Mapping of Engineering Knowledge in a Product Development Organisation

Knowledge Management Possibilities in a Global Organisation

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Master of Science Thesis in Product Development

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Abstract

This thesis has been conducted at the Climate group at Volvo Group Trucks Technology (Volvo GTT) with the purpose to investigate the potential for an implementation of a Knowledge Management (KM) system at the component level of the truck. The aim is to create a generic system enabling the design engineers to capture, distribute and reuse knowledge regarding the pipes and hoses in the air conditioning system. The thesis is a part of a pilot study with the overall goal to reduce Volvo GTT's research and development costs with 30 %. Three research questions have been formulated:

a. Where is the knowledge find in the Climate group and how is it stored?
b. In which system shall the knowledge be captured, stored and distributed, in a way that is suitable for the design engineers?
c. What are the prerequisites for the created system to be maintained and support the design engineers in their decision making?

Interviews with employees at Volvo GTT have been conducted to receive an insight in the current situation. A survey has also been conducted to provide the basis for the creation of the KM system. As the thesis progressed, the achievements were presented and modifications were made upon the feedback from the management and design engineers of the Climate group.

The thesis included literature studies regarding KM and Lean Product Development, which functioned as a theoretical framework when the KM system was created. Benchmarking of three companies was conducted with the purpose to investigate how they are managing knowledge in their organisations, if they are using a system and how other organisations have improved their way of working.

At the beginning, there was a desire to implement a system that increases the efficiency of work and interviews with the design engineers and other employees confirmed the desire.

Initially, focus was on the creation of a knowledge database, but later on the effort was put on identifying what content should be included in the database. Thus, the main part of the new KM system is Check Sheets and trade-off curves with an owner structure. The trade-off curves, together with golden and generic rules can be explained as compressed knowledge possessed by the employees. They capture the knowledge and store it in the Check Sheets, providing features for maintenance and distribution of the content throughout the organisation. Together, they are providing the mechanical designers to make decisions based on knowledge, minimizing decisions based on guessing, thus reducing late upcoming errors leading to reduced costs.

The Check Sheet features an inbuilt chat function allowing discussion and attachment of documents. Every generic rule has a link to relevant documents stored in present databases, with the idea to provide fast and accurate access without having to know about a specific project, which is the case of today.

These deliverables have significant implications for the increased work efficiency. It appears that the system is a sufficient base to develop further so that it becomes a daily used tool for the design engineers at all Volvo sites. Volvo GTT will take the thesis with its recommendations and further developments into account and other thesis workers will continue the work.

Definitions

Component owner = Mechanical designer
DIKW = Data, information, knowledge & wisdom
DVG = Design Verification Guideline; a design tool at Volvo Powertrain.
GDP = Global Development Process; a process used at Volvo in their product development.
KM = Knowledge Management
SMT leader = Sub Module Team leader; a management position.
STS = System Technical Specialist; technical expert.
Volvo GTT = Volvo Group Trucks Technology

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Mattias Dotevall
Ömer Yasar

“Information is not Knowledge”

- Albert Einstein -

Contents

1. Introduction

What is knowledge management?

From a product development organisation perspective, dealing with Knowledge Management (KM) is vital for the organisation's development and competitiveness in a world becoming constantly globalized. With a transformation to go from an outdated structure – where pure technical practices were in focus – to an organisational structure that takes greater account of being competitive, have an engaged workforce and do continuous improvements, companies has realised the value of KM (Morgan & Liker, 2006).

To get an understanding of the term KM, it is essential to clarify the meaning of the terms individually and later on to state the outcome of the purpose of merging these (Davenport & Prusak, 1998).

Knowledge comes in different forms and it has different definitions – all from the old philosophers to definitions from top organisations. Dealing with knowledge in an organisation can be explained by Business Dictionary's definition:

> *"The sum of what is known and resides in the intelligence and the competence of people"*

The term management normally means that "something" has to be managed (Wiig et. al, 1997). Thus, the synergy KM will identify and create the knowledge and store, share and apply it in the organisation. Below is a definition from Barth (2001):

> *"Systematic approaches to help information and knowledge emerge and flow to the right people at the right time so they can act more efficiently and effectively. It is about creating a corporate culture that learns from experiences, so if mistakes do happen, they will never be repeated"*

There are mainly two types of knowledge discussed in business, explicit and tacit knowledge where the tacit knowledge is in majority (Cognitive design solutions, 2003). Both types of knowledge are valuable in an organisation and the thesis will investigate the proportions at the department of air conditioning with its pipes and hoses and the possibilities to implement a method providing efficiency in their work.

This is also valid at the Climate group of the Cab department where a large portion of knowledge is tacit knowledge – non-codified personal/experience-based knowledge. Thus, articulating tacit knowledge into explicit knowledge is the main focus – defined as codified knowledge, such as found in documents (Frost, 2010).

Notwithstanding the definition above, KM is a vague conception. There are basically three main KM business objectives identified for a product development organisation; reduce risks, innovate and save resources (AB Volvo, 2011) as illustrated in Figure 1.

Figure 1: ***The three business objectives of Knowledge Management (AB Volvo, 2011).***

Reduce risks

It is important to store captured knowledge within the organisation that otherwise could be lost in time. To be able to learn from previous projects and avoiding that the knowledge is moving along with the employees is important. Transfer knowledge from person to person and reusing existing ideas are also important factors in maintenance of the knowledge. It is necessary to secure a product development organisation's competence and its transfer between employees (AB Volvo, 2011).

Innovate

The base for innovation in a product development organisation is the knowledge capital. From a mechanical designer's point of view, it is important to have a toolbox with knowledge to be able to create new innovations. New combinations of current solutions or critical design parameters are useful tools. Profit from external knowledge is important to keep the innovation level of a product development organisation on a high level (AB Volvo, 2011).

Save resources

Having a well-functioning KM is vital for the engineers in a product development organisation. To be able to automate routine tasks, using the best practice or avoid doing mistakes upon lack of knowledge of lessons learnt saves plenty of time and money in the product development process (AB Volvo, 2011).

1.1 Importance of Knowledge Management and its different levels in a Product Development Organisation

According to Nonaka (1991), KM derived from the need for companies to manage their resources more effectively in a competitive, global economy. The competitiveness puts pressure on innovations and development companies' products and services.

KM provides decision-making based upon precognition and adaptation, in contrast to the traditional way based on prediction (McCampbell et al., 1999). Thus, adapting KM allow engineers to make product development decisions based upon reliable knowledge minimizing the defaults that the earlier predictions caused. It will intercept the possible defaults early in the product development process, which save costs since changes later on in a product development process is expensive.

A study conducted by American Productivity & Quality Center (1996) shows:

- KM practice is dynamic and that it often starts by creating, finding and collecting internal knowledge and best practices.
- Sharing and understanding those practices so they can be used.
- Adapting and applying those practices to new situations.

The importance of the support from the top down management was highly valuable to incorporate a good KM process. The involved firms also underscored the importance of teams, relationships and networks (American Productivity & Quality Center, 1996).

The first point indicates that there are more levels of KM. Hedlund (1994) says, "*The notion that knowledge resides not only at the individual level is of course not new*". In an organisation one can divide it up in individual, group and organisational level. Nonaka (1994) developed the concept of a spiral of knowledge creation where the knowledge starts at the individual level, moving to the group level, and then up to the organisational level. The levels are interdependent in the enrichment and amplification of the knowledge, thus only concentrating on one level inhibits KM. According to Hedlund (1994), the prominence of small groups in innovation and product development indicates that much of knowledge transfer and learning take place at this level. The levels are illustrated in Figure 2 below:

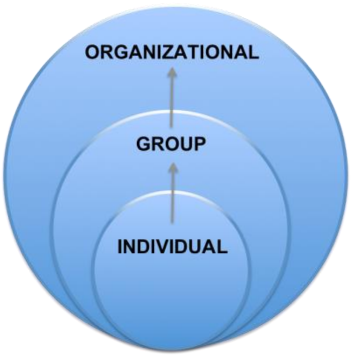


Figure 2: ***The KM level-circle.***

1.2 Presenting the Case Company

Volvo Group Trucks Technology is a part of the Volvo Group and is one of the largest manufacturers of trucks in the world (AB Volvo, 2012). Volvo GTT is a global company and offering a wide range of different models and Renault Trucks, Mack, UD Trucks and Eicher are sister brands. The company is a cross functional organisation and within the product development area, it consists of a number of departments where the Cab department and, in our thesis, the Climate group is in focus. The Climate group is a center of excellence, which means that it develops, in addition to the climate system for Volvos different models, also the basis for the climate system for the company's sister brands.

The Global Development Process (GDP) in Figure 3 is used within the whole Volvo Group organisation in product development projects. The purpose is to provide a uniform stage gate process to ensure the development of reliable products with high customer value.

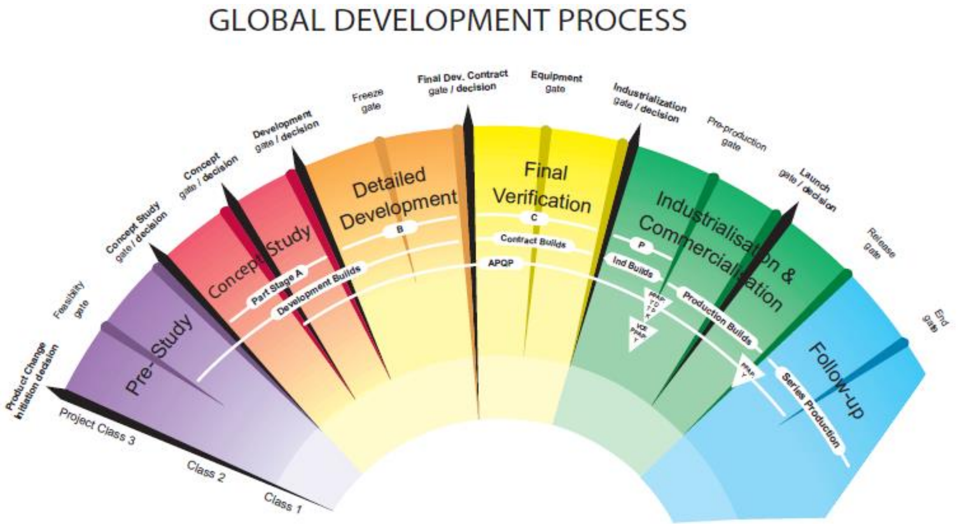


Figure 3: ***Global Development Process (GDP).***

Depending on how extensive the product development project is, it has different numbers of gates to proceed. At each gate the product development project need to meet deliveries in order to proceed to the subsequent stage.

Volvo GTT has initiated a program called RnD30 with the main purpose to decrease the research and development costs with 30 %. Twenty percent cost-reduction will be achieved by reducing lead times in product development projects and the remaining ten percent savings will be achieved by strategic portfolio management.

1.3 Purpose

The project is a pilot project out of four with the ambition to provide insights in how the department operates today, how other companies manage their knowledge and as a step in fulfilling the RnD30 cost savings, develop a system which captures and reuses engineering knowledge and by learning from mistakes and successes. The insights will be used for the KM implementation in the whole organisation of Volvo GTT and in all its sites around the world. The thesis will further investigate how the possessed knowledge and new knowledge such as innovations, new technologies etc. can be captured in a compressed and visualized format.

During the thesis, the purpose has been taking different shapes. Initially, the purpose was to create a prototype of a knowledge database within the area of air conditioning and its pipes and hoses at the Climate group at Volvo GTT in Gothenburg. The database would recapture and reuse knowledge within the Climate group to reduce the lead time in their product development process.

The Climate group is suitable department for a pilot project since it is a center of excellence. Thus, the insights from the department will be valuable to the field of KM and its attempts to be implemented in other departments. The project can be illustrated in Figure 4 below which describes the progress with the KM system.

