, for instance, actions to be fixed after testing of the machine. The plan was also to interview these project leaders, but since this work was done during the COVID-19-outbreak it was hard to get in touch with these people. The points of interest of what was found was these:

- The worse performing set of machines had 140 entries of action in their AR and the good had 100 entries.
- The project tied to the worse performing machine seemed to have more significant delays during their project due to different causes like waiting for documentation from the supplier and pushing installation dates since the equipment was not ready in time.
- Slightly higher number of warranty issues on the worse performing set of machines.
- More thorough documentation on the testing for the better performing set of machines.

The overall evaluation was that these points give an indication to might have gone wrong with these projects. However, they were not significant enough to say anything for sure regarding their correlation to the performance of these machines, since it's only one deep-dive in to this type of documentation. Worth to mention is that nothing in this documentation could be used to determine how much information from earlier projects could be re-used or used to improve these particular projects. What was the most interesting though, was that many of these documents contained information that potentially could be very beneficial to know in other similar projects.

4

Improving the acquisition process by facilitating knowledge reuse

This chapter covers research question two: an initial background to the problem, the method towards a solution, and the development of a tool to aid knowledge reuse. Throughout this chapter, terms like lesson, experience and similar are used interchangeably but they refer to the same idea that is Lessons Learned, which is explained in section 2.4.3.

4.1 Background to answering research question two

As previously mentioned during the search of documentation, found in section 3.3, it was observed that the whitebooks had a substantial lack of standardisation, in many cases a lack of relevancy for future projects which undermines the purpose of the whitebook; and a lot of information that could be put in to whitebooks were mentioned elsewhere in the documents. This was echoed by transcriptions from interviews conducted by Blomberg and Håkansson (2019, p. 29), where multiple interviewees noted how looking through whitebooks is a tedious and often fruitless labour. The lack of relevancy was also noted by interviewees, arguing it is a good thought in theory but does not translate well into practice with the current method. This was also argued by a project manager, mentioning how whitebooks are used when working with frequent suppliers, as they are often specific to each supplier; and although a few points might be usable for other projects as well, the amount of information is difficult to take in (Anonymous, personal communication, March 3, 2020).

To get an overview of how much information could be gathered and thusly the potential of being able to reuse this information, the project documentation mentioned in 3.3.2 was revisited but this time the search was for specific relevant data to other projects, what documents contain this data can be found in appendix H. In total 22 out of 39 of all project documents were deemed to contain relevant information. These are documents that currently are never revisited and contain a lot of other irrelevant information, which makes it hard to bring this information onwards.

A potential improvement for the EEM-process, brought up by Blomberg and Håkansson (2019, p. 60) *Introduce a central knowledge repository for EEM*, indicated a need for a better process for knowledge transfer. This includes both a method to systematically capture knowledge and improvements as well as disseminate the knowledge between projects, with the intention to avoid making the same mistakes again and reduce unnecessary work. Therefore, the process and result of the development of such a tool is the focus of this chapter.

Important to note regarding the whitebook is that extensive searching was conducted, both on the internet as well as the case company's intranet, to find definitions of whitebook without success. It was noted however, that the usage and how interviewees had mentioned the whitebook suggested it was a way to capture important experiences to bring to future project; a task which is usually associated to the area of lessons learned. Which is the explanation for why the literature study was focused on lessons learned and relating terms instead of whitebook.

4.2 Method for developing a solution

The overall method for developing a solution to this problem is largely based on Design Thinking, explained in section 2.3. The key process of which is to go through the steps *Define the problem*, *Needfinding & Synthesis*, to understand the user, *Ideate*, *Prototype*, *Test*, and back to *Redefining the problem*, iterating the loop again. What is important here is that it is an iterative process, which means that each of these steps are revisited multiple times, the problems and needs are continuously updated and a number of simpler prototypes and tests are made.

To get clear view of what has been done in this project, the following sections describe the work for each step in its own chronological order as it makes it easier to see the whole process. In other words, the following is not showing the process in chronological order, as ideating, prototyping, testing etc. revealed new input for other steps as the work proceeded and are therefore presented in the appropriate section rather than the section the result originated from.

4.3 Define The Problem

To frame the initial problem and starting point, a short brainstorming session was conducted; capturing different topics related to the one at hand: *not reinventing the wheel, support for the entire KVC, support decision-making, minimise loss of knowledge* and many more. Further, the *who, what, where and why* for this problem was defined to ensure the right focus when solving the problem:

- Who - Project group
- What - Utilising earlier experiences, to their full potential
- Where - In the EEM-process

- Why - To reduce non-value adding work

These were combined to a *Goal* and a *Problem Definition*, and with multiple discussions and iterations regarding both goal and problem definition it finally culminated in the following:

Goal: Reduce wastes in the acquisition process

Problem Definition: How can the team improve how they utilise experiences from earlier projects?.

The problem definition is the most important factor of the two when considering solutions throughout the development, as it sets the mission for what the solution shall actually achieve.

4.4 Needfinding & Synthesis

As a start, a couple requirements were gathered from reading interview transcripts from Blomberg and Håkansson (2019). The most relevant ones are presented below.

- Accessible to all relevant users
- All relevant perspectives should be covered
- Reduce non-value adding work
- Ease the search of relevant data, relative to the system used today
- Ease the interpretation of data
- Relevant to the end-user, not necessarily the author

From the first ideation cycle found in 4.5, more requirements were found based on the literature:

- To maintain a focus on Industry 4.0, there is a need to *include digital solutions*, which can aid the user in navigating and searching, as the amount data involved would turn it into a very laborious task if done manually with physical objects such as archives and folders.
- Preferably, *passive and proactive dissemination should be used* simultaneously. Realistically, in this stage of development, there is little chance of implementing a solution with a real proactive dimension as it requires knowledge which the authors do not currently have or have access to. However, it might still be possible to implement it partly or develop a solution which allows for it to be implemented in the future. Passive dissemination on the other hand is an inefficient but cheap method, and can still have potential if used correctly.

- *Standardised lessons learned.* What to include and not, how it is included and when to use it. Interview transcripts showed how they are tedious to find and use, and having a standard and a clear process regarding this makes it easier capture and find relevant lessons.

- A final solution should preferably *not exclude any knowledge-conversion modes*, as all modes are necessary to create knowledge and facilitating as many as possible lessens the workload needed to apply the other conversion modes.

Many requirements originate from section 2.4.3, as that provided a lot of general insights to lessons learned systems and what is important to consider when developing such a system. However, it is important to note that many of these requirements is not solution-specific, in that many of them can be implemented independently of the solution. These requirements come from the usage of the system, for example that it should be implemented in the existing process, maintenance of existing content are necessary, and ensure all content is adapted for the end-user which uses the lessons.

To further increase the user-focus when developing, use cases, or scenarios, were created. The scenarios were validated and approved by case-company employees and are as follows:

- **Scenario 1: User - Project Manager**
  Responsible for planning, wants general lessons for the start-up phase or what to consider when assembling a team or creating a timeplan and similar tasks.

- **Scenario 2: User - Project Team**
  When conducting a certain task, for example a Risk Analysis for the upcoming phase, and you need tips for what to consider or look out for.

- **Scenario 3: User - New member of the project team**
  Wants to know how a certain task is conducted and needs help with the most important aspects to consider. Might need more information, or more details, than an experienced user.

- **Scenario 4: User - Any member**
  One part of the acquisition process is to compare different suppliers quotes for a machine. As part of this process a user wants to look up how the collaboration with a few selected suppliers have worked in the past.

These scenarios was also working as a way to test out the functionality through the prototyping phase, as it is easier to develop with a few select cases in mind rather than developing functions in an ad hoc manner.

4.5 Ideate

In the next step, we considered the KVC-model by M. C. Lee (2016, p. 786), which is described in 2.4.1 and is found in figure 4.1, to find important aspects of each step and how they can manifest as a way to find potential solutions and remember what to keep in mind when developing a solution. The choice to use the KVC as basis for future development lies in how important it is to ensure the whole chain functions properly; it is only as strong as its weakest link and if any were to be omitted, the whole chain breaks. The result can be seen below, note that *Knowledge Protection* is not included as that part of the KVC covers the need of a way to store and secure information or knowledge; such a system is already in place at the case company which means influencing or proposing a change to it will mostly cause extra work with little chance of any reward for it.

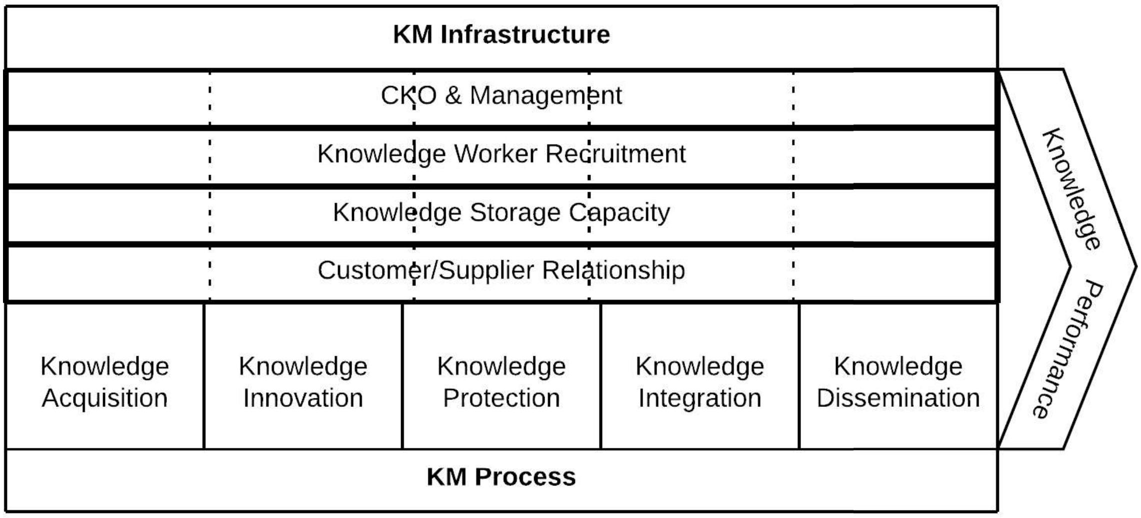

Figure 4.1: A visual representation of the Knowledge Value Chain. Adapted from *Knowledge Value Chain*, by Lee, C. and Yang, J., 2003

A - Knowledge Acquisition

Finding ways of acquiring knowledge was based on articles, earlier communication and education etc. and the solutions are summarised below, some are more or less useful for the problem at hand but it is important to consider as many ideas as possible at this point in the process so they were left in.