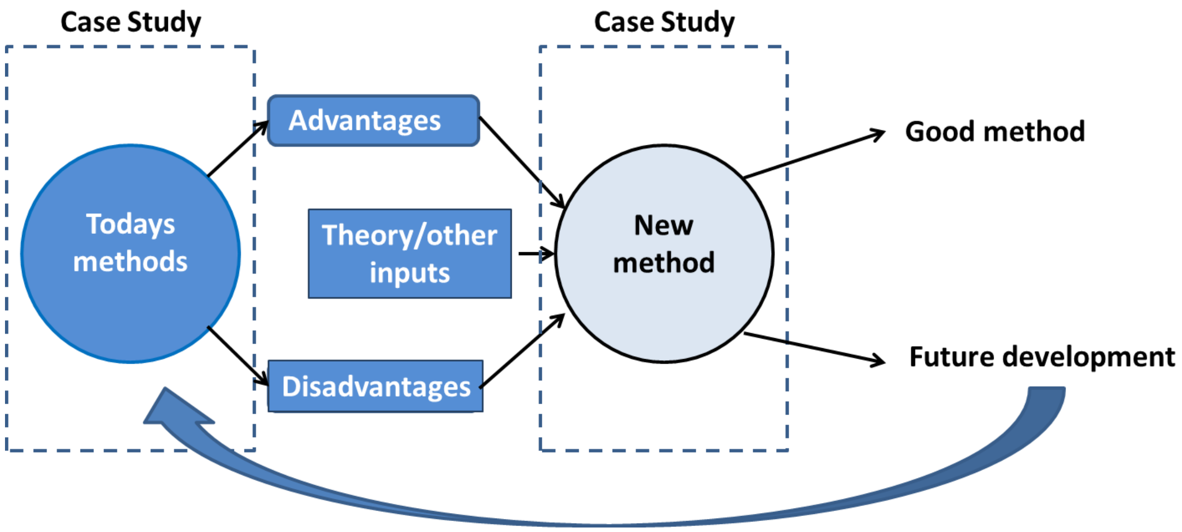


Figure 4: ***Methodology for how the system continued to develop throughout the thesis.***

The figure is divided up in a loop of case studies with the aim to provide feedback of the present situations for further developments. Simply, theory of important attributes together with observations and interviews with users will lie as a base for the developments. This method is looped throughout the whole thesis and can be illustrated by the development from database 1 to the database 2, which will be presented in chapter 6.

Although, after some work with the creation of the database, it showed out that in order to create a long lasting, easy used database one had to first define what knowledge it should include. Therefore, the objective changed to create a KM system that captures the core knowledge for components providing the design engineers to make knowledge based decisions upon designing. It should also include a respective ownership structure to keep the

knowledge up to date and maintained. This ended up in the creation of trade-off curves and Check Sheets (Chapter 6.2).
Hasanali et. al. (2001) talk about content management and that user demands for up-to-date, accurate and personalized content. Further, the report says that content is much more than data or information;

> "*It is knowledge that has been codified so that it can be more easily distributed and reused for a specific purpose by a targeted audience. Its value is realized only when people use it to make better decisions for the organisation."* (Hasanali et. al. 2001, p. 7).

The change of the objective can be supported, from a KM perspective, by the real question for content managers "*What content do I need?*". This question leads to the next questions "*What content do I have?*" and "*What is the best way to get it*" (Hasanali et. al. 2001, p. 7). Hasanali et. al. (2001) says that creating a knowledge database make sense only when these questions are asked. Hence, attempts to answer these questions are made by the creation of trade-off curves and Check Sheets.

1.3.1 Research Questions

The purpose is broken-down in the following three research questions. They are formed in a way to support the progress with the thesis and to make sure a common line is present throughout the thesis.

RQ 1: Where is the knowledge find in the Climate group and how is it stored?

To be able to create a new way to capture, reuse and deliver knowledge in the Climate group, it is necessary to get deep understanding of how the personnel are working and where and how they receive their data, information and knowledge. An important part is also to investigate how other departments are working within the Volvo GTT organisation as well as investigating how other companies are working with KM.

RQ 2: In which system shall the knowledge be captured, stored and distributed, in a way that is suitable for the design engineers?

Today, there are many different ways to store knowledge. There are companies that sell complete KM software solutions and there are more traditional tools, which are used in for instance the Lean philosophy. The second research question is focused to find the optimal KM system for the Climate group.

RQ 3: What are the prerequisites for the created system to be maintained and support the design engineers in their decision-making?

The third research question relates to keep the new knowledge system sustainable by creating an ownership maintenance structure to encourage the use of it, by senior as well as new employed engineers.

1.4 Scope & Limitations

The KM group within Volvo GTT has created the requirement specification and chosen the Climate group in the Cab department as the division, which the system will be tested and implemented on. Thus, the scope of the project will include the knowledge from the Climate group, more specifically knowledge regarding air conditioning and its components, such as pipes and hoses. Thus, the KM levels included in the thesis will be on an individual and group level, as illustrated in Figure 2.

The delivered system will, in a basic and simple way, be illustrated in Microsoft Office. Further, the project will focus on KM with the segment of data and knowledge gathering.

A big importance is to distinguish between establishing a requirement specification and programming a valid IT-tool. Focus will be put on what the system shall include rather than the system itself.

2. Theoretical Framework

The purpose of the Theoretical Framework is to provide relevant theory for the topic of this thesis. The theory will serve as support for the analysis of the interviews but also support the conclusions, recommendations and further developments of the result. The chapter begins with defining knowledge and KM. Further, knowledge in Product Development and Lean Product Development are described. Subsequently, the chapter deals with knowledge ownership, barriers and challenges in KM and trade off curves.

2.1 Define data, information, knowledge and wisdom

The ground concept and idea with KM is that knowledge is important and that one has to better understand how to control and lead knowledge within an organisation (Jonsson, 2012).

This thesis makes a distinction between data, information, knowledge and wisdom (DIKW). It also point out that Volvo GTT has monstrous amounts of data and the need of knowledge contextualization is crucial for its survival and continued expansion. Therefore, it is of biggest concern to explain what is meant by these terms and how they interact.

It may sound simple, but there is disagreement on what DIKW are. Zeleny (2004) argues that KM does not fulfill its original purpose due to a lack of well-defined differentiation from information, information management and IT applications. It gives room for interpreting knowledge in "whichever suitable way" (Zeleny, 2004).

Ackoff (1989), founder of the DIKW hierarchy, describes data as products of observations with no value until they are processed into a usable form to become information. Information is contained in answers to questions (who, what, where, when) and knowledge (how) makes possible the transformation of information into instructions. "*It makes control of a system possible*" (Ackoff, 1989, 4). Knowledge may be enough for effective problem solving but not for planning; it also requires wisdom (Ackoff, 1974, p. 7). Ackoff also includes the term understanding, between knowledge and wisdom, which is the appreciation of "why".

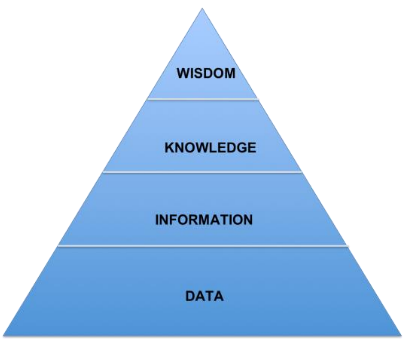


Figure 5: ***The data, information, knowledge and wisdom hierarchy (Ackoff, 1989).***

Zeleny (2004) is supported by Weinberger (2010), who argue that the DIKW hierarchy was invented due to the problematic outcome of information overload (initiated 1970 by Alvin Toffler). Weinberger describes the invention of DIKW as a need to characterize the value extracted from information. His statement is that the definition given to knowledge is quite facilitated and too narrow.

In his book, Leistner (2010) says that knowledge cannot be managed since it only exists in the mind and is connected to all the prior experiences. The manageable part of knowledge are ways to enable the flow of it to others and what is being passed is information, which Leistner defines as data in context, not knowledge.

Leistner's view is similar to Ackoff's who defines knowledge as the value of information - *"It [knowledge] is what makes possible the transformation of information into instructions"* (Ackoff, 1989). Since the thesis is written at a global organisation, it will use Davenport & Prusak's (1998) pragmatic descriptions:

> "*Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms*." (Davenport & Prusak, 1998, p. 4)

The hierarchy implies that knowledge derives from information as information derives from data. Davenport & Prusak (1998) further state that if information is to become knowledge, humans must do virtually all the work - explained below:

- Comparison: how does information about this situation compare to other situations we have known?
- Consequences: what implications does the information have for decisions and actions?
- Connections: how does this bit of information relate to other?
- Conversation: what do other people think of this information?

According to Davenport & Prusak (1998), data is explained as facts and descriptions of the world. Further, it is not organized in any way and provides no direct value. Once the data is processed, it becomes information. Davenport & Prusak (1998) further state that it must be contextualized, categorized, calculated, corrected and condensed, i.e. for what purpose is the data gathered, what are the units of analysis or the key components of the data, is it mathematically or statistically analysed, are errors removed from the data, is the data summarized in a more concise form.

2.2 Tacit and explicit knowledge

From the definition of knowledge in chapter 2.1, one can derive different types of knowledge; knowledge that are carried in people's heads and knowledge that are, in some way, captured. Nonaka & Ichijo (2007) explains this as tacit and explicit knowledge.

Tacit knowledge – the valuable and highly subjective insights and intuitions that is difficult to capture and share because people carry them in their head. It can be expressed in words, sentences, numbers or formulas and also as cognitive and technical skills like beliefs, images, intuition, craft and know-how (Marchev & Tuzharov, 2006). The knowledge can be deeply ingrained thus difficult to articulate.

Explicit knowledge – the advice from how to distill objective and transferable knowledge from tacit knowledge (Nonaka 2007). It encompasses knowledge that can be examined by and shared with others. Explicit knowledge is knowledge that is transmittable in formal, systematic language and may include explicit facts, axiomatic propositions, and symbols (Kogut & Zander 1992). It can be codified or articulated in manuals, computer programs, training tools, and so on.

Briggs (2006), with the support of Nonaka's text, believes that none of the knowledge alone promotes knowledge creation and it negates the innovation process. To incorporate new knowledge into the organisation, there has to be an interaction between tacit and implicit knowledge. The interaction can be illustrated by the SECI-model in Figure 6 made by Nonaka and Takeuchi.

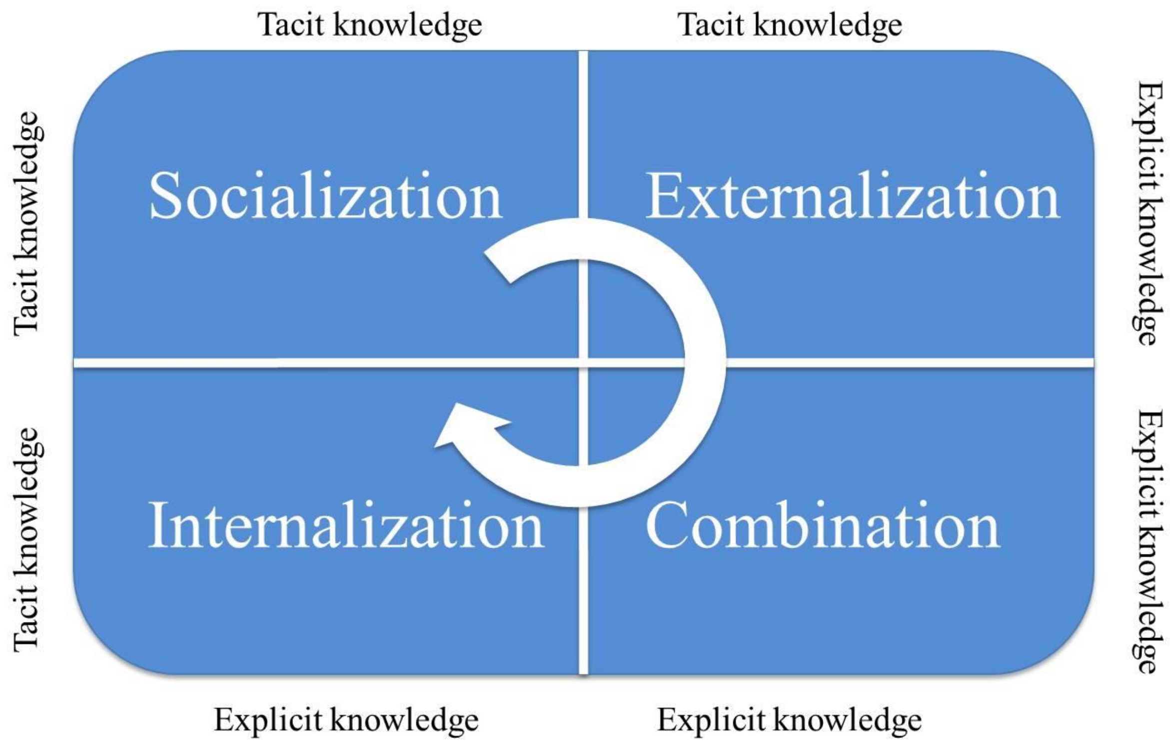


Figure 6: ***The SECI-model (Nonaka and Takaeuchi, 1995).***

Nonaka (2007) explains that organisational knowledge is created by the completion of all four conversations/conversions and the amount of knowledge grows with each completion. The circuit begins at the upper left with the tacit to tacit conversation.

- Socialization - Knowledge sharing through physical and face-to-face experiences. It can be illustrated by an apprenticeship. (Tacit-to-Tacit)
- Externalization - Conversion of tacit knowledge into explicit by development of concepts and models which can be interpreted and understood by others.
- Combination - "*Systematizing concepts into a knowledge system*" (Nonaka and Takeuchi, 1995, p. 67). It can be the embodiment of knowledge into products, exchange and combination of new explicit knowledge with the knowledge that has been found earlier.
- Internalization - "*Learning by doing*" (Nonaka, 1994, p. 19).