- Wiki
- Searchable database
- Talking (direct interaction)
- Billboard
- Archives
- An expert on the subject
- Given info involuntarily
  - Person coming to you
  - System prompting info
- TV-screens
- Chatbot
- Charts
- Power BI (or similar)
- Forum

- Assistent
- Learning by doing
- Education
- Reading on your own
- Demonstration

B - Knowledge Innovation

This part is divided into the four conversions of knowledge mentioned in section 2.4.1, and tried to find different solutions for each step.

- **Socialisation**: *Workshop, Calls, Study Visits, After Work, Cooler talk*, casual interaction on breaks during the workday, *sports* and *GEMBA visits*, referring to where you go to a workplace or factory to see the actual process in action.
- **Externalisation**: *All types of lessons learned, Checksheets, Own notes*
- **Internalisation**: *Analysis of data/information, Test of knowledge*, can be in the form of an exam or e-learning activity for example.
- **Combination**: *Analysis of data, Build data models, Organising, structure, Integration of systems, Build an AI*

A final solution should facilitate as many of these conversions as possible, so it can act as the sole system needed to create knowledge.

C - Knowledge Protection

Not applicable as mentioned, and therefore omitted.

D - Knowledge Integration

Apply Codified Knowledge, Single Source of Truth, Integrate in current process, Obliged Usage.

These aspects were considered important factors which can enhance the efficiency of integration, aspects which a solution should aim to utilise; either in full or at least partially.

E- Knowledge Dissemination

This step is based on findings by Weber et al. (2001, p. 22), further explained in section 2.4.3, and related to different methods on how to spread lessons learned within an organisation. Since this step is entirely dependent on the solution for *Knowledge Acquisition*, the focus lies on developing a solution which facilitates for easy dissemination. To get a better understanding of each method, an example of a solution from *Knowledge Acquisition* is included.

- Active Dissemination - To be *Given information involuntarily* or without asking is an example of this.
- Passive Dissemination - A *Wiki or database* are very passive solutions.
- Proactive Dissemination - *Given information involuntarily*, always a step ahead of the user.
- Reactive Dissemination - Can be realised through a *Chatbot* or *Forum.*
- Active Casting - An example of this is to show the lesson on a *TV-Screen* or similar nearby the individual in question.
- Broadcasting - For example *Billboards*

The choice of which type of dissemination to use is important as, according to Weber et al. (2001, p. 22), it may be the most important sub-process of reusing lessons, and they all have varying qualities in terms of complexity to implement and efficiency in transferring lessons learned. Therefore it is essential to make a conscious decision in regards to dissemination, so the shortcomings are weighed in and handled appropriately.

As it was deemed necessary to make a solution which is long-lived and applicable to Industry 4.0, which demands a solution that is computerised, the physical options were omitted. The next problem was to find what information is necessary for the end-user, the one reusing the codified knowledge, and how to categorise this information, as any digital solution would need to include this in one way or another. By consulting whitebooks and interview transcripts from (Blomberg & Håkansson, 2019) again, along with a literature study on the topic of *lessons learned*; a list of potential categories was created.

- Issue description/Originating action
- Solution
- Chance of occuring again
- Cost of problem occuring
- Time-loss of problem occuring
- Machine
- Machine-type
- Supplier
- Project-phase
- Deliverable, a certain task from the EEM-proces, e.g. LCC or Timeplan
- What/How/Why
- Author
- Other measures of impact
- Lesson/Problem/Accident?
- Conditions/Circumstances

To further take these ideas onwards, the basic functionality of the solution had to be decided. Since the main issues today is that the information is saved in so many different places, it was decided that some form of digital database for this information was needed. Further, to live up to the demands or wishes connected to relevancy, it was decided that some filter functionality was needed. Finally, it was decided that relevancy would be an important factor to include, and each first look at a lesson should be easy to grasp and not overwhelm the user with information. Therefore a way to dig deeper to each piece of information was needed.

4.6 Prototype

To be able to make prototypes or mock-ups, data to populate them was needed. Therefore, to get a somewhat realistic scenario, using an Excel-sheet as a mock-database with most of above mentioned information as categories was created, using excerpts from whitebooks to fill out as many categories as possible. To start off with a prototype, the preferred software to make it was gone through. The choices were limited to the ones offered by the case company and since Power BI had been used with the work done on AR, it was deemed a possibility. Other tools within the Microsoft Office-package such as Sharepoint lists, a tool for simple online databases, Excel and Power Apps, a software for creating simple apps for PC and/or mobile, were also considered. The integration between the office-services works very well and since this prototype mainly was for a proof-of-concept rather than a very well functioning app, not too much time was put in to comparing the different options, but the choice was to go for a mix between sharepoint lists and powerapps since it offered more customisation than power BI.

In the beginning, the basic functionality was needed. A sharepoint list with the columns of information from the knowledge dissemination section 4.5 was created. This list was populated by the mock-data to create a mock-database to have something to work with that was similar to what the case-company is expected to fill it with. With this sharepoint list it was easy to try and create ways to display it using powerapps.

When this part was deemed a success, an effort to create a complete chain was attempted; from codifying lessons, which corresponds to A – Knowledge Acquisition, transferring them to a database and visualising them in Powerapps, which corresponds to E – Knowledge Dissemination. To complete this chain, Excel was used to codify lessons, the sheet would then be put in a specific folder where Power Automate, an automated script called a *Flow*, would read the sheet and put each row into a database in a Sharepoint list, which in turn is connected to Power Apps that displays the lessons. How each part works will be explained in the following sections, but it is important to note that neither solution regarding Excel nor Flow is especially refined. This is due to feedback from a test of the whole process with the examiner and supervisor, explained in section 4.7, where they recommended focusing on one function at a time and developing it properly rather than working on multiple functions and then running out of time for making any of them to work sufficiently. Therefore, once the template and Power Automate had been proven to work as a proof-of-concept, but far from bug-free, all work regarding the prototype

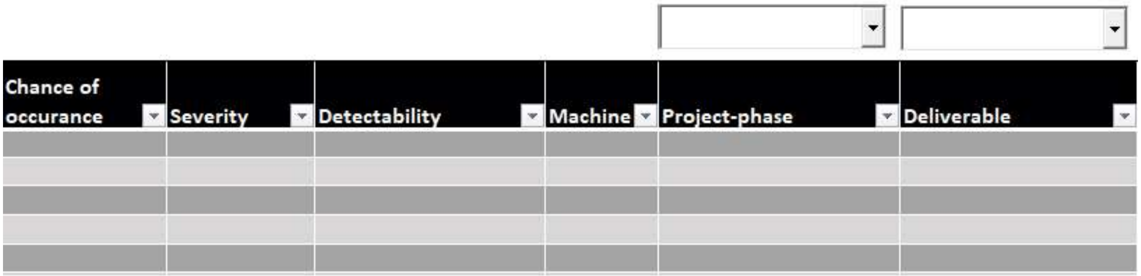

Figure 4.2: Excerpt from the template, showing the title of a few columns, as well as the combobox related to project-phase and deliverable respectively in the top right corner.

was focused on developing the lesson retrieval in Power Apps, and thus leaving the other parts significantly less refined. This decision was based on needing a medium to use in testing, and the lesson retrieval was deemed the most suitable part of the process as it would be the one most people would interact with when completed.

4.6.1 Template to input lessons using Excel

The purpose was to find how the lessons could be put in to the database, utilising Power Automate, and the easiest and most obvious solution would be to create a template in Excel. A form was considered for a short while, but it was omitted as each lesson would have to be filled in and sent one by one, meaning the risk of filling the database with duplicate lessons is greater when you cannot see what you already have covered. Thus, a template was created, utilising components from Visual Basics for Applications, VBA, in addition to the ordinary Excel functions and formulas.

The template included the following columns and an excerpt of the template can be found in figure 4.2.

- What
- Why
- How
- Chance of Occurrence
- Severity
- Detectability
- Machine
- Machine-Type
- Project
- Supplier
- Project Phase
- Deliverable
- Conditions/Circumstances
- Concerning

Most of the columns are free-text input with no data verification, but there are exceptions: Chance of Occurance, Severity, and Detectability are referring to the components of the Failure Mode and Effect Analysis, FMEA, and utilise the same point system on suggestion from the testing session with employees at the Skövde plant, explained in section 4.7. As such, only numbers ranging from 1 to 10 is accepted. Furthermore, the columns Supplier, Project-Phase, Deliverable and Concerning are not simple free-text input either. As the lesson retrieval benefits greatly from filtering to narrow down the most relevant lessons, it was decided that these would need to selected from a list of choices to ensure the input is correct. Such a list is easy to implement using data verification, but as certain lists can become relatively large, a search-function would be beneficial. The search-function was created with combobox, a component in VBA, for each column where the user can write a term in the box and a dropdown list shows up with all entries which contains the search term. By clicking the entry, the active cell is filled with that entry. This function also allows for multiple choices as well as a function where clicking the same entry again erases it from the cell.

Several columns in this template are subject to removal in the future as each machine already has a corresponding answer to machine-type, project and supplier regardless of lesson. This can therefore be automated. This is possible by utilising a separate list with this, and perhaps additional, information for each machine, which the Sharepoint List can use to look up the specified information for any given machine, thus reducing such unnecessary operations. This is done once the lessons have been transferred through the Flow and entered in the Sharepoint list. Such a list of machines as suggested already exist, and would only need to be updated when a new machine is purchased.

4.6.2 Power Automate

There are probably more ways to transfer data from excel to a database that could have been used. But using power automate was deemed to be the easiest to get access to and to make work within the limited time frame. Power automate is a Microsoft office service that lets the user automate tasks that otherwise would require manual labor to accomplish, in this case, that is transferring the input data from excel to a sharepoint list. This is done by a flow in power automate that reads in a new excel file if it is uploaded to a certain sharepoint site. The flow then maps each column in the excel sheet to the corresponding column in the sharepoint list and transfers the data.

4.6.3 Powerapps

Powerapps is essentially an easy way to create an "app" using data from different sources, and works very well with sharepoint lists. The app is built up by different screens and to follow the basic functionality, these screens are divided in to:

- a home screen where all the available information is accessible together with a search function.
- a filter screen, where all available filter functionality will be visible.
- and a detailed information screen, where all available information connected to the selected piece of information is displayed.

The most effort was put in to making the scenarios presented in the needfinding phase, work. This meant to make the filter section work properly. At first it was tried with the filters that can be seen in figure 4.3 below.