The SECI-models universal validity (Nonaka & Takeuchi, 1995) has been challenged with arguing that cultural differences between countries make the model unsustainable (Doyle, 1985; Glisby & Holden, 2003). Nonaka and Takeuchi postulate that knowledge creation is a social process. Andreeva (2011) implies that the model needs adaptation since social processes are culturally rooted hence it cannot be a culturally universal concept, as the authors promotes.

It has also been met with criticism, i.e. by Adler (1995), which argues that the correlation between explicit and tacit knowledge is too static in the model thus inadequate for a dynamic model of tacit-explicit knowledge affinity. Adler further states that if tacit knowledge is the source of new knowledge, it is not clear why knowledge conversion has to begin with the socialization mode.

Nonaka (1994) is supported by Stillwell (2008) who sees that Nonaka's work has a potential for radically changing the West's view of tacit knowledge, and conceptualize it differently

In his book *"The Tacit Dimension"*, Polanyi (1966) makes knowledge synonymous with action. He says that the lack of explicit knowledge of uncertain things advocates that there can be no explicit justification for scientific truth. Thus, pointing that there is no explicit knowledge, only information. He further claims that *"we can have a tacit foreknowledge of yet undiscovered things*." (Polanyi 1966, p. 23)

Polanyi's beliefs regarding action are also expressed by Nonaka with a difference that Nonaka et. al. (1996, p. 835) mean that both tacit and explicit knowledge exists and interact with, and change into, each other in the creative activities of human beings.

Polanyi (1966) is further dividing tacit knowledge into two terms; proximal and distal. What he means is that all knowledge a person possesses is not able to be explained due to the fact that the knowledge is deeply rooted as intuition or due to the lack of awareness of possessing the knowledge. The knowledge that is unable to be expressed is defined as proximal knowledge and distal is the opposite, or as Polanyi (1966, p. 11) expresses it;

> *"...we are aware of the proximal term of an act of tacit-knowing in the appearance of its distal term; we are aware of that from which we are attending to another thing, in the appearance of that thing."*

This distinction confirms the value and need of people with their experiences and it indicates that replacing such person is not as easy as one may think - no matter how much of his/her tacit knowledge has been stored.

2.3 A Knowledge insight in Product Development

Kennedy (2003) defines Product development as "*Collective activities, or system, that a company uses to convert its technology and ideas into a stream of products that meet the needs of customers and strategic goals of the company*" (Kennedy, 2003, p. 14).

Competing through development capability is a key factor for success for companies (Wheelwright & Clark, 1992; Kennedy, 2003; Fiore 2005). To streamline a product's development cycle, match it against customers' needs and expectations create a significant competitive leverage. On the other hand, companies who are slow to market, developing products that mismatch customers' needs will sooner or later be unable to meet the competition. Wheelwright & Clark (1992) state that product and process development is a key factor for companies to be a successful player at the global market. Furthermore, Wheelwright & Clark argue that this have had a great impact on the development process on every consumer product worldwide, particularly on the automotive industry. The Japanese automobile manufacturers realised few decades ago the importance of a dynamic product development organisation that is designing vehicles with high reliability and customer value, delivered at the right time (Wheelwright & Clark, 1992). The authors pinpoint that this was a contribution reason why Japanese automobile manufacturers experienced a huge success worldwide and especially in the U.S in the 1980's.

The need for an improved product development management tool made that Cooper invented the Stage Gate process, illustrated in Figure 5 (Cooper, 1990; Cooper, 2008). The Stage Gate process divides a product's development cycle into a number of stages and gates, from idea generation stage to post industrialization stage. Cooper's idea with the Stage Gate system is to have a standardized and transparent methodology for a whole organisation. There should be well-defined deliverables and criteria at each gate which will work as a basis for decisions if the development process shall continue, be recycled or be paused (Cooper, 1990; Cooper, 2008).

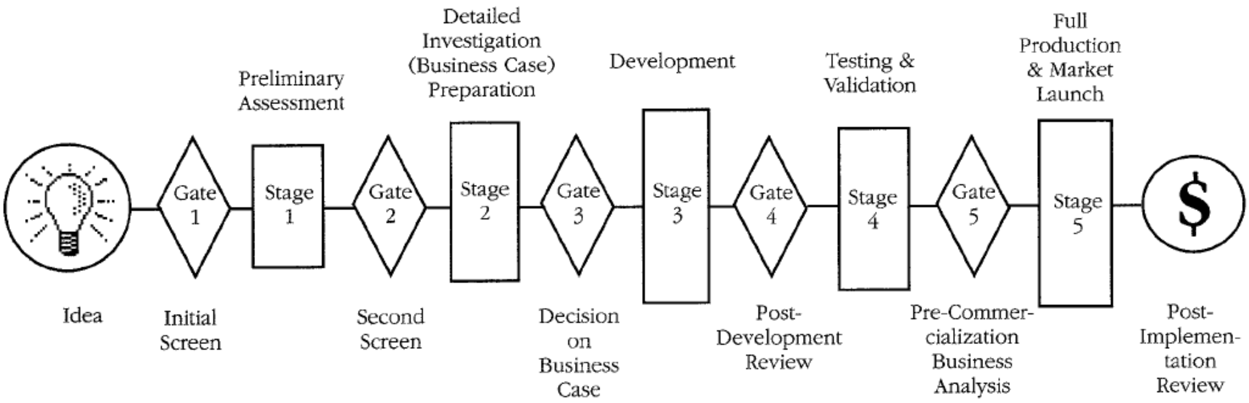


Figure 7: ***The Stage Gate process (Cooper, 1990).***

The Funnel in Figure 8 is another product development management tool, similar to the Stage Gate process above, developed by Wheelwright & Clark. The mouth of the funnel shall capture potential good ideas and as the funnel is narrowing down, the ideas shall be evaluated in different screens (Wheelwright & Clark, 1992), as in the Stage Gate process.

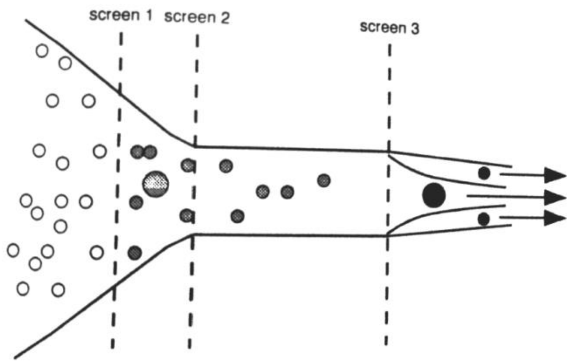


Figure 8: ***The Funnel (Wheelwright & Clark, 1992).***

During the latest decades, product development has made big progress in for example shortening lead times, increase productivity and decrease development cost for the companies (Kennedy, 2003). The Stage Gate process has been adopted by many different companies worldwide, like the GDP process in chapter 1.2 at Volvo Group, and worked as a key tool for achieving these improvements (Cooper, 2008). Though, the Stage Gate process does not deal with knowledge that is captured during development processes.

In the beginning of the 1990's, "Lean" became well known for the people in the U.S and Europe and Lean means eliminate waste in processes which is not contributing to any value for the company and its customers (Liker, 2004; Fiore, 2005). The word was created by James Womack who wrote the book "*The machine that changed the world*" in 1990 (Holmdahl, 2010; Liker & Morgan 2006). On that time, scholars in the U.S investigated why and how the Japanese auto manufacturers were able to outclass the American and European car manufactures in terms of production efficiency and shorter research and development lead times which ended up in more reliable vehicles with higher customer value than its competitors (Holmdahl et. al, 2010). There are of course a number of factors why the Japanese auto manufacturers became successful; one contributing factor was the Toyota

Management System, TMS. The system is linking the company's different operation areas (production, marketing and development) tight together (Holmdahl, 2010). Nowadays, many companies in the rest of the world have adopted Toyota's way of working where expressions like Just-in-time deliveries (Kanban) and continuous improvements (Kaizen) have been well known terms when companies are streamlining their production lines (Holmdahl, 2010). Holmdahl says that experts do not advice to implement Lean in product development but he is arguing that Toyota has done that since the 1960's. Methods like Concurrent engineering and Set-based design were invented by Toyota but are since the latest decades widely used by many product development organisations worldwide (Holmdahl, 2010).

Liker & Morgan (2006) emphasize that there is a huge competitive advantage by adopting the Lean philosophy in product development rather than in for instance production and manufacturing. The reason is because, since 1980's, a majority of companies already have made major improvements in production and manufacturing methodologies due to an adoption of the Lean philosophy. Still, the gap between the best and other product development organisations is increasing, especially in the automotive industry (Liker & Morgan 2006). According to Liker & Morgan (2006), a reason why Toyota has been very successful during the latest decades is because they have an elaborated Lean philosophy throughout the whole company where the knowledge capturing and collective learning are central.

In the Lean philosophy, it is important to capture the tacit knowledge, e.g. the know-how knowledge that allows the organisation to reuse it and make the organisation grow (Liker & Morgan, 2006). Kennedy et. al. (2008) has developed a Lean development model, as seen in Figure 9, consisting mainly of two value streams. There are product value streams that illustrate the development process of new products. In the knowledge value stream, knowledge is captured with different tools (trade off curves, Check Sheets, A3-reports etc.) to ensure a reusage of it in upcoming development projects. When the knowledge is provided, the knowledge value stream continues forward and the start of the next product development project can begin on a "higher knowledge level" (Kennedy et. al. 2008).

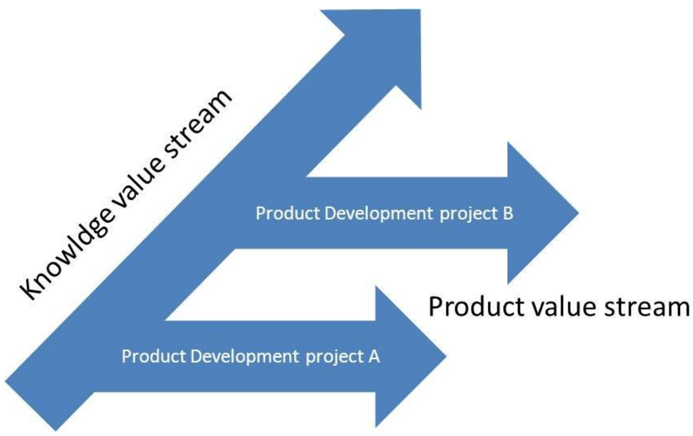


Figure 9: ***The knowledge and value stream (Kennedy et. al., 2008).***

2.4 Knowledge ownership and maintenance

Davenport & Prusak (1998) state that the responsibilities to implement KM lie in the interests from the upper management. With their engagement in and statement of KM's influence for the organisations survival and the individuals' development may motivate the personnel attitude towards KM and trigger their motivation to make their knowledge accessible across the organisation (Davenport & Prusak, 1998). This will create a give-and-take culture hence foster the relation between the organisation and its personnel to share the same vision (Davenport & Prusak, 1998).

Many factors will affect the outcome from the initiative; one of them is the knowledge ownership (Davenport & Prusak, 1998). Why this is crucial is because the implemented method has to be up to date, accessible and available for the engineers within the business (Davenport & Prusak, 1998). Parallel, the knowledge has to be presented in a usable format.

Jonsson (2012) provide a five-step model for how to manage knowledge transfer;

1. Analysing approaches and needs
2. Create the right conditions
3. Clarify responsibility roles for knowledge transfer
4. Communicate knowledge and the chosen strategy as part of an overall vision
5. Learn, live and lead the transfer of knowledge into practice - in the daily work

Jonsson (2010) clarifies that these steps are not a so-called quick-fix, rather a way to lift key issues that are vital for a well-functioning knowledge transfer. A closer look at step 3 will provide a reflection of why it makes sure that knowledge transfer is maintained.

Jonsson (2010) explains this with the need of having a balance between exploration and exploitation and Jonsson points that this can be achieved by clarifying who is expected to do what, when and where. The term explore implies to have an ability to rapidly explore new innovative solutions and exploit implies to have an ability to exploit assets - tangible (e.g. databases, products) as well as intangible (e.g. colleagues experiences).

Jarvenpaa et al. (2001) suggest that knowledge ownership could be classified into three types:

- Organisational - knowledge belongs to organisation, hence it should be shared within organisation to benefit the organisation.
- Individual - knowledge belongs to each individual, who have control and rights to exchange their knowledge to others to satisfy their own self-interests.
- Collaborative between an organisation and an individual - shared ownership without the loss of control and rights on the knowledge.

Boyne (2002) adds to the list the perception of knowledge ownership with respect to sectors and states that the perceptions differ between people in the public and private sector.

2.5 Barriers and challenges in Knowledge Management

As mentioned earlier, KM is growing bigger and more and more organisations are becoming interested in implementing KM. Du Plessis (2005), Ndedla (2001) et. al. argues that the implementation may (1) provide competitive advantage, as it allow organisation to solve problems and size opportunities, (2) increase responsiveness and innovation, (3) save costs, (4) support decision making, (5) facilitate collaboration, (6) increase employees' productivity, (7) reduce the negative impact associated with knowledge attrition, i.e. knowledge loss when employees leave the job.

Despite this interest there are barriers and challenges that organisations must consider to gain value of the KM implementation. In his review of industrial cases, BenMoussa (2009) concluded that organisational planning, enabling and motivating is the first type of barriers and the second type of barriers *"is more personal, and relate to the distinct attitudes and behaviours held by users when adopting KM systems"* (BenMousse, 2009, p. 902).

By insufficient planning, BenMoussa means the lack of or poorly defined KM initiatives', goals and clear communication of what drives the implementation of knowledge management in the organisation. With the argument that "change is rapid, radical, discontinuous, or nonlinear, what is required are non-linear strategies that cannot be based on a static picture or information residing in the company's databases" (BenMoussa, 2009, p. 902), BenMoussa argues that what knowledge is critical to keep and what should not be kept must be included in the planning.

By enabling, BenMoussa means that even though enabling information technology is essential for KM it can be a significant barrier when information is confused with knowledge. Accordingly, the information must be accessible and relevant to a situation to support meaningful knowledge application (BenMoussa, 2009, p. 902). Other barriers are (1) the unrealistic expectations of technology where organisations think that the technology alone will encourage knowledge sharing, (2) the neglection of tacit knowledge upon the conversion of the experts' knowledge to explicit knowledge, (4) inappropriate technology integration mismatching the employees' needs, (5) departmental activities. At least, BenMoussa includes the technology-related barriers such as adoption, support, IT project management, upgrades and costs.

No matter how good IT solution an organisation have it will not deliver the desired goals unless the personnel is motivated to contribute to the KM effort and share their knowledge. This is the third organisational aspect that BenMoussa calls motivation. A major barrier to motivate people is corporate culture (BenMoussa, 2009, p.903). Hibbard & Carillo (1998) say that getting employees to share knowledge is not a technology challenge anymore rather a corporate culture challenge. Tiwana (2001) point out that in order to maximize the KM implementation effect, both a complete KM system and a supporting corporate structure need to be present.

Another motivation-related barrier is the lack of managerial leadership, which can limit knowledge sharing practices. Stillwell (2008) talks about management rotation based upon suitability for a particular stage within a project. The benefits need to be understood by management and be communicated to the employees. In absence of this communication, the employees will only see added responsibility or burden for the implemented system (BenMoussa, 2009).

The second category that BenMoussa chose to call personal barriers is involved attitude and behaviors. Without digging deeper into the factors some barriers in this category is user acceptance, time and effort since "time is money", lack of incentives.

Table 1: ***Some barriers for an accurate KM implementation.***

Barriers to KM implementation
Poorly defined KM goals
Unclear communications of why KM is implemented
What knowledge to keep
Distinction between information and knowledge
Unmerged technology and corporate culture
Corporate culture to fit technology rather than vice versa
Local focus rather than organisational
Poor managerial leadership
Lack of incentives
No time and big effort to share
User acceptance
"Knowledge is power"
"Errors will be penalized"

Paulin & Sunesson (2012) state the importance of understanding how to pass or lower knowledge barriers to not interrupt or slow down the development of innovations within an organisation. One vital part in KM is knowledge transferring. Paulin & Sunesson (2012) say that the transfer between individuals is a challenge based on motivational and knowledge barriers.

Attewell (1992) draw parallels between knowledge barriers and lack of technological knowledge. He pushes on the importance of understanding the system with its features in order to use it correctly. Attewell also says that lack of knowledge of how to implement the usage of the system in the processes of the specific organisation may harm the output of the implemented system. The connection between the organisation and the system has to be obvious. The presences of a knowledge barrier cause misunderstanding and misinterpreting of new information (Paulin & Sunesson, 2012).

In their journal, Paulin & Sunesson (2012) refer to Suzlanskis' (1996) paper where knowledge barriers are identified by (1) absorptive capacity (the recipient's ability to embrace the knowledge), (2) casual ambiguity (uncertainty of the knowledge) and (3) an arduous (difficult) relationship between source and the recipient.

Paulin & Sunesson states that knowledge barriers are connected to interpersonal relations and ways of communicating. Another reason could be a resistance to sharing knowledge because a difference in experience level.

Jonsson (2010) says that relatively many KM initiatives in organisations had not met the initiators requests. An answer is that the initiator has not understood the user's needs and wishes (Jonsson, 2010). The author gives an example about a company that implemented a new intranet to create a well-functioning platform for knowledge transfer. The platform failed because the user rather used e-mail to communicate because there was a reluctant to share knowledge between each other.

2.6 Management systems and knowledge-based decision making

A decision maker is in a problematic situation if he or she (1) is dissatisfied with the state the mechanical designer or the system that the mechanical designer controls is in, (2) choice of means or ends is possible, and (3) the mechanical designer is in doubt as to which directed at removing doubt, making a choice, and eliminating the dissatisfaction (Ackoff 1974, p. 4).

According to Ackoff (1974), dealing with problems and solutions has been a waste of time because of the wrong approach towards them. What has been useful though is the engagement but he states that it is limited and that there is a more important job to be done.

Ackoff (1974) talks about problems as messes and defines them as something of a whole - the system. He says that messes cannot be decomposed into independent problems Therefore, Ackoff claims that 'no mess can be solved by solving each of its component problems independently of the others' (Ackoff, 1974, p. 5).

Ackoff's view of a management system (a system which controls another system) is that it must be capable of performing following four functions: (1) identifying problems, (2) making decisions, (3) controlling the decisions made, and (4) providing the information required to perform each of the first three functions.

A good information system is a system that can provide solicited data and information but there is usually more unsolicited data & information to handle in such a system (Ackoff, 1974). The information systems should be able to filter and condense unsolicited information.

2.7 Trade-off curves

Ever since KM became a significant focus for many companies, it has been improved with sophisticated tools and methods while the level of knowledge reuse in the decision-making early in product development have remained quiet (Ward, 2012). This is where the trade-off curves come in and its major element is to synthesize knowledge into the curves thus creates usable knowledge. It can be expressed as a compression of data and it provides the freedom of deciding designing upon where one wants to be in the trade-off curves.

The trade-off curves was used in the US army during the Second World War and made it possible to make design decisions really fast, although their usage also disappeared really fast (Ward, 2012). Ward (2012) describes its disappearance as a process problem with the computers entry. The computers made it possible to design and simulate safely. This fits well in how the U.S air force contracted in a project - they did not want to spend a lot of money in creating basic understanding. As a result, the aircraft industry has moved to a design than simulate system rather than doing the hard work of understanding how to formulate trade-off curves and then designing products that will work (Ward, 2012).

Ward (2012) says that Toyota have to get better in using computers but they are afraid their computers will become more widely used, consequently engineers will begin to lose their intuitions and design performance will decrease, through use of primarily trade-off curves - not the use of computers. Further, Ward (2012) says the opposite prevails in the U.S, thus they are good at simulation but they need to be good at basic understanding - and that is what trade-off curves are for.

Ward (2012) provides an example from Toyota. The trade-off curves for exhaust systems at Toyota are created by demanding a variation of designs from their suppliers that works as the basis for their trade off curves creation. One of the exhaust systems functions is to reduce noise. To do so, backpressure is created in the exhaust and the gas flows out of the engine. At the same time, backpressure reduces the performance of the engine. By having a trade-off for this system the engineer can, upon desired outcome between performance and noise for the engine, decide where he wants to be on the curve. Ward (2012) says that this is not meaningful except for purely qualitative purposes, although it can be important - they can help one understand even though it does not have any numbers.

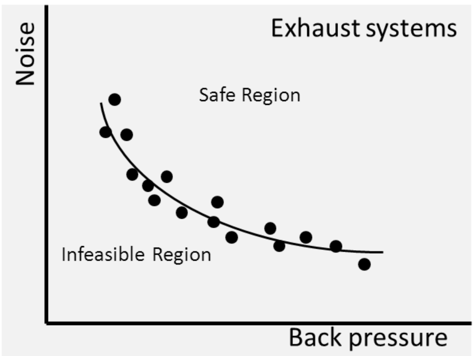


Figure 10: ***A trade off curve for exhaust systems (Ward, 2012).***

Ward (2012) says that there are two things to add to make the trade-off curves meaningful. First, numbers has to be put on the scale. Second, the trade-off curves lose its meaning if it is too situation based. For example, noise level should be substituted by noise reduction - the change in noise level as a result of adding the exhaust system. Similarly, backpressure is only meaningful at a particular flow - it would be better if backpressure was plotted as a ratio to the amount of gas flowing through the engine. To make it more valuable, volume of exhaust system and its cost could be included. The results will be a general curve valid in a variety of circumstances Ward (2012).

2.7.1 The LAMDA model and its correlation to trade-off curves

The LAMDA-model was developed by Ward (Ward, 2002; Domb & Radeka, 2013) after studying Toyota and other Japanese firms. Ward thought that the PDCA model (plan-do-check-act) was insufficient in describing what the firms actually did when they set out to solve a problem. (Plan do check act = create the plan, do it, than go back and check and see what happened and take action to correct the problems.)

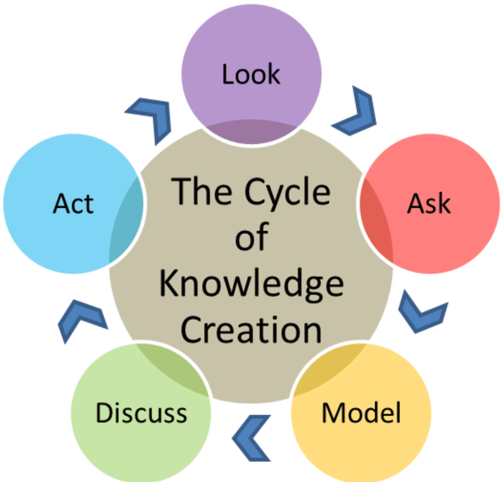


Figure 11: ***The LAMDA model (Ward, 2002).***

According to Ward (2002), the LAMDA-model is a basis of science and a general idea for how knowledge is gathered and the trade-off curve system is a special case of the model. Trade-off curves emphasize the look and model portion but every time one of the steps in formulating a trade-off curve is made one have to go through all of the steps in the LAMDA-model. Each of those steps emphasizes one or another of the LAMDA-model steps and the correlation can be seen in Figure 12.

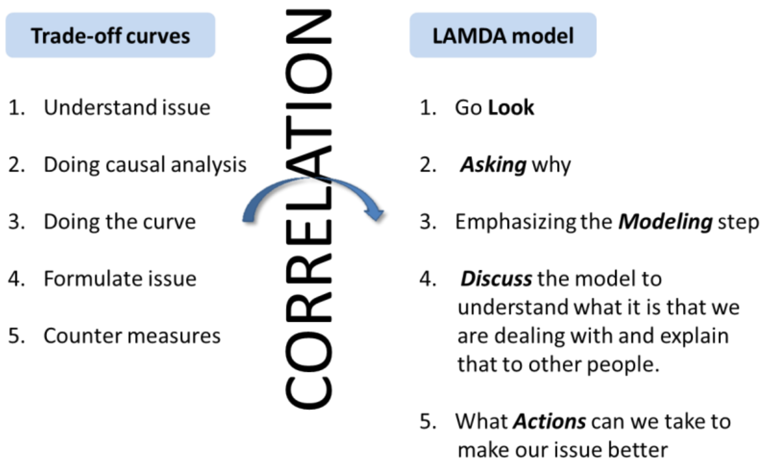


Figure 12: ***The correlation between trade-off curves and the LAMDA model.***

2.8 Summary of the theoretical framework

Talking to engineers at Volvo GTT, there is a misunderstanding of what knowledge and information is and these two terms are often used as synonyms and are as Zeleny says interpreted in "whichever suitable way" without carefully reflection. The existing databases include some knowledge but are hard to find, thus not used. Therefore, it cannot be called knowledge and the DIKW hierarchy at Volvo GTT will have, if any, a little knowledge top as the one illustrated in Figure 5.

Since the thesis is written at a global organisation, it will use Davenport & Prusak's (1998) pragmatic descriptions:

> "*Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms*." (Davenport & Prusak, 1998, p. 4)

Describing a project at Volvo GTT can be used as a prove confirming Adler's thoughts that the SECI-model does not need to start with socialization; at Volvo GTT, one can start by looking at stored documents (internalization) and if there is none valid one can ask colleagues (socialization) or gain the necessary knowledge, combine it with existing knowledge and store it (externalization & combination).