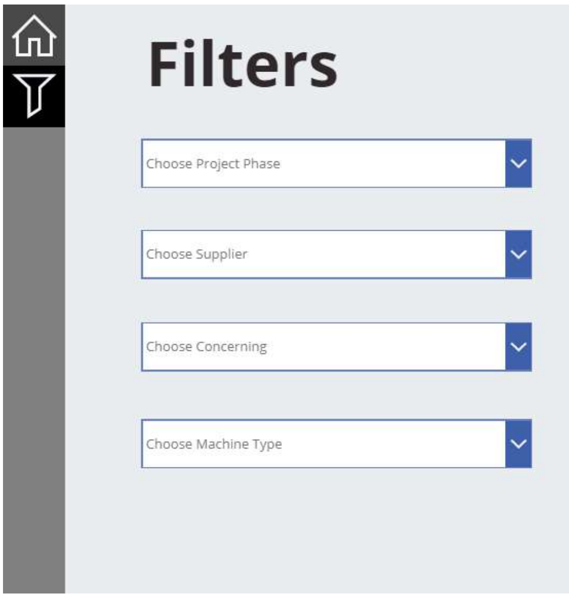

Figure 4.3: Picture of the filter-screen from the prototype in powerapps

After selecting one of these filters, the home-display will only show information connected to for example a specific supplier. The general idea is that depending on what filters you choose, you can dig deeper in to different levels of a project. For example, in the beginning of a project you might want to find some interesting information about what to think about regarding putting a team together or when to start a time-plan. But later when the time-plan is actually started, you can choose that filter and get information connected only to the time-plan.

To further determine the relevancy of the displayed "lessons" three "impact"-filters were chosen. Namely *Estimated cost of the problem, Estimated time lost and chance of occurrence*. These filters were given sliders in the app, like shown in figure 4.4. After choosing for example the number 5 on the *Chance of occurring-slider*, the home-screen will only display lessons that are deemed to have a chance of occurring again over 5 on a scale from 1-10.

The last function to be implemented was the detailed-screen, where all the information connected to the lessons can be seen. It can be seen in figure 4.5 and is basically just two columns displaying all the columns that are available from the share-point list with all the lessons.

As this prototype's basic functionality had been implemented it was used to further discuss more detailed things of the solution. For example what filters to use to easily find the most relevant information. The main points that were changed from the testing described in the next chapter were:

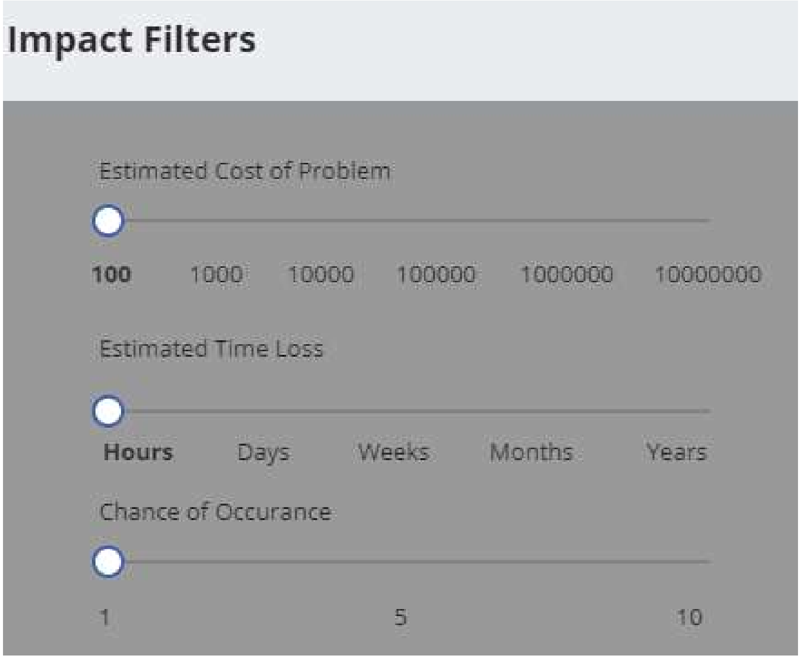

Figure 4.4: Picture of the impact-filters from the prototype in powerapps

- Including ”general” as a filter for project-phases as a way to have somewhere to categorise the more top level information for how to handle projects.
- Changing the impact-filters that from *Estimated cost of problem, estimated time lost and chance of occurring* to something that is closer to the concept of FMEA(Failure Mode Effect Analysis), which is a concept for determining risk that the case-company is already used to. The new filters are sliders with:
  - **Occurance** - How high the risk is of this happening again. On a scale from 1-10.
  - **Severity** - How severe the consequences from this happening was. On a scale from 1-10.
  - **Detectability** - How easy it is to realise that this might happen and how easy it can be to avoid. On a scale from 1-10.
- Removing some of the project-phases originally included in that filter. This was to give the chance of having more general points of information on the specific project-phases, rather than a few on each little phases since the improvement of individual phases like each handover is more covered in other ways than the whitebook.
- Changed the machine-type category to include another variety of machines than what was in the original. The new categories better determine how much of the information that is transferable to a similar project than before.

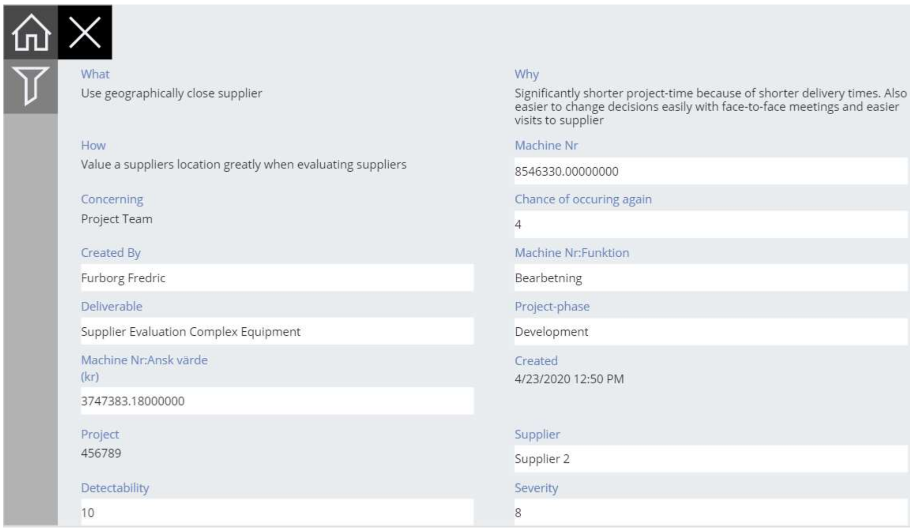

Figure 4.5: Picture of details-screen from prototype in powerapps

4.7 Test

An initial demonstration of the whole system, from template in Excel to lesson retrieval in Powerapps, was conducted with the examiner and supervisor. This was mainly to show the functions and process to get feedback on further development with less focus on the content. The demonstration was conducted through Skype with screen-share from one of the authors computer. A demonstration face to face would have been preferred but was deemed to be an unnecessary risk due to the COVID-19 pandemic. The takeaways from this session can be found in section 4.5.

Another demonstration on Skype was conducted with two employees involved in the EEM-process at one of the plants. The focus this time was on the content, and especially what factors they deemed important for finding relevant lessons and what information is necessary or most significant to be able to apply a lesson. The feedback and insights is presented in section 4.6 Further, this meeting was used to present and get feedback on the created scenarios, the result of which is found in section 4.4.

4.8 Concluding remarks

To summarise, this chapter has explained the work to create a tool that can aid the project group in the process for transferring knowledge between projects and continuously improving their acquisition process. A prototype for this tool has been created as an app in microsoft powerapps that is connected to a database in the form of a sharepoint list. This goes well in line with the need of using something that is close to the organisation today. This also enables the whole company to access it without much extra effort.

The home-screen shown in figure 4.6 enables a search function to be able to find

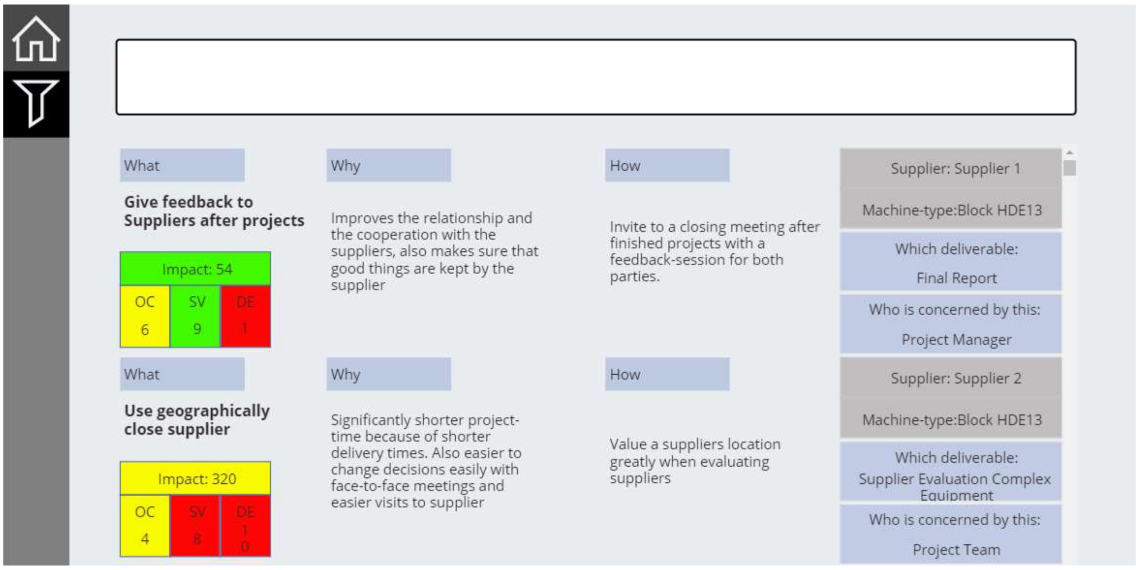

Figure 4.6: Picture of the home-screen in the powerapps prototype

relevant lessons to what a user might be looking for. The square that shows the ”impact-filters” also gives a clear view of how impactful one particular piece of information has been for a project to determine it's relevancy quickly. Together with the ability to see what supplier, machine-type, deliverable or to whom this piece of information is written for gives an even better first-glance as to not overwhelm the user with too much to read.

With the filter-screen shown in figure 4.7 a user can sort the home-screen with different filters that the case-company has selected to give their users the most important information.

The detail-screen that can be seen in figure 4.8 gives the user the ability to see all information connected to a certain lesson. This to be able to find for example who wrote the lesson to get personal information from the author which can be beneficial very often.

To use columns in this matter gives each lesson a standardised structure that enables both easier ways to structure the repository and better uniformity in how lessons are written and what they are filled with. It enables the user to not repeat lessons that already exists which was very common with whitebooks.