Polanyi says that there can be no explicit justification. However, tacit knowledge can be certain (knowledge that can be expressed) and able to store. Once it is stored it is, by definition, becoming explicit knowledge. Knowledge is basically a process making us understand consequences and that decisions are based of the obtained knowledge, i.e. an act will probably give the expected outcome.

Chapter 2.3 implies that capturing the right knowledge efficiently, storing and distributing it to the right people in an organisation is what KM in product development is all about. This will, together with a Stage Gate system, contribute to shorter development cycles and increase products customer value and reliability. The described Stage Gate process includes well-defined deliverables and criteria that has to be fulfilled to proceed, although observations has been made showing that the criteria can be overlooked, i.e. in the GDP model adopted at Volvo GTT.

Comparing Ackoff's thoughts regarding component independently problem solving to the thesis situation, the truck can be seen as the whole system containing i.a. the air conditioning system which in turn is a system built up by a number of components. Each component is dependent of another, thus in decision making for a component the mechanical designer has to take the interaction with other components into account.

Ackoff's view of management systems (Chapter 2.6) are implemented in the thesis as following; Function (1), identification of problems is made today in form of i.e. PROTUS (see chapter 4.1); function (2), (3) and (4) have been included in the thesis as follows: the knowledge content facilitating decision making, the ownership structure controlling the contents validity thus indirectly the decisions validity and the last function is being fulfilled by the Check Sheet with its content and ownership structure.

3. Methodology

This chapter describes the methodology used in this thesis. It is divided into research strategy, research design, research method, validity and reliability of the research. Each sub section will alternate between theory and discussion.

3.1 Research strategy

Both Bryman & Bell (2007) and Lantz (2007) point out the important distinction between qualitative and quantitative research strategies in a methodological discussion. The major differences between the quantitative and qualitative research strategies are the way data is collected and analysed (Bryman & Bell, 2007). The quantitative research strategy focuses on quantification, the collection and analysis of data. The quantitative research strategy is suitable when there is a need for large sample to enable generalization and relevant conclusions (Bryman & Bell, 2007). Qualitative research strategy is used when a deeper understanding of the target groups is needed and when the researcher do not know what information from the target group that might be interesting for the study (Lantz, 2007 and Bryman & Bell, 2007). Since the focus of this study is to create a KM system that capture, store and reuse engineering knowledge, the data collection and analysis is therefore characterized by a qualitative research strategy.

3.2 Research design

A case study is chosen as the research design since the purpose of the study requires an investigation of an organisation and its members' perception of a problem. In the literature, Bryman & Bell (2007) define a case study as a detailed and complex analyse of a single case. The authors say that the most well-known studies in business and management are based on case study research design, further the most commonly place to conduct a case study research is at a single organisation, a single place (e.g. factory) or in a group of people. At these places, researchers are able to critically investigate and in depth analyse the object (Bryman & Bell, 2007). Bryman & Bell also point out that there is a tendency to associate case studies with qualitative research approach but the authors state that such identification is not appropriate. However, it is common that researchers who are performing a case study also favor the qualitative research method such as semi structural interviews and observations because these methods are viewed as particularly suitable in generating an intensive, detailed examination of a case (Bryman & Bell, 2007).

Interesting discussions in the research case design are the degree of validity and reliability of the study. It means that it is important to make sure that the result of the thesis is based on solid information and observation, which are collected and measured in a deliberate way. Bryman & Bell refer to the authors Lincoln & Guba who have found a way to measure the quality of the quantitative research by assessing the trustworthiness. Lincoln & Guba have divided the trustworthiness into four categories; creditability, transferability, dependability and conformability. The creditability discuss how realistic the findings are, the transferability discus how the results can be applicable to for instance another organisation, dependability discus if the same results would appear if the research is repeated and conformability ensure that the findings have not overtly personal values or theoretical inclinations in the findings. These aspects have been taken into consideration and will in detail be discussed in sub chapter 3.4.

3.3 Research Methods

The following sub chapters describe the literature studies and interviews that were conducted in the thesis. A vital part was to clearly understand KM to answer the research questions and fulfill the purpose of the thesis. Therefore, big effort was put to understand the term. Subsequently, interviews were conducted to proceed with the thesis.

3.3.1 Literature studies

Literature study has been carried out throughout the project. In the beginning of the project, previous thesis and master thesis has been studied with the purpose to receive ideas and inputs of theory and methods. As the project progressed, an extensive literature study about Lean Product Development, KM and Organisational learning was conducted with focus on tools and theory about how to capture, store and reuse knowledge with the purpose to sharpen the aim. “The snowball effect” has been continuously used in reference lists to receive and find more literature within the areas. Literature from Gothenburg City Library, Chalmers Library and Gothenburg University Library has supported the theoretical framework of the thesis.

3.3.2 Interviews

We have used a method from Lantz (2007) to perform a qualitative data preparation from our interviews. The pattern we have followed is illustrated in Figure 13. A common theme throughout the interviews is to have a systematic way of reducing the data from the interviews and have a continuously quality control of the findings by analyzing the content (Lantz, 2007).

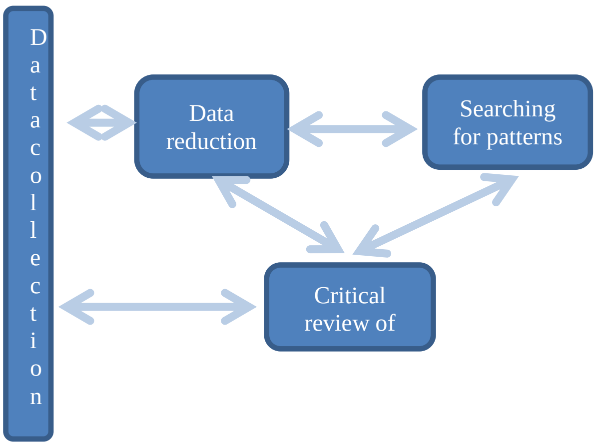


Figure 13: ***The Data reduction model (Lantz, 2007).***

The interviews conducted during the project have been crucial for the result. 30 interviews have been carried out with 20 different people within the Volvo GTT organisation, see Figure 14. Three interviews have been carried out on three different companies in other industries with the purpose to investigate how companies in other sectors are working with KM. The interviews have also change shape throughout the project, but could mainly be divided into three categories, namely; pre-study interviews, shaping the aim interviews and Check Sheet interviews. Semi structural interviews were carried out and each interview was held during a 30-60 minutes session. All the interviews were recorded with a digital recording tool and took place in calm rooms equipped with white boards to enable interviewees to illustrate their thoughts if necessary. Since the interviews contained a lot of detailed information, the easiest way to include all the useful information from the interviews, a recording tool was necessary to use. Both of us made notes that worked as a supplement to the recordings.

During the pre-study interviewing phase, the interviews were held with the different component owners of the climate system. To understand how personnel are working on a daily basis and how the organisation at the Climate department is structured was the purpose with these interviews. Important outcomes were to identify how they are working with the different databases and what they experiences are difficult and preventing them in their daily working procedure.

With the inputs from the pre-study interviews, an outlook on how different organisation within the Volvo GTT organisation was carried out to sharpen the aim for the thesis. By interviewing the personnel at Volvo Powertrain, their well-developed knowledge-capturing tool could be evaluated. Also different personnel at the Cab division were interviewed to get a better overview of how they are working and dealing with knowledge capture. An interesting part in this stage of the thesis was to investigate how other companies are managing knowledge gap and obstacles in their product development projects (Appendix I).

Including the outputs from the interviews a decision was taken to develop trade-off curves and Check Sheets as the tools to capture, store and reuse knowledge. A component was chosen and its owner was interviewed during three occasions since it was a challenge to elicit the component owner’s tacit knowledge. The result was analysed and revised after the interviews to optimize the content of the Check Sheets and trade-off curves.

Table 2: *Overview of interviews.*

Interviewees' role	Number of interviewees
Vice president	1
Design Engineer	5
Quality Knowledge Manager	1
Section Manager	1
Q/E Contact	1
Knowledge Manager	1
Cab Climate System Specialist	2
Knowledge Manager Specialist	1
Group Manager	1
IT specialist	1
System Technical Specialist	1
Global Component Responsible	1
Other Companies	
Design Engineer	2
Chef Engineer	1

3.3.3 A survey in the creation of the trade-off curves

Initially, an attempt to create own trade-off curves was made but it failed due to the lack of specific component knowledge. Hence, a survey was created aimed to the component owners in order to elicit inputs to create the trade-off curves. The survey was created to be easy understandable and be quick to make for the receivers. Therefore, the layout consisted of a brief explanation about trade-off curves together with illustrations (Appendix II).

3.4 The trustworthiness of the study

While conducting this study, we have carefully considered the validity of the reliability. Therefore, in this sub section, we discuss the trustworthiness of the study stated by Lincoln & Guba (Bryman & Bell, 2007).

We believe that the credibility in our study is relatively high according to several aspects. We have spent four month at the Climate group's working environment and being a part of their social context in form of meetings and coffee breaks. We have also interviewed relatively many people and, in addition, we have triangulated the interviews in order to receive as broad spectra of the KM in Volvo GTT as possible. Further, we have tried to triangulate all our sources, besides the interviews also articles, books and other thesis.

We have discussed the results regularly with our tutor at Volvo GTT, who has a research background as well as experience from the industry, throughout the project. We believe this have had a positive impact on the credibility even if we have critically examine our tutors' thoughts. The credibility of the interviews with the people on the companies outside Volvo GTT may be relative low. However, our initial thoughts with these interviews were to receive inspiration to our study.

From transferability point of view, the study is based at the Climate group, which is a quite narrow domain and consists of a relatively small amount of people. However, we believe our findings are applicable for many product development organisations since the issues of how the manage knowledge are very crucial for these kinds of organisations.

From a dependability perspective, we have had a structured working approach throughout the project. The research questions worked as a frame for us to shaping the aim of the research and we have documented the findings continuously. We have also recorded our interviews, which mean that others are able to replicate our study.

The conformability of the study concerns the degree of objectivity from the interviewers and interviewees' point of view. It is hard to assess the conformability but we have tried to minimize our own influence during the interviews by having an open discussion and asking open-ended questions. The triangulation of our sources is an important aspect to minimize the individual interviewer's impact of the result with their own opinions.

4. Results

This chapter deals with the current situation at Volvo GTT and how the knowledge flows in the organisation. The chapter will provide a good basis for analyzing how the organisation captures, store and reuse knowledge. The first part gives a detailed overview of the knowledge flow at the Climate group. The second part describes the Knowledge Management system Volvo Powertrain is using. The content of the Results is mainly based on the semi structural interviewees performed at Volvo GTT.

4.1 Present organisational and database structure

Figure 15 illustrates a simplified view of the organisation in the Climate group and the Cab Department. The Climate group is a sub group to the Cab department. Each component in the climate system has a design engineer as an owner, which means that the owner has the responsibility for the component in projects and in contact with suppliers etc. The compressor, pipes, hoses and parking heater are some of the components in the climate system of a Volvo truck. Each design engineer could own a couple of components each.