But this app alone is not going to solve all problems as many of the problems and needs brought up both for lessons learned in section 2.4.3 and in the needfinding section 4.4 are more connected to a way of thinking and the process itself. The key points are presented below.

- Always have the reader in mind when writing. The lessons should not be written for the author to remember, but to be able to transfer what was learned to someone else.

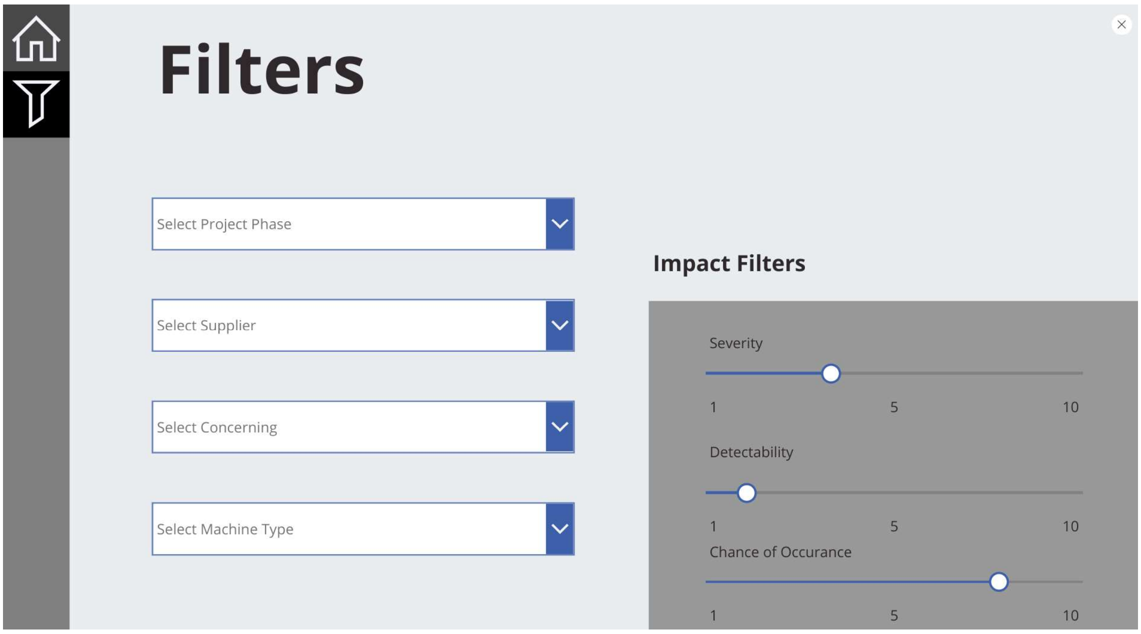

Figure 4.7: Picture of the filter-screen in the powerapps prototype

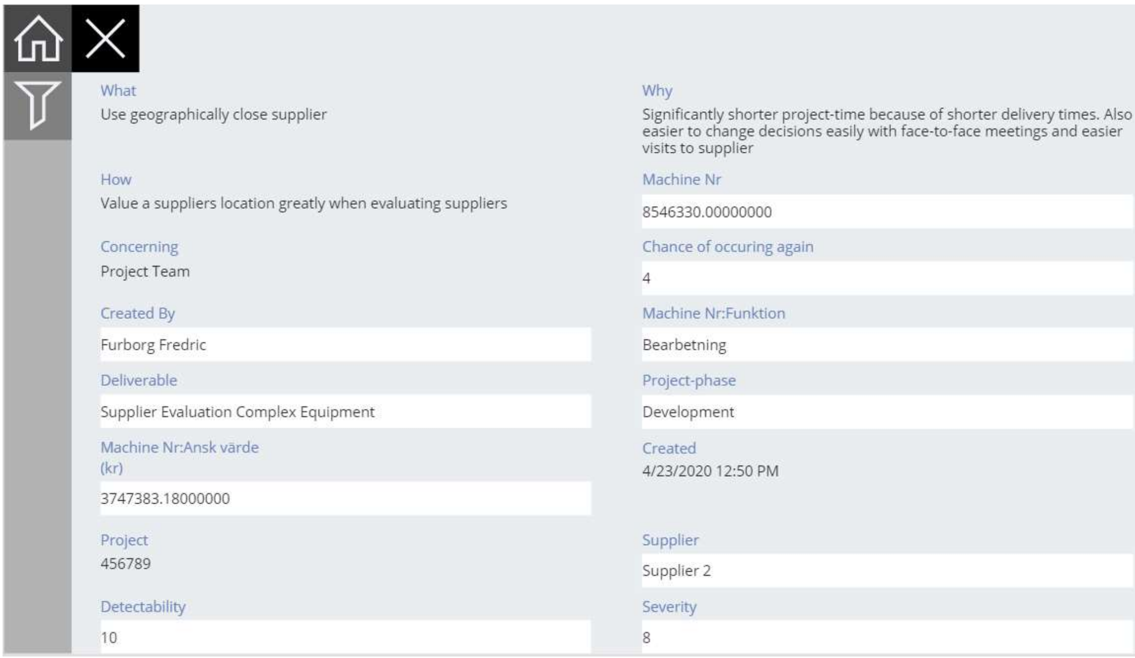

Figure 4.8: Picture of the details-screen in the powerapps prototype

- Lessons must always be written in an actionable format, meaning that whoever reads it can understand what to do directly, without having to do further research.
- The act of using a tool like this must be incorporated thoroughly in to the process that the case company is working with today. Both to make it a reoccurring thing to write and use this tool, and to make it something proactive rather than reactive. This means that both how people use the tool and how they write lessons should have the focus on how to eliminate problems in the process altogether without ever risking their occurrence.
- Finally, it is crucial to remember that not everything you learn should be put into a lesson database; certain experiences brought up would benefit from being dealt with immediately rather than pushing it to the next project to deal with. An example of this can be experiences that require an update to an existing instruction or template.

There have been efforts to address all phases of the KVC: a template for capturing lessons was created, connected to A – Knowledge Acquisition, as was a flow using Power Automate to transfer data from the template to a master-list of all lessons. Including the author in each lesson simplifies investigation of certain lessons, while also creating incentive to knowledge conversion through socialisation. Externalisation is also facilitated by using a template to codify knowledge. Facilitating for these knowledge conversions connects to B – Knowledge Innovation. Further, an interface to disseminate the lessons and aid assimilation was established, which is connected to E – Knowledge Dissemination. D – Knowledge integration is harder to deal with in the solution itself, and should instead be addressed by integrating it in the existing process, and ensuring it is used repeatedly with regular intervals throughout the project.

Table 4.1: Table of requirements for the prototype and whether they are fulfilled.

Requirement	**Fulfilled**	**Comment**
Ease the search of relevant data, relative to the system used today	✓	A single database for all lessons, with filters and search functions eases the task significantly
Accessible to all relevant users	✓	All softwares used are already used at the case company, and can be accessed as long as you have a connection to the intranet
Include digital solutions	✓	Nothing analog is used
Passive and proactive dissemination should be used simultaneously	✗	This tool is entirely passive, as the user needs to actively choose to use it. No proactive dissemination is possible currently
Standardised lessons learned	✓	The template ensures a standardised way of writing down the lessons
Not exclude any knowledge-conversion modes	✓	It does not exclude any modes, but is not directly promoting internalisation

5

Discussion

This chapter brings up a discussion, where the authors can be both critical of the work that has been done, together with reasoning around the research topic and other ideas that surfaced from doing this project.

5.1 Correlation between documentation and performance

As noted in section 3.2, the Acceptance Record did not provide much insight as to what could have made a certain machine to break down more often. It did however show the lack of consistency between projects and, in many cases, an apparent lack of information in certain columns. As some interviewees has said that these records are the most important documents, it is not reflected in how they are used, and the usage could therefore be improved in terms of standardisation and thoroughness. It is impossible to know if the absence of content is due to a miss or a conscious decision; but if certain information is omitted due to being deemed irrelevant, there is a discussion to be had whether it was necessary to include it in the first place.

When the analysis of documents was completed, it was intended to discuss the findings with a project manager to verify or reject the conclusions. This could not be done as the temporary furlough had just started, meaning no project managers were contactable.

The choice to compare project information of only a few projects is explained by the sheer amount of documents available, as well as the time it takes to navigate the folder-structure to find what you are looking for. In hindsight, the chosen projects could possibly have been chosen with better accuracy, in terms of how well they relate and apply to other machines, if we had consulted employees from the plant. However, it might not have mattered much as little to no correlation between the project documentation and machine performance was found.

It should be noted that initially there was a test of how a quantitative analysis could be conducted on AR, using Excel and Power BI, but it proved to be difficult to get any relevant information from this and was therefore not used further. Thus, all analysis should be considered to be of qualitative, and a considerably analogue, nature so to speak, as the only softwares used were simply to display the documents or summarise the data; no extended analysis tool was used. This is certainly a point of improvement, if there exists dedicated software for this kind of analysis. It is also important to note that our analysis was very narrow, and should not be considered a general truth, but can be applied to the case company and the documents in question.

5.2 Concept for facilitating knowledge reuse

We believe a tool like the one presented in chapter 4 can be beneficial to improving the knowledge reuse between projects, but it requires more than only a tool to be utilised; it requires a new mindset from the workers. The current process have fallen into a common trap for lessons learned systems, described in section 2.4.3, where there are lessons in place but they are too difficult to find. This tool is hopefully a remedy to this, as it eliminates the time-consuming task of searching through folders to find relevant whitebooks, and collects them in a single database.

As previously mentioned, the tool itself is not enough however, as other shortcomings were noted when looking through the project documentation; experiences suited for a lessons learned system were found in multiple documents, many of them likely to never be returned to again. Furthermore, the whitebooks generally does not contain experiences that are helpful for the next project, or at least not in a format that makes it clear on how to act on the lesson. Multiple articles on lessons learned are emphasising that the content of the system is crucial for the result, and this case is no different; there are multiple changes required in how the whitebook is used today compared to what is needed to use this system efficiently. Some of the most important changes consist of: using a template when codifying the lessons, storing all lessons in the same place and verifying the content regularly. These points are arguably more important than the tool for lesson retrieval itself, as the tool can only be as good as the lessons it is referencing.

When applying the Knowledge Value Chain to evaluate a process like this it becomes apparent what is lacking in the organisation. We did find that many parts of the process was lacking, but most importantly we found that there is no one responsible for the holistic view of knowledge management. We also showed that this model can be applied for the area of acquiring new factory equipment aswell, which, judging by the scopus analysis is not something that has been used before. It is also interesting that everything that we found regarding what to think about in lessons learned could be recognised to some part of the KVC. This points to that it is a model that covers a lot.