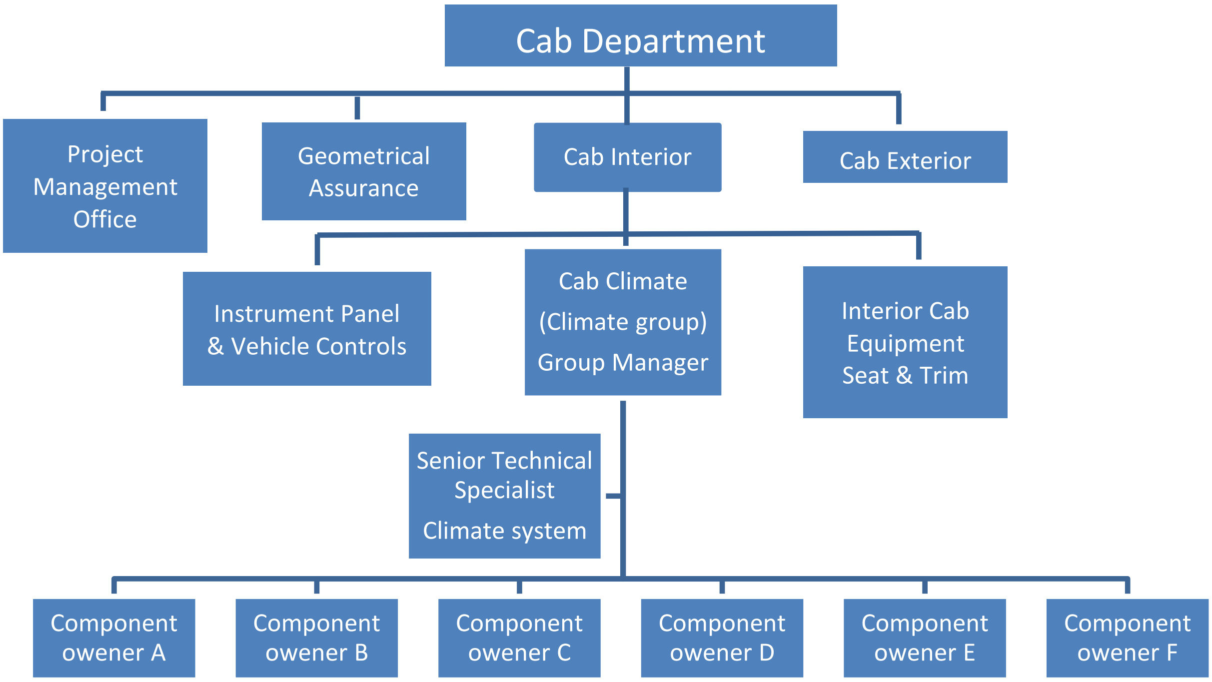


Figure 14: ***The Cab department organisation.***

The Senior Technical Specialist (STS) is a role that is dedicated to a person who has a lot of routine and experiences in climate systems, i.e. the STS has a lot of tacit knowledge. There are in total 32 different STSs' within the Volvo GTT organisation and the reason Climate group has a STS is because the climate system is a feature where Volvo GTT should be market leading in. The STS has no component responsibility and could therefore support the component owners with suppliers-issues and supporting other component owners with issues regarding the climate system. The STS is also a climate system expert in the projects. At the Climate group, the STS is the major input when the component owners are facing knowledge gaps.

The major challenge for the component owners are eliminating knowledge gaps in their working process. There are a couple of databases where the component owner could search for data and information. Some of them are illustrated in Figure 16.

KOLA (KOnstruktionsdata LAstvagnar) is the PDM system where all components are stored in CAD-format. The components are sorted by an article number and have a technical regulation attached.

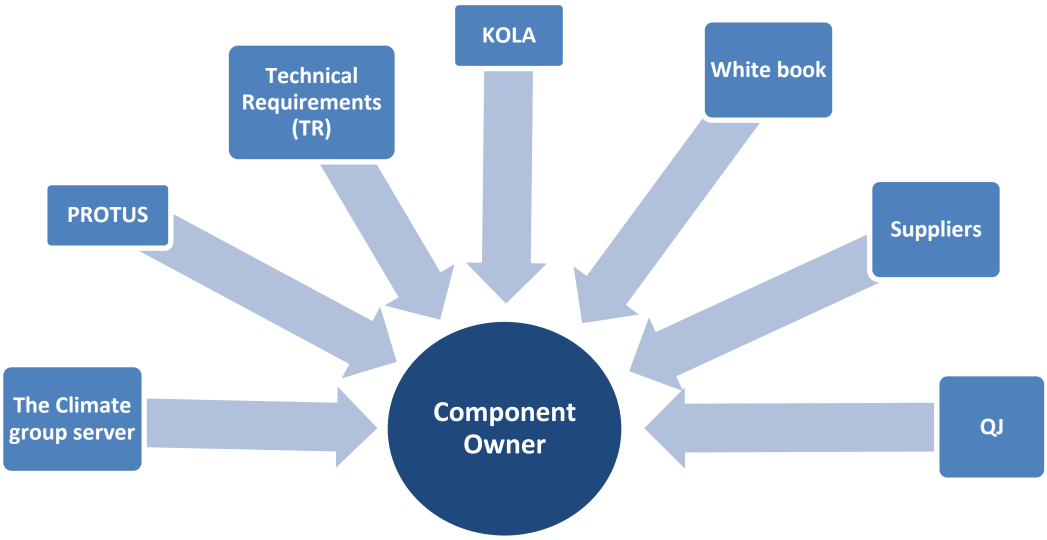


Figure 15: ***The data, information and knowledge flow to the component owner at the Climate group.***

In KOLA, the mechanical designer can see which version of a truck a specific component fits into or to see if the component is still in production. The KOLA database is therefore very extensive but it is build up as a logical tree structure. If the component owner is looking for a specific component but does not have the article number, the KOLA structure does not facilitate the search. The component owner needs to look in the specific area of the truck where the person assumes the component could be placed in or ask the component owner. There is a KOLA tutorial, which the component owner could go through to get used to the data system.

The Technical Requirement list (TR) is a list of requirements mainly aimed for the suppliers of Volvo GTT. A TR is established for each component and in the TRs', there is information about how the supplier should validate the components they are going to manufacture to match the requirements from Volvo GTT. There is also some knowledge embedded in the

TRs', useful in the daily work for the design engineers. The component owner has during some periods in projects relatively close contact with the suppliers. The suppliers often have detailed knowledge about their components they are manufacturing which could be a source of knowledge for the component owners.

PROTUS (PROTotype follow Up System) is the main system for giving system support regarding prototype validations. In PROTUS, the component owners could receive information about prototype structure and problems regarding their component. Reports regarding problems or deviations during assembly, testing or problems linked with the production process are common PROTUS. The follow-up is done by using different report types and a scale of statuses, which are handed over to the component owner.

The Climate group has a group server where each component owner has an own map. In the group server, useful documents could be stored such as Engineering Reports (ER), which is analysis about PROTUS results for instance. The group server is more of a library or documentation storage rather than a tool that the component owners have incitements to use in their daily work.

White books are a relatively new invention at Volvo GTT. After each project is finished, the team members should write a White book about captured knowledge and lessons learned during the project. There are White books that have a more holistic view of the project as well as white books on the development process regarding specific components.

The Quality Journals (QJ) is the information that the component owners receive when the end customer is affected by quality problems or if quality problems are arising during assembly.

4.2 The KM tool at Volvo Powertrain

There is no general KM tool used throughout Volvo GTT. However, organisations within the Volvo GTT are using different KM tools. For example, Volvo Powertrain has adopted a tool called the Design Verification Guideline (DVG). Volvo Powertrain started using the DVG in 2005 and external actors as well as people within Volvo GTT's different sites around the world developed it.

The DVG's initial thought is to work as an answer for the mechanical designers' issues by:

- Making the DVG as generic guidelines which are not connected to a specific project rather to a specific component
- DVG should be easy to use and maintain
- Each DVG has an owner
    - The owner is responsible for updating his or her DVG
    - The owner should spend 4-6 days each year to maintain his or her DVG
- DVG's main purpose is to support a junior mechanical designer

The DVG is designed as a Wiki and each component in the Powertrain area has an own DVG and is maintained and operated by an owner. A common thread throughout all the DVG's is plenty of CAD pictures of drawings with the purpose to illustrate lessons learnt or captured knowledge of the component.

The DVG may sound as an ideal KM tool, but in reality the DVG struggles with a number of problems and challenges. One interviewee said that the DVG is *"like a database, a good book, written about powertrain development"*, which is not optimal from a KM perspective. The owner is responsible for the maintenance, which usually is done through regular meetings approximately three, times per year or when a project is finished. One of the interviewees states that when a DVG is completed, the owner feels no incitement or need to update it with knowledge. This is because the owner and its closest co-workers already have the knowledge needed for the specific component. The owner knows that its colleagues working on other components will not use its specific DVG. Using the DVG is not a requirement from the engineers' perspective; they can participate in a whole project without checking the DVG's.

One makes various gate structures that need to get approval for the next passage, i.e. the GDP (Chapter 1.2). Today, it is still possible to pass by. There are differences in the content-quality in some of the DVG's; a lot of its content is common sense for the mechanical designers. These DVG's are working more like a *"tutorial for dummies rather than know-how source"*, says one interviewee.

5. Analysis

In the following chapter, the content of the previous chapter is reviewed and analysed. First, a general analysis of the knowledge flow at the Climate group is presented. Thereafter, the KM tool Volvo Powertrain is using is being analysed. The chapter will provide the reader with analysis of the current situation, which will be one factor to the synthesis.

5.1 Analysis of Knowledge flow in the Climate group

Analyzing how Volvo GTT manages its knowledge today and how departments operate, we have seen diverse approaches. There is no common thread throughout the organisation and new efforts are popping up everywhere without any knowing about others initiatives. The organisations unawareness about the various departments' attempt contributes to the non-participation of all of the organisations employees. Thus, the insight in the other departments' projects decreases and inhibits the understanding in collaboration and the knowledge exchange. This in turn affects the initiatives negatively since beneficial KM demands collaboration and an open-minded attitude, i.e. open for organisational changes and one's sense of participation.

Simultaneously, throughout the thesis we have been observing a willingness to gather and merge all the initiatives to achieve a collaborative approach from which all of the employees are involved. There seem to be a development towards a core group having a holistic view and overall responsibility of the organisations KM.

It is very positive for the Climate group to be the center of excellence for climate system components for several reasons. This will most likely ensure the knowledge about these components will have a priority from upper management and the Climate group will get the resources needed to capture and maintain knowledge, which will result in a new KM system. It also requires demand on the new KM system, that it should be as generic as possible to facilitate usage for Volvo GTT's different sites working with climate system development around the world.

The component ownership is having impact on the KM in the Climate group. The component owners will sooner or later be expert on their components. As the component owner is being more comfortable with the knowledge about his/her component the need for a KM system is decreasing. In other words, the incitement for using a KM system will sooner or later disappear. Therefore, a properly designed KM system could be integrated in the component owner's daily working process in projects, independent of the component owner's own level of knowledge about the component itself.

The STS is a necessary role at the Climate group. The STS represents an invaluable support for the other component owners but the challenge is to transfer the STS's tacit knowledge into explicit knowledge via a KM system and then once again to tacit knowledge when the knowledge ends up in a mechanical designer's brain in an efficient way as possible. As the current situation looks like, the STS has plenty of different roles in different projects, i.e. supporting contact with suppliers – which take a lot of time. The STS could be affected by information overflow from email or telephone calls, which will affect the knowledge sharing within the Climate group.

Many of the databases that Volvo GTT uses, for example KOLA, have relatively complex structures. Finding components which not is in a component owner's knowledge area could be hard. Regarding the risk of documentation overflow, it could be both complicated and time consuming for a component owner to find the right contact information to the right person.

In the Technical Requirement (TR) list, Volvo GTT set relatively detailed requirements to their suppliers on what the products have to fulfill in terms of tests and validations. Some suppliers have hard to validate and test the components in a proper way which cost Volvo GTT a lot of resources in terms of extended development lead times and overall decreased quality levels.

The communication channels regarding the PROTUS report tends to end up as long chat conversations and not direct handling. A new KM system has to find a way to incorporate the PROTUS reports in an easy format.

Having a Climate group home map at the Cab department server is a good KM initiative. However, there is no structural system regarding what kind of documents that should be stored neither is it an integrated tool in the component owner's daily working process, which make the server, from that point of view, not very useful.

Capturing knowledge and lessons learned from previous projects is necessary to avoid that same mistake is done in future projects. It is important to incorporate the White book and make it as a natural stage for the component owner to encounter in development projects. Today, the White books from the latest projects exist in Word documents, which are not optimal in KM perspective.

An air conditioning system contains 6 main groups of components; each component is dependent of another. Further, one can see the whole air conditioning system as a group connected to other groups hence depending on other components. Therefore, including how the components/groups are interlinked and dependent of each other will be essential for mechanical designers in their decisions. Including how design decisions may affect other components will provide the constructor with information about which changes are allowed without infringing on the other components and on whom to contact.

5.2 Analysis of the KM tool at Volvo Powertrain

With a first look at the DVG, the structure is relatively user friendly with a lot of drawings and pictures of the components but the quality in terms of useful content differs a lot from DVG to DVG. As it looks like today, the DVG is not completely unused tool but it is obvious that the system has stagnated in development. The main reason why the DVG did not develop in the direction the initiators at Volvo Powertrain wanted is due to that there is no incentive to use it. The DVG is more of add on to the daily working process rather than an integrated KM tool. The mechanical designer can continue a project without checking anything in the DVG and this is a major drawback.

If the mechanical designers face knowledge gaps in projects, one asks the expert or colleagues to over bridge the gaps. If the DVG owner feels that the content of the DVG does not give anything, it will not be updated and the system will stagnate. The content of the DVG could be compared, as an interviewee expressed, as a *"cookbook about engine and transmission design*" i.e. the content is more of information character rather than knowledge and often too general to be useful for the mechanical designers.

6. Synthesis

This chapter presents the initial as well as the later formulated goals with the research, e.g. the creation of a knowledge base and further on, the Check Sheet and trade-off curves based on the theoretical framework, interviews and observations. It can be explained as the deliverables for the case company.

6.1 A knowledge database and its development

The first attempt to create a knowledge database landed in the structure illustrated in Figure 17. The idea with the database was to have a search function from which the right component can be chosen. The lower left square illustrates the data, information and knowledge hierarchy showing the most important content in a compressed form about the component. If the mechanical designers want to immerse themselves in the component specifications, this can be done in the square to the lower right. This square contains e.g. the DVG and links to other sources such as; KOLA, Technical Requirement list or PROTUS. (See chapter 4.1 for definitions and details).

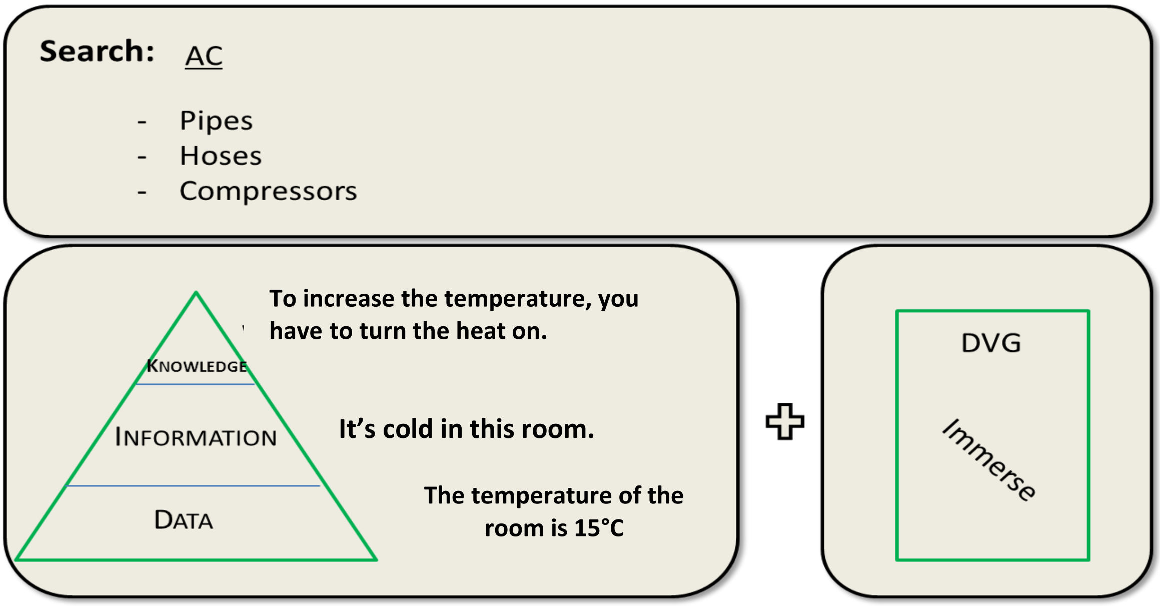


Figure 17: ***First version of the knowledge database, database 1.***

The easy understandable format of this knowledge database was something to develop further but the overall content would be too extensive. Capturing data and information about all the climate system components would be unnecessary since it would have been very time consuming and the data and information could be found in already existing data bases.

In the updated version, the gates in the GDP were included in the knowledge database with the idea to match the different deliverables in the GDP with design guidelines. The eight boxes; design, validation, purchasing, vehicle assembly, maintenance, quality, future challenges and supplier process were inspired from the KM tool "Design Verification

Guidelines", see Chapter 5.2. These boxes are identified as critical points in product development projects.

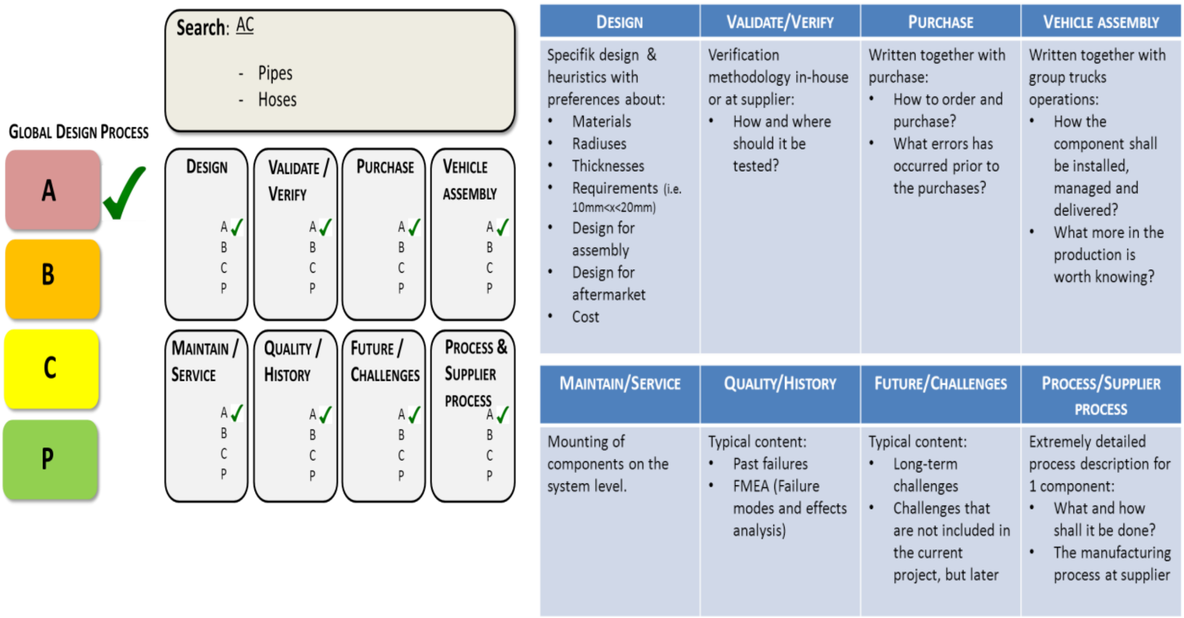


Figure 18: *Database 2, updated version of the knowledge database 1 with detailed explanations of each box.*

In the updated version of the knowledge database, Figure 18, the search field in the upper square is the same as in the first version of the knowledge database. Merging the two models would represent a database with an accurate search function allowing the user to see how far the project has reached and it provides knowledge and the possibility to immerse in the details. The content in the boxes was compiled during interviews and meetings with our supervisor and component owners at the Climate group. At this stage, a first idea of a knowledge ownership structure was taken into consideration. The idea was to build a community around each component with representatives from the eight different areas, i.e. Quality and Purchase departments, to support the component owner with designing guidelines in projects within their areas of responsibility. This kind of ownership structure would involve many people, which may be hard to coordinate. Therefore, the ownership structure was revised into a more compressed format, which will be explained later in this section.

6.2 The creation of the Check Sheet, Trade-off curves and ownership structure

After the creation of the two knowledge databases explained above, the thesis took another direction. From the updated knowledge database, focus was directed to the first box named *Design* which later was renamed to *Engineering* since this was more suitable for its purpose – to provide the mechanical designers with knowledge. Here, the idea was to capture the engineering content in form of Check Sheets and trade-off curves and ensure an updated and maintained KM system with a knowledge ownership structure.

6.2.1 Check Sheet

The Check sheet provides the mechanical designers with knowledge in an easy and general format. Figure 19 illustrates a mockup, made in Microsoft Power Point, of a Check Sheet for a pipe and hose attachment. The Check Sheet is divided into three main categories; Golden rules, Trade-off curves and Generic rules. The Check Sheets are component specific, i.e. there should be one Check Sheet per component-family.

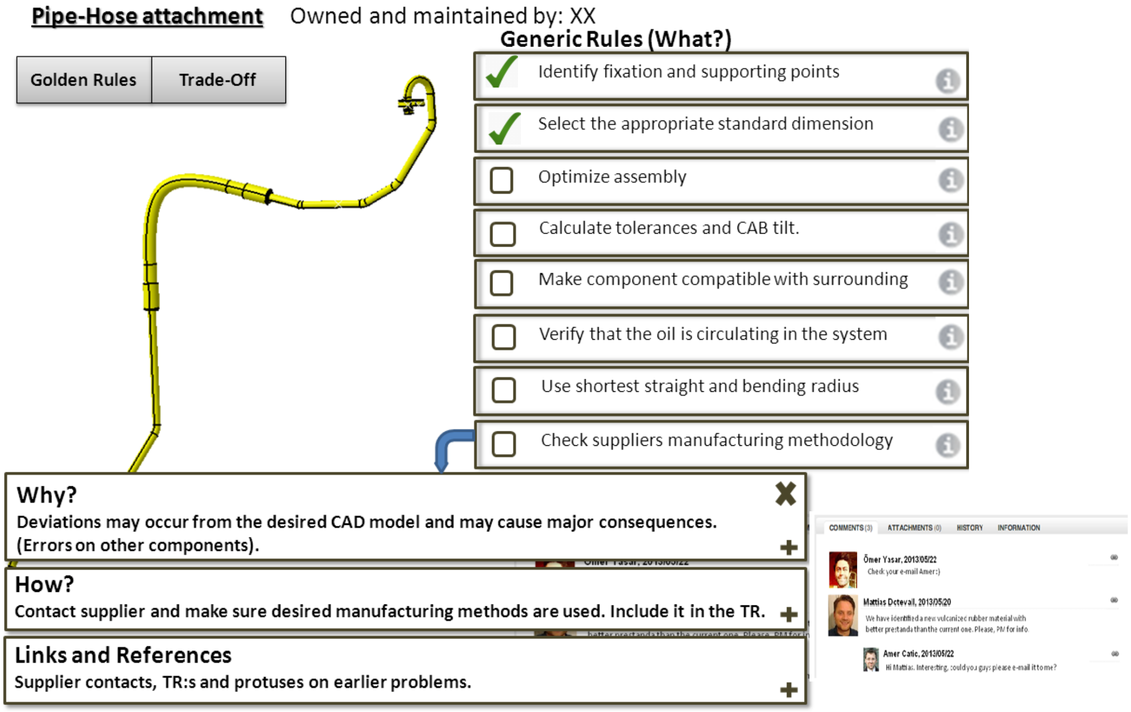


Figure 19: ***A mockup of a Check Sheet for pipe-hose attachment.***

The trade-off curves, which will be further explained in chapter 6.2.3, are aimed to give the mechanical designer visualization of important relationships between design variables. The generic rules systematically explain what the mechanical designer should do when designing the component. Depending on how technologically advanced the component is, there should be maximum 6-10 generic rules. Each generic rule has an information button and a plus sign, which will provide the reader with more information about the specific rule and also the ability to modify and edit the content. Within each generic rule, there are explanations about why the operation is important and how it shall be executed. There are also links to relevant databases or contact details to suppliers or system architects. Another feature is the chat function where, for instance members in a project can discuss issues around the component or attach useful documents. One of the strengths with the Check Sheet is that the user can check off each generic rule when it is fulfilled. This will ensure that for instance a deliverable in the GDP is met and the chat function can allow the users to see who is responsible for which check off.

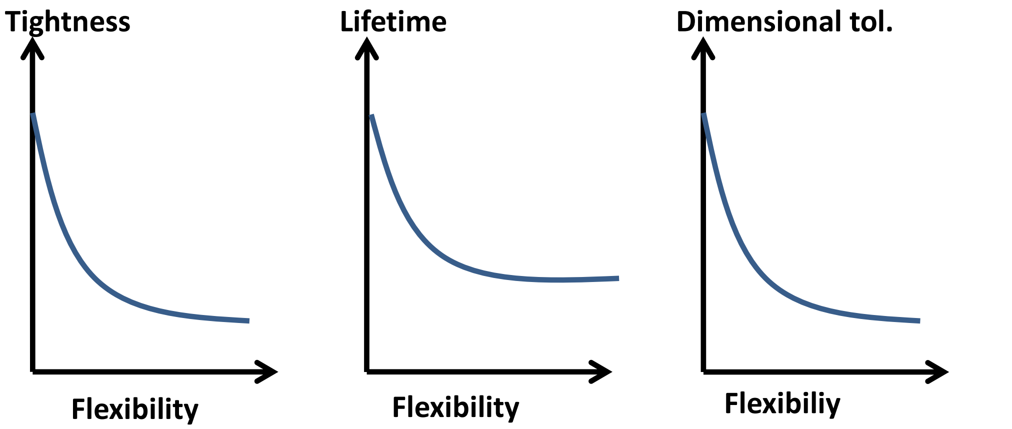
The development of a Check Sheet occurs through collaboration between the interviewer and the mechanical designer who is the component owner. Since the mechanical designer is unfamiliar with Check Sheets and what content the interviewer desires, proper questions has to be asked to elicit "pure" knowledge suitable for the Check Sheet. The first interview establishes a first draft for a Check Sheet. This gave an opportunity to present the Check Sheet on the second interview so that the component owner understood the purpose of having Check Sheets. This increased the answers quality in the second interview and the Check Sheet was modified upon these answers. The Golden rules are a summary of the generic rules providing a holistic overview.