Further, the template is especially important as it determines what information is gathered, which is crucial for creating means of distinguishing relevant lessons; for example which actors who can have interest in a particular lesson.

Lastly, the development of a system with a significant amount of user interaction like this one should include more user-testing. This was not possible during this project as the COVID-19 pandemic caused mass-furlough on the case-company, meaning all relevant users were out-of-work for several weeks and unable to be involved in the testing until the very last stages of development.

5.3 General notes regarding the area of interest

During the literature study, it was evident how the area of purchasing machines, as well as the process regarding the same, was lacking research, especially connected to knowledge management. This means the theory used on the area of knowledge management is not ideal, but still deemed sufficient as it should not differ too much between fields.

Overall, combining what was found during the literature study together with our findings in project documentation and how it is handled by the case company makes us think that this area is significantly underdeveloped considering the amounts of money and time that goes in to theses types of projects. Writing down experiences is often overlooked and the first thing to be cut when there is little time in a project which just makes the next project lose time. This is thought to be because of the lack of direct results from taking this more seriously. To improve this, there needs to be a change in mindset about knowledge management within the company, or by making efforts to better show the benefits of it.

There are many articles pointing to the importance of working with organisational knowledge and continuous learning that it feels strange to not prioritise this area. In a perfect scenario, this data would be managed by a certain team at the company, that updates it and makes sure that everything is correct and orderly.

Finally, it has been shown that this whole area needs further research; root-cause analysis is being conducted for each breakdown, but no root-cause analysis has been conducted with regards to the process as a whole and why breakdowns occur so frequently. This should be addressed to improve the proactive activities connected to breakdowns, rather than relying on preventive and reactive measures.

6

Conclusion

A thorough analysis of project documentation within a large automotive company has been conducted that found no evident correlation between the recorded project documentation in regards to how well the project performed in relation to how many issues the machines acquired by these projects had caused. This analysis has been done on a very specific case and has been of a more qualitative nature rather than quantitative.

The fact that not much in regards of research could be found in this area combined with results from the documentation analysis shows how big of an issue the knowledge re-use is for the acquisition process today. Efforts to reduce this problem have been made in the form of a prototype tool that the project group can use to proactively eliminate problems that occurred in previous projects and to take action to improve project performance. This in the form of a lessons learned repository with large efforts made to create relevancy through smart filtering and a thought out first-look at these lessons to quickly get a grasp of what to do and what to learn more about.

This tool alone is not going to solve all problems regarding knowledge-reuse but in unison with a clear connection to current project processes and the right mind-set both when writing and when reading, it is thought to be able to improve projects significantly to the point where they can deliver machines that achieve zero breakdowns due to design-weaknesses.

The thought of our tool only being a part what needs to be fixed can be connected back to the Knowledge Value Chain in section 2.4.1 that we based the development on. Our focus was put on the knowledge management process at the bottom of the model, mostly on *Acquisition, Innovation, Integration and Dissemination.* To make sure that the entire value model is covered to create as much knowledge value as possible, more focus should be put on the supporting parts of the chain, the knowledge management infrastructure with *CKO & Management, Knowledge Worker Recruitment, Knowledge Storage Capacity and Customer/Supplier Relationship.* Providing this framework for knowledge management can also give the case company a new way to discuss how they look at writing down lessons for later use, as this is something that was missing from before.

7
Future work

To further research the area this report covers, we have identified two main areas to focus on: a broad research into why machines break down, and how the tool presented in chapter 4 can be improved with the help of elements from Industry 4.0, both of which are presented below.

7.1 Research towards understanding poor machine performance

As any correlation regarding documentation and machine performance could not be found, a deeper analysis regarding causes for poor machine performance due to design weaknesses need to be conducted. This report focused on finding it in documentation, and found major problems with it as well as found a possible solution to one of them, namely the whitebook. However, the root cause for poor machine performance may be found somewhere else; therefore we need to involve employees, people close to the machines and with extensive knowledge regarding the same, in the search for these causes. Finding the root cause can be done in numerous ways but a starting point would be to conduct interviews with employees from various departments, as to what they think can be the root cause and analyse if any hypotheses can be validated.

As the scopus results showed, this was quite an underexplored area for research which meant there was no pre-defined way of conducting the documentation analysis. This means there is a lot of room for improvement in regards to that analysis as it had to be analysed in a manual and qualitative manner. Therefore, it is still possible to analyse the documentation in a more systematic manner if appropriate software exists, or at the very least a better method than we used.

7.2 Developing towards Industry 4.0

Since Industry 4.0 is taking up a lot of space in all things regarding the industry of the future, some points of interest connected to this particular project has surfaced, especially in regards to machine learning and AI.

- Easier categorisation - To reduce time to fill out the forms for creation of lessons, NLP (Natural Language Processing) could be used to interpret the data written in the free-text columns to determine for example what project phase that experience is connected to. It could also be used to create tags for lessons, these could be things that are not pre-defined by users, like the categories are today, but tags that NLP-software might find interesting among the lessons that could create relevancy for users.

- More data - Since it's very probable that machines will be able to provide more data regarding their performance in the future, this is something the field of knowledge management will need to address. In this specific case it could give the project group much needed information about older machines and their performance to be able to make them better. This combined with the knowledge regarding the project itself will improve projects even more.

- System integration - If more software can communicate, they can work together to create even more data. In it's most simple form, it can allow users to get data for example from a budget report directly in to a lesson learned on budgeting or to include all machine data available if a lesson is connected to a specific machine.

- Create lessons automatically - Combining system integration and large amounts of data with machine learning or AI could create a system that could interpret all relevant project data and find new lessons that humans might not have been able to find. It would also create a larger bank of organisational knowledge within this area.

- Make decisions using machine learning - To take this even further, if it's possible to create a good evaluation structure for project performance, one could imagine a scenario where users can learn an AI to take the best decisions automatically in a project based on existing lessons within the organisation. If the project performance is measured correctly from each of these decisions, eventually you could end up with an AI that can take decisions for entire projects.

The proposed improvements above are ambitious, and that is by design. Knowledge re-use is an incredibly underused asset in many companies, and utilising it to its full potential can give a company a big advantage as less resources need to be put into reinventing the wheel and keep making the same mistakes.

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Appendices

A. Literature Study Visualisation

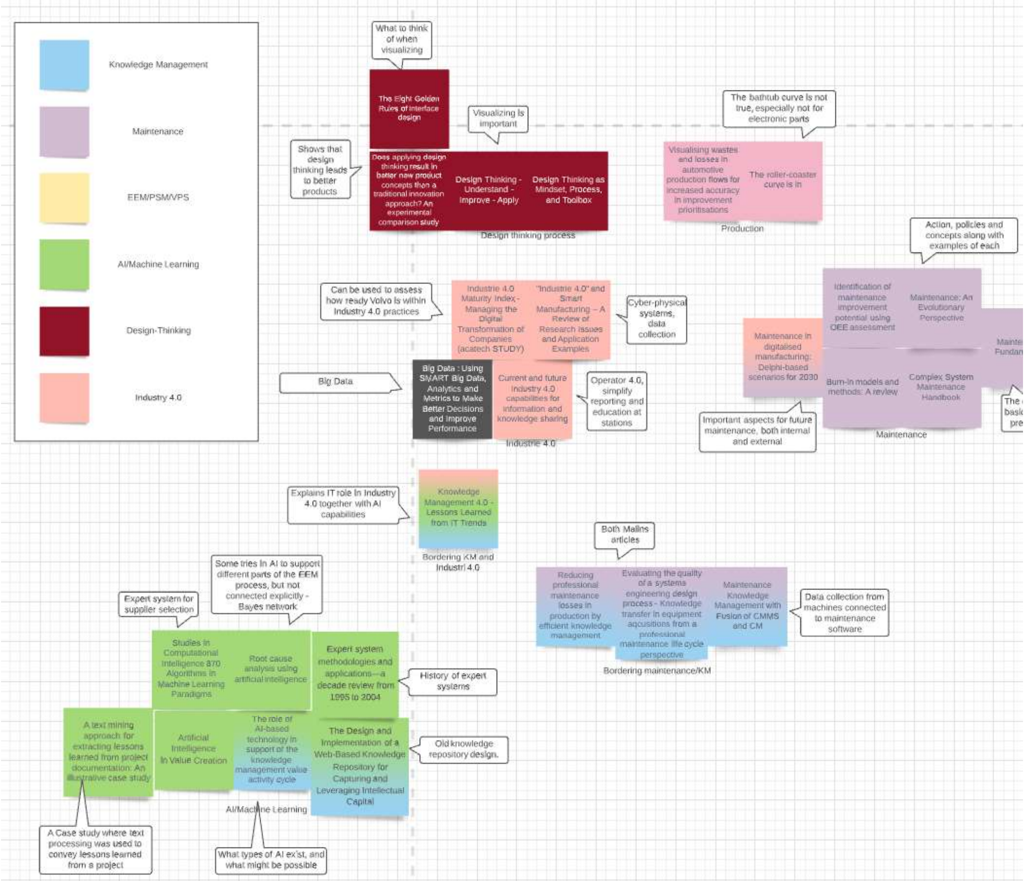


Figure A.1: Detailed view of visualisation of researched literature

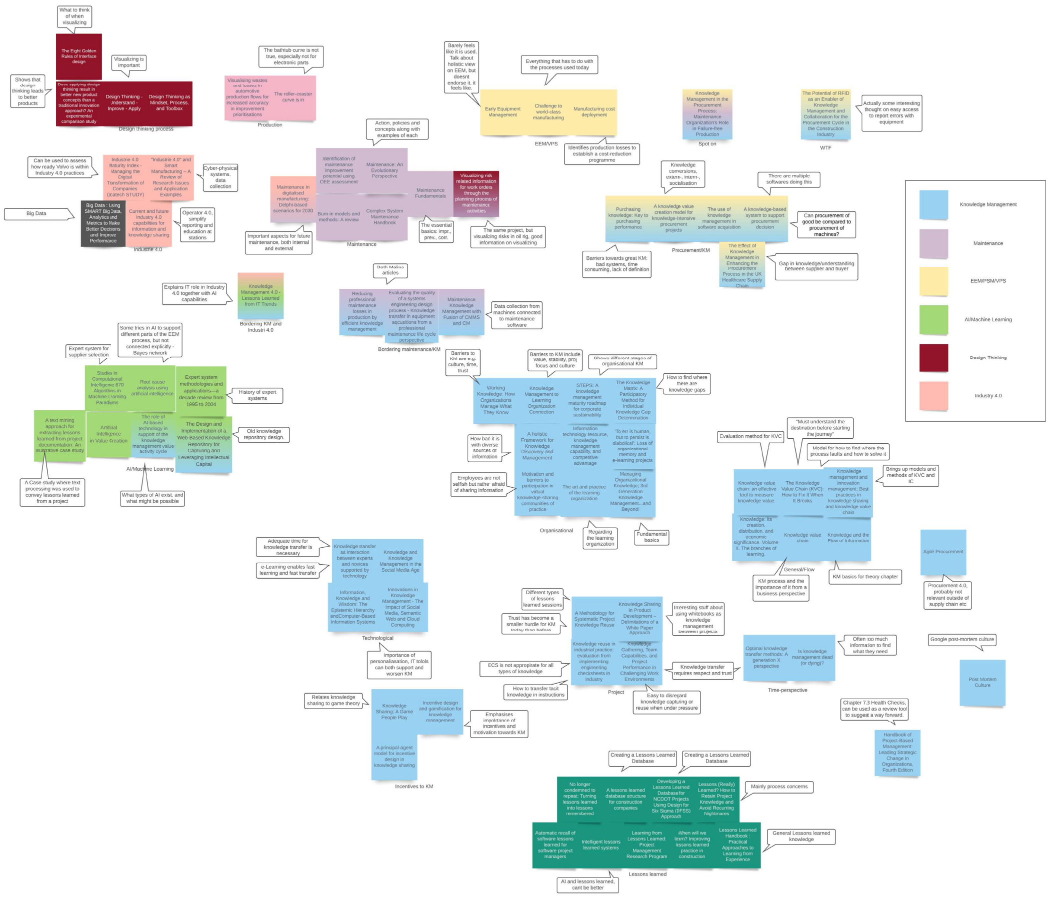
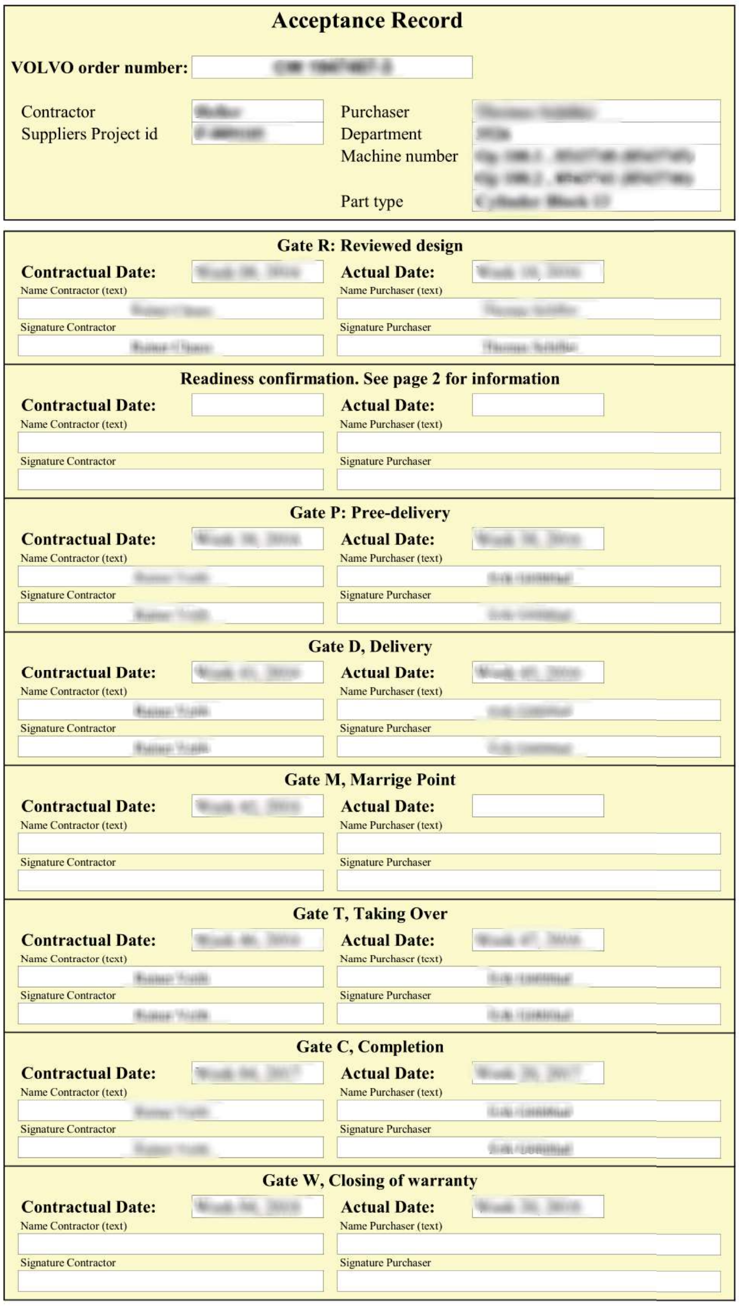


Figure A.2: Visualisation of all researched literature

B. Acceptance Record


Acceptance Record

VOLVO order number:

Contractor
Suppliers Project id
Purchaser
Department
Machine number
Part type

Gate R: Reviewed design
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Readiness confirmation. See page 2 for information
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Gate P: Pree-delivery
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Gate D, Delivery
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Gate M, Marrige Point
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Gate T, Taking Over
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

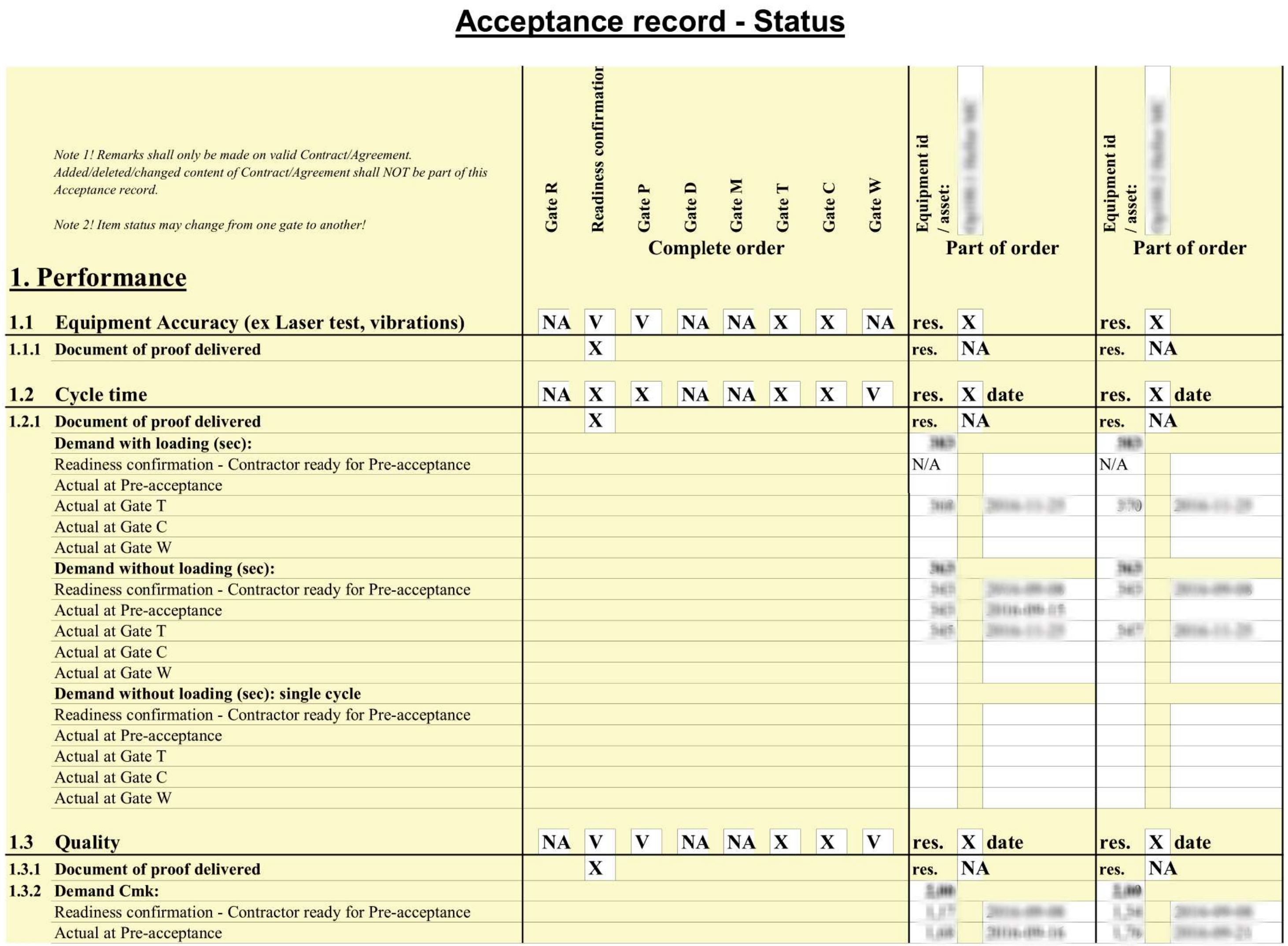
Gate C, Completion
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Gate W, Closing of warranty
Contractual Date: **Actual Date:**
Name Contractor (text) Name Purchaser (text)
Signature Contractor Signature Purchaser

Figure B.1: Example of the first page of the acceptance record which is signed when contractor and purchaser finishes each separate gate. Sensitive information is blurred out.

C. Acceptance Record – Status

The status page of an acceptance record is used to monitor the progress of the machines, an example of this can be found in C.1. The first column corresponds to each requirement put on the machine; the second shows the gates from the EEM-process and how far each requirement has progressed; remaining columns, up to four, shows the individual machines which is part of the contract. If five or more machines are involved, there is a second status page for the remaining machines.



Acceptance record - Status

Note 1! Remarks shall only be made on valid Contract/Agreement. Added/deleted/changed content of Contract/Agreement shall NOT be part of this Acceptance record.

Note 2! Item status may change from one gate to another!

		Gate R	Readiness confirmation	Gate P	Gate D	Gate M	Gate T	Gate C	Gate W	Equipment id / asset:	[illegible]		Equipment id / asset:	[illegible]	
		Complete order								Part of order			Part of order		
1. Performance															
1.1	**Equipment Accuracy (ex Laser test, vibrations)**	NA	V	V	NA	NA	X	X	NA	res.	X		res.	X	
1.1.1	**Document of proof delivered**		X							res.	NA		res.	NA	
1.2	**Cycle time**	NA	X	X	NA	NA	X	X	V	res.	X	date	res.	X	date
1.2.1	**Document of proof delivered**		X							res.	NA		res.	NA	
	Demand with loading (sec):									[illegible]			[illegible]		
	Readiness confirmation - Contractor ready for Pre-acceptance									N/A			N/A		
	Actual at Pre-acceptance														
	Actual at Gate T									[illegible]		[illegible]	[illegible]		[illegible]
	Actual at Gate C														
	Actual at Gate W														
	Demand without loading (sec):									[illegible]			[illegible]		
	Readiness confirmation - Contractor ready for Pre-acceptance									[illegible]		[illegible]	[illegible]		[illegible]
	Actual at Pre-acceptance									[illegible]		[illegible]			
	Actual at Gate T									[illegible]		[illegible]	[illegible]		[illegible]
	Actual at Gate C														
	Actual at Gate W														
	Demand without loading (sec): single cycle														
	Readiness confirmation - Contractor ready for Pre-acceptance														
	Actual at Pre-acceptance														
	Actual at Gate T														
	Actual at Gate C														
	Actual at Gate W														
1.3	**Quality**	NA	V	V	NA	NA	X	X	V	res.	X	date	res.	X	date
1.3.1	**Document of proof delivered**		X							res.	NA		res.	NA	
1.3.2	**Demand Cmk:**									[illegible]			[illegible]		
	Readiness confirmation - Contractor ready for Pre-acceptance									[illegible]		[illegible]	[illegible]		[illegible]
	Actual at Pre-acceptance									[illegible]		[illegible]	[illegible]		[illegible]

Figure C.1: Example of the status page of an acceptance record. The picture does not show all rows as it would be too big for a single page.

D. Acceptance Record – Action

The action page of an acceptance record is used to collect all aspects of a machine which does not meet the requirements set out on the *status* page. *Tagged (Y)* shows if there is a tag on the place where the action originated, which can be seen on the pages *Tag – Photos* and/or *Tag – Machines Layout*. *From which point under status* shows which entry of *status* the action deals with. *Subject* refers to which area is affected. . *Responsible* shows whether contractor or purchaser is responsible for solving the action. *Finish gate* refers to the deadline, and corresponds to the gates in the EEM-process.

Item id:	Tagged (Y)	Tag type	Started Date (YYYY-MM-DD):	Started (person):	From which point under status	Equipment id:	Subject:	Description: (All remarks from the 'status'-tab shall be noted below. Avoid extra documents/appendix with remarks.)	Decision, comment:	Responsible:	Finish gate:	OK Contractor: (YYYY-MM-DD):	OK Purchaser: (YYYY-MM-DD):
1	Y	Safety	[illegible]	[illegible]	3.3	All	Function	Spray gun, cutting fluid, jumps out of holder when coolant pressure peaks occur.		[illegible]	Gate T		[illegible]
2	N	Operating	[illegible]	[illegible]	1.6	All	Function	If roof hatch is open it shall only be possible to open the operator door with interlock.	Desired function sent to [illegible] & [illegible], [illegible] is waiting for answer	[illegible]	Gate T		[illegible]
3	N	Operating	[illegible]	[illegible]	1.6	All	Function	Start button is flashing together with home position while running homeposition. Start should only flashing when home position is finished.		[illegible]	Gate P		[illegible]
4	N	Operating	[illegible]	[illegible]	1.6	All	Function	(Maybe only for F8000..) After Sister tool change it is doing a measuring detail in machining without part. The machine shall not consider duplo strategy when working without part.	Acceptable problem	[illegible]	Gate P		[illegible]
5	N	Operating	[illegible]	[illegible]	2.1	All	Function	(Maybe only for H10000..) Fixture front/left/right is not working correctly when choosing this function from HMI		[illegible]	Gate T		[illegible]
6	N	Operating	[illegible]	[illegible]	1.6	All	Function	If roof hatch is open it´s not possible to enter machine even if you use interlock. (H10000)	OK	[illegible]	Gate T		[illegible]
7	N	Maintenance	[illegible]	[illegible]	2.1	All	Electrical	Gear box, problems with gears, alarm 700119 (warranty issue from OP 20/30)	[illegible] has done actions in op 20/30. Last alarm in op 20/30 20th June.	[illegible]	Gate T		[illegible]
8	N	Maintenance	[illegible]	[illegible]	2.6	All	General	Part list, Not all electrical parts visible (parts classified by Heller as mechanical)	[illegible] reviews documents	[illegible]	Gate D		[illegible]
9	N	Operating	[illegible]	[illegible]	1.6	All	Function	Duplo tools; after changing to new tools the machine sometimes uses the old tools for the first piece (warranty issue from op 20/30, 290)	Operator does not work as instruction says	[illegible]	Gate P		[illegible]
10	N	Operating	[illegible]	[illegible]	1.6	All	Function	When changing to new tools the wear data is not cleared. (warranty issue from op 20/30, 290)		[illegible]	Gate P		[illegible]
11	N	Operating	[illegible]	[illegible]	1.6	All	Function	Duplo tools; When operator is using duplo2 and resets, duplo1 is also reset (warranty issue from op10.4)	Can not simulate this problem	[illegible]	Gate P		[illegible]
12	N	Operating	[illegible]	[illegible]	1.6	All	Function	Example hole number on front F86 and hole number on right hand side RH86 will cause problems since both ends with 86		[illegible]	Gate P		[illegible]
13	N	Maintenance	[illegible]	[illegible]	2.1	All	Electrical	Problems with bysplit for sensor signals in fixture, weak part (warranty issue from op 290)	Received, [illegible] will replace. Unclear how many is needed, maybe more to be sent	[illegible]	Gate D		[illegible]
14	N	Operating	[illegible]	[illegible]	2.2	All	Mechanical	Lubrication of moving parts in fixture. Lubrication shall be done by mecahnical counters (warranty issue for earlier delivered OP10-4 and OP20-1/30-1) if hydrualic oil system is used for the lubrication.		[illegible]	Gate P		[illegible]
15	Y	Operating	[illegible]	[illegible]	2.3	All	Mechanical	(warranty issue from op20/30, 290) leakage problems of cutting fluid.	Ok during 30 piece test.	[illegible]	Gate T		[illegible]
16		Operating	[illegible]	[illegible]		All	Function	When changing duplotool in 10.4. new tool makes first cut both tool makes a countdown in lifetime.	[illegible] shows [illegible] after gate D	[illegible]	Gate T		[illegible]
17	N	Operating	[illegible]	[illegible]	1.6	All	Function	Heat problems in gear box, discovered during test week 35 with [illegible]	[illegible] to follow up.	[illegible]	Gate W		
18		Operating	[illegible]	[illegible]	1.1	All	Mechanical	Position of spindle not stable, discovered during test week 35 with [illegible]	Geometry -measuring by [illegible] done with ok results	[illegible]	Gate T		[illegible]

Figure D.1: Example of an Action page. Sensitive information is erased. This includes employees names in the ”Started”, and the suppliers name in ”Responsible”.

E. Acceptance Record – Photos

The photos help to show where the problem is located or in another way clarify the cause of the action. *Item ID* refers to the entry on the *action page*.

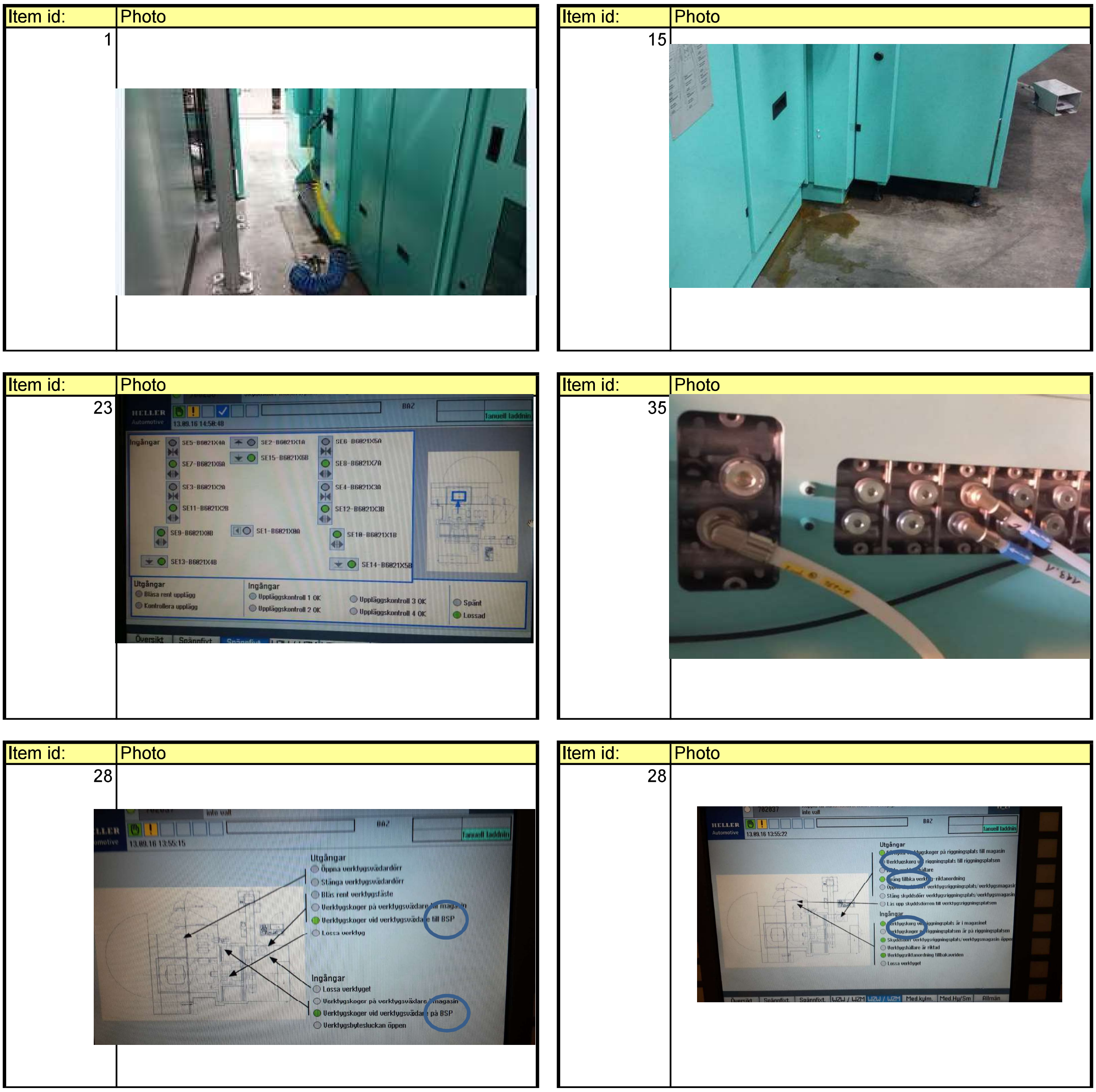


Figure E.1: Example of a Tag-Photos page.

F. Acceptance Record – Machine Layout

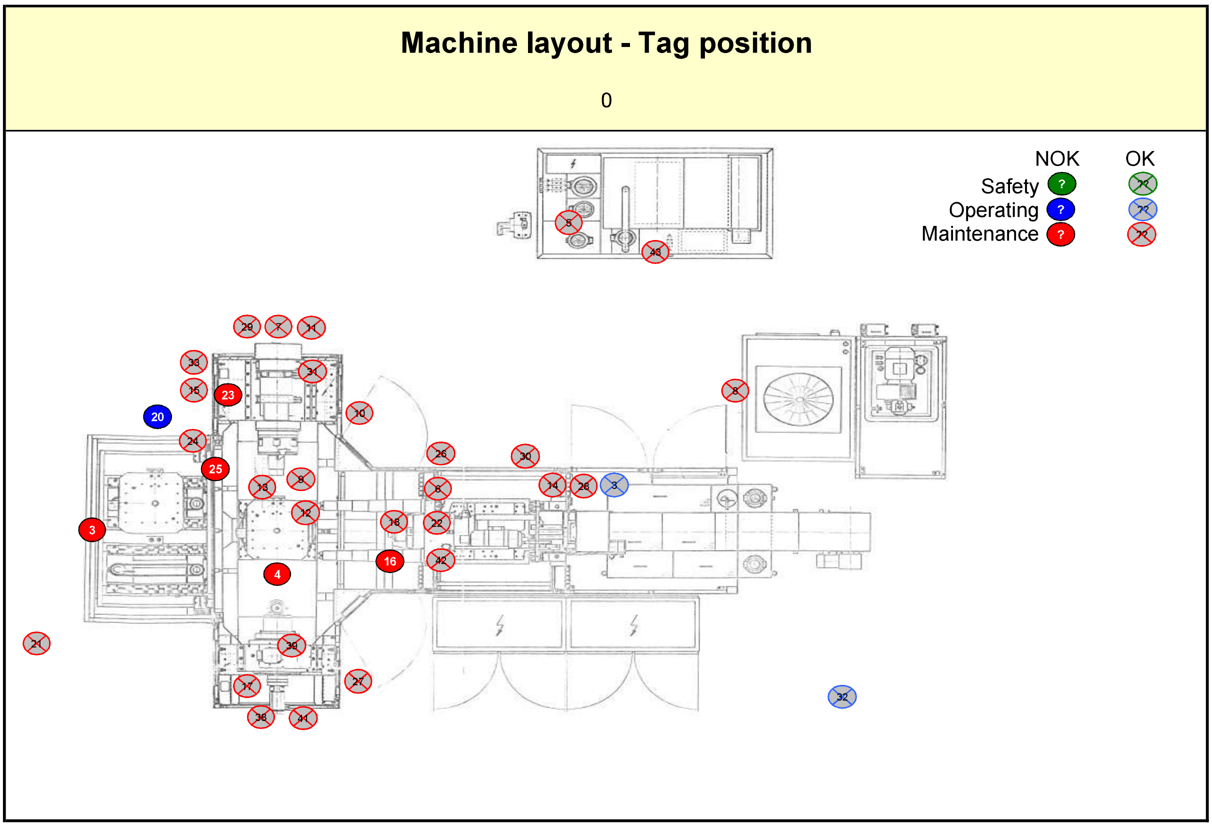


Figure F.1: Example of how a machine layout with tags can look like.

G. Result of analysis of earlier research

Table G.1: Search terms and number of results for each document type

Search String	Total Results	Article	Conf. Paper	Book Ch.	Book
TITLE-ABS-KEY (”Knowledge management” AND (purchasing OR acquisition))	5 427	1 864	3 198	106	19
TITLE-ABS-KEY (”Knowledge reuse” AND (purchasing OR acquisition))	105	53	48	1	1
TITLE-ABS-KEY(”Knowledge management” AND (purchasing OR procurement))	393	139	220	8	4
TITLE-ABS-KEY(”Knowledge management” W/10 (purchasing OR acquisition)	413	200	162	18	4
TITLE-ABS-KEY(”Knowledge management” W/10 (purchasing OR acquisition)) AND NOT (”knowledge acquisition”)	138	73	49	7	2
TITLE-ABS-KEY (”Knowledge management” AND procurement)	234	95	113	6	4
TITLE-ABS-KEY (”Knowledge management” AND acquisition AND NOT ”knowledge acquisition”)	1 524	557	825	49	15
TITLE-ABS-KEY (”lessons learned” AND (”TPM” OR ”Total Productive Maintenance”))	5	2	3	-	-
TITLE-ABS-KEY (”lessons learned” AND (procurement OR acquisition) AND automotive)	14	1	12	1	-
TITLE-ABS-KEY (”knowledge management” AND ”early management”)	2	2	-	-	-
TITLE-ABS-KEY (”lessons learned” AND ”early management”)	10	6	1	-	-
TITLE-ABS-KEY (”lessons learned” AND ”industrial engineering”)	196	43	138	10	2

Continued on next page

Table G.1 – continued from previous page

Search String	Total Results	Article	Conf. Paper	Book Ch.	Book
TITLE-ABS-KEY (”project review” AND ”industrial engineering”)	10	-	6	-	-
TITLE-ABS-KEY (”lessons learned” AND (procurement OR acquisition) AND industrial) AND NOT ”knowledge acquisition”	122	32	72	4	2
TITLE-ABS-KEY (”knowledge management” AND purchasing)	174	50	115	3	0
TITLE-ABS-KEY(”Knowledge management” AND procurement)	234	95	113	6	4
TITLE-ABS-KEY (”lessons learned ” AND (session OR method OR process) AND (procurement OR purchasing OR acquisition))	1 139	392	643	28	8
TITLE-ABS-KEY (”lessons learned” AND procurement)	504	187	251	11	4
TITLE-ABS-KEY (”lessons learned” AND purchasing)	166	84	52	10	3

H. Overview of project documentation analysis

The table starts on the next page.

Table H.1: Table of analysed documentation from acquisition projects at the case-company with information about it, the last one being if the document contains information that might be relevant to other projects.

Name	Type of Document	Tag	Contains	Machines	Relevant
Acceptance record	Excel-sheets	During	Actions that come up during testing to be finished at certain gates in the EEM-process	Seperate	x
Action List	Excel-sheets	During Project	Actions that come up during the project and when to do them	All	x
Agreement	Word-document	During Project	Agreements between buyer and supplier		
AM-Steprevision	Excel-sheets	Planning	Checklist of what resposibilities AM should live up to during the project	All	x
Assorted calculations	Excel-sheets	During Project	Different budget-proposals, maintenance estimates etc.	Seperate	
Building-documents	Assorted	During/ Planning	Specifications and other things regarding the building	Seperate	
Checklists for installation and tests	Excel-sheets	During	A list of tests to perform on the machines both at the supplier site and in the buyer site	Seperate	x
Contract Practicalities	Word-documents	Not connected to project	General terms of agreement between the case company and the supplier		
Cost-split up	Excel-sheets	During	Agreements of cost split up	Seperate	

Continues on next page

Name	Type of Document	Tag	Contains	Machines	Relevant
Dash-board	Excel-sheets	During Project	Overview of status and project information	Seperate	x
EEM-Project improvement list	Excel-sheets	During Project?	List of things to improve with the EEM-process itself	All	x
End Effects Fulfillment Report	PP-Presentation	After Project	Fulfillment of End Effects, positive and negative experiences and recommendations for future projects.	Seperate	x
Final Report	PP-Presentation	After Project	Fulfillment of Project objectives(time and cost), positive and negative experiences and recommendations for future projects.	Seperate	x
FMEA riskanalys	PDF	During	PDF of suppliers risk assesment for installation	Seperate	x
Function test	Word-document	During	A list of tests to perform on the machines both at the supplier site and in the buyer site	Seperate	
Guarantee Status Report	Word-document	During	Agreement of warranty period and what it involves and how the status is atm	Seperate	
Handover record	Excel-sheets	During	Actions that come upduring testing towards production	Seperate	x
Installation-diary	Excel-sheets	During Project	Points of actionduring the installation of the machines.	All	
IT-System project document	Excel-sheets	Planning	Checklist of actions to be taken for implementation of IT-system for the new machines.	All	x

Continues on next page

Name	**Type of Document**	**Tag**	**Contains**	**Machines**	**Relevant**
Kaizens made connected to the project	Excel-sheets	During Project	Smaller improvements	Seperate	
Master Plan	Mulitple	Planning	Planning for the entire replacement of lines in steps	All	x
Meeting minutes between supplier and buyer	Excel-sheets	During/ Planning	Lots of planning, other agreements between buyer and supplier	Seperate	x
Meeting minutes from SC and connected materials to meetings	Word-document	During Project	Decisions and discussions regarding points from the project	Seperate	x
Pre-acceptance plan	Excel-sheets	Planning	Time-shceduele for testing phase of the project	Seperate	
Project Directive	PP-Presentation	Planning	Dates, Background(WHY newmachines are bought), interactions with other projects, goals(end effects), objectives, delimitations, should have[resource plan, projects costs, organisation]	Seperate	x
PSM Checklist	Excel-sheets	During Project	Checklists of what to do during projects to make sure nothing is missed	Seperate	x
Resource-plan	Excel-sheets	Planning and During Project	How to allocate resources for the projects	All	

Continues on next page

Name	Type of Document	Tag	Contains	Machines	Relevant
Responsibilities	Word-document	Planning	What every team-member is responsible for carrying out	All	x
RFQ	Assorted	Not sure	Agreements and all things related to the quotations	All	
Risk assesments	Word-documents	During	Risk, Risk-situation, and countermeasure	Seperate	x
Scope of Supply	Word-document	During	Specification for the machine	Seperate	
Simulations	Word-documents	During	Simulations of pace with new machines	Seperate	
Status Report	PP-Presentation	During Project	General summary of project, status of phase deliverables, fulfilment of gate criteria, project health summary, risks, gate recommendation, project experiences(positive and negative)	All	x
Time-schedule	Excel-sheets	During Project	Dates for all parts of the line-replacement	All	
Time-schedule	Excel-sheets	During/ Planning	Planning dates	Seperate	
TS	Assorted	During	General Specification	Seperate	
Warranty issues	Excel-sheets	During	List of things that have gone wrong during warranty, cost of downtime and fix	Seperate	x

Continues on next page

Name	Type of Document	Tag	Contains	Machines	Relevant
Whitebook	Word-document	Before and after project	Assorted notes about the project, not much description at all	All	x
Volume Plan	Excel	Planning	Planning for capacity	All	

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