6.2.2 Trade-off curves

The literature does not contain much of what is meant by trade-off curves. A definition from Business Dictionary (2013):

> *"A technique of reducing or forgoing one or more desirable outcomes in exchange for increasing or obtaining other desirable outcomes in order to maximize the total return or effectiveness under given circumstances."*

This definition leads to identify desired properties for the pipe-hose attachment. Naturally, the subsequent step was to find out in which way the desired properties are correlated. After defining the correlations the next step was to visualize it. The correlated properties was put on the Cartesian coordinate system and by intuition, the graph was drawn with inputs from the survey (Appendix II). These trade-off curves, Figure 20, are a first rough draft and there will be a lot of calculations and validations to make them complete.



- *Flexibility = The need for hoses. The more hoses, the greater flexibility (agility)*
- *Tightness = Hose tightness for diffusion of cooling media.*
- *Lifetime = The total lifetime of the hose*
- *Dimensional tolerance = Approved tolerances, small dim. tol. desired*

Figure 20: ***Trade off curves for the pipe and hose attachment.***

6.2.3 Ownership structure

Every Check Sheet has an owner. The owners' contacts details are visibly at the top in each Check Sheet together with the name of the component. This leads to the important ownership structure seen in Figure 21 below.

The ownership of the Check Sheet describes how it is supposed to be maintained. The flowchart below is a draft for how it could be but it is not validated in a case study. However, we believe that the rough draft is sufficient for the created Check Sheet.

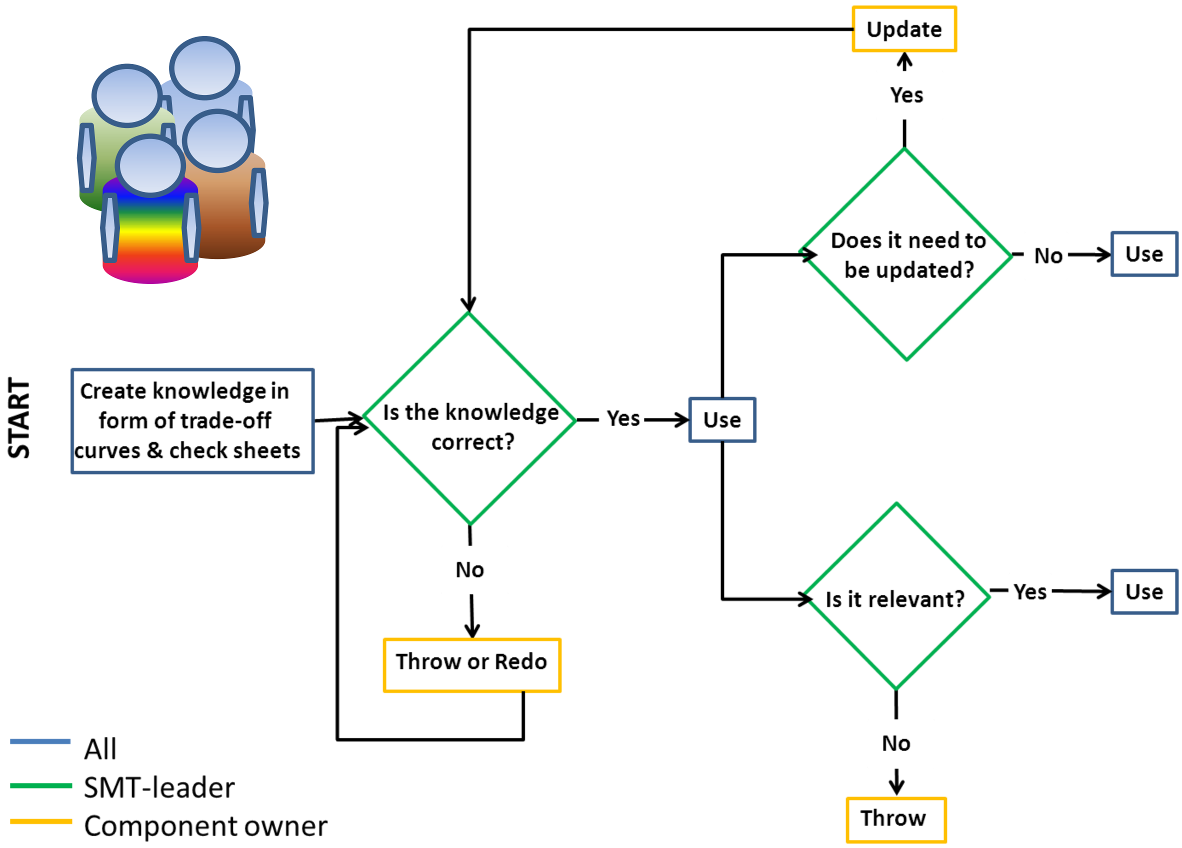


Figure 21: ***Ownership flow chart.***

As it shows, the blue and yellow rectangles indicate a process/task. The blue ones can be performed for instance by all the members in a project and the yellow ones are set to be rendered by the component owners.

The idea with this is to encourage all the employees in knowledge creation and to make this process to become a natural act/a culture within the organisation. The yellow processes are set to be owned and rendered by the component owners since they are the actual experts of their components thus, able to include the sufficient knowledge for the component. Although, rendering could be performed by other experts as well.

Further, the green squares are decisions made by the management where we have chosen the Sub Module Team (SMT) leader. The green squares have always a “query form”. The questions are formulated in a way where the answer always is *Yes* or *No* and upon the answer the subsequent step will be a process. The flowchart may be divided up into two parts. The first part will end after the first *Yes* where the process is *Use*. With new technology, errors that are detected or if the knowledge in the Check Sheet no longer is relevant or valid in some way, the second part will be what to do with the knowledge.

7. Discussion

After having studied KM we have realised that the key factor for a successful method is consistent knowledge reuse - with a mindset of using knowledge well in the first place minimizing decisions based on random chance. Embracing this would probably contribute to a knowledge-based decision-making process enabling effective knowledge use leading to achieve knowledge reuse.

7.1 The thesis goal was amended

KM is an expression and as mentioned in chapter 1.1 there can be KM systems on different levels. In the beginning of the thesis, we did not know what kind of KM system was suitable for the Cab division. Therefore, we started by reading about KM and do interviews, parallel to this sketch on a knowledge database. Further in the thesis we realised that the database comes in a later phase. Together with our supervisors we made the decision to focus on what came to be our new goal - what knowledge content (on a component level) to put into the database? Although, developing and working with the databases gave good insight in KM and facilitated the development of Check Sheets and trade-off curves.

7.2 Trade-off curves can be improved

The trade-off curves indicate how the correlation between parameters could be like upon the intuition of one engineer. The curves have not been tested on a real project and to obtain confidence for the decision-making, numbers should be put on the coordinate axes and the formulation should be more precise. Further, the survey does not include the knowledge of how to measure the coordinate axes. The questions “What do you mean by these parameters?” and “How do you measure these parameters?” should be included in the survey.

Further, why are not trade-off curves used today and shall individual engineers create the trade-off curves by tests or shall Volvo GTT demand it from the suppliers? First, companies do not want to spend money on basic understanding. Although, after doing our own ones by the survey, we believe that letting the supplier do the trade-off curves is the best way. The money spent on creating those will facilitate the decision-making and make it more accurate with no guesses. Although, an investigation whether the money spent on the creation will give a pay-back or not is important because the time-intervals between totally new trucks on Volvo GTT is relatively high, in comparison to the car industry.

This lead to the next question: how shall the suppliers do the trade-off curves? The suppliers are experts in their field and by demanding not one but a couple of prototypes, each prototype will be a knowledge source in the creation of the trade-off curve. An illustration is provided by figure 10 in chapter 2.6. This can be made by design of 10-20 exhaust systems. The exhaust system is reducing noise. In order to reduce the noise, backpressure must be created in the exhaust and the gasses flows out of the engine. In turn, the performance of the engine is reduced. This provides a trade-off between reducing the noise and creating the backpressure. The trade-off can be shown as a curve with a safe and an infeasible region. With this knowledge, the design engineers' can chose what kind of trade-off between performance and noise they want for their engine.

In order to be useful, the trade-off in the figure must be completed with two things. First, numbers need to put on the scale. Second, and most important, the coordinate axes needs to be formulated in a precise way so that the trade-off is valid for every situation. Noise level only means something at a particular engine condition (a particular amount of noise coming out of the engine), it would be more reasonable to plot noise reduction (the change in noise level in adding the exhaust system). Similarly, backpressure is only meaningful at a particular flow and should be changed to backpressure as a ratio to the amount of gas flowing through the engine. To make the trade-off curve even better, volume of exhaust system or its cost may be included.

7.3 Check Sheet - content and feature

Besides the trade-off curves, the Check Sheet also contains golden and generic rules. These are based upon an interview with a component owner. The golden rules are supposed to be the rules that are crucial for a good component design and the generic rules provide knowledge that are of highest importance to take into account.

The answers to the questions during the interview did not answer what was defined as golden and generic rules - those were set by us and should be confirmed by knowledge specialists and other component owners.

A big question has been to classify which level the knowledge should be placed on. Do we want to have it detailed or general? The answer is that we struggle to have a balance between these two. A detailed content makes it hard not being project- and brand-specific while a general content tend to be easy in the way that the employees learn this really fast - thus, raising the question if it is necessary to be put into the Check Sheet.

At the same time, knowledge must be of a general nature, every employee should be able to understand without being familiar with the project. Mechanical designers should not have problems interpreting the knowledge.

This leads to the question: How shall knowledge from projects be captured in the Check Sheets as they proceed? A proposal for the usage of the Check Sheets is that when a mechanical designer starts a project, he or she takes the Check Sheet and uses it throughout the project with the steps that are in it. If knowledge can be taken, the mechanical designers needs to put this into the Check Sheet as the project proceeds so that it always is up to date with the faults and successes from the earlier projects. If projects are run parallel and knowledge can be taken from each project, there has to be a communication between the project members, otherwise the knowledge can get lost.

Since the Check Sheet is not programmed and programming is not a part of the thesis, it is difficult to set specifications for it and specifications are always being modified upon trying existing features. One could ask the question “Is it possible to simplify the process for non-owners to give feedback regarding the content?” so that the owner can modify and edit the content, we will leave this to further investigation and improvements.

The Check Sheets are supposed to be used of all the employees. Assuming that some employees are confident with the content may cause a habit for not using Check Sheets. To promote the usage of the Check Sheets it has been important to think about features that all employees, independently of content confidence, can take advantage of. This is supposed to be solved by using links & references and the chat-function. We have observed cases where it has been difficult to find documents. Even though one knows where to find documents today, it takes a lot of clicks to end up there. The links & references in the Check Sheets provides a faster way to receive desired and relevant documents, thus content confident employees will also use it. Another feature is the chat-function enabling discussions, attachment of documents, asking questions and showing who that checked off the generic rule.

The synthesis illustrates a Check Sheet for one component made of us by interviews with component owners. This leads to the question “Who shall create the Check Sheets and how?”. We believe that everyone can create Check Sheets but it is of biggest value to have deep understanding regarding the component the Check Sheet is destined for. Further, a simple methodology, distinguishing what knowledge really is, is relevant so that the Check Sheet do not become just another information sheet. With this said, there will be a difference in content level depending on the creator, although this is not a problem since the Check Sheet is being maintained and updated and will be accurate by time. The maintenance approach also prevents documentation overload since the content always is screened through and maintained.

The proposed ownership flow is not validated. After a Check Sheet is created, the knowledge has to be confirmed so that it is correct. We placed the SMT-leader to decide but it can also be experts in the field of the component. Although, what quality is it in the ‘*Yes*’ answer? How do we know what correct knowledge is? One answer is in the paragraph above; the importance of distinguishing what knowledge really is. The reason why we put the component owners as the one editing the Check Sheets is that we thought that they are most suitable as they are the ones responsible for the component.

There is little literature about Check Sheets and a quick search on the web for the word “check sheet” shows that it is a method for capturing problems as they arise. There is a distinction between that Check Sheet and ours. Ours are designed so that it also captures new thoughts, ideas and technology, not only problems.

7.4 Search system

The search functions in the created methods are just an illustration of, or one may call it a specification of, a further development of an IT-tool. In further development, we see that the search function have sophisticated search functions as described in Infoday (2013). This may play a big role in the early phase of the KM implementation in the way that users perceive the system as a help tool to trust on. However, we have a desire for reducing the impact of the search function and go for a system where the knowledge one need is made visible automatically when needed, without needing to search for it.

As long as one need to search, then there will be knowledge that is not found when it is needed due to several reasons; did not search for the right thing, did not know one needed to search, did not bother to search, searched for the right thing but still did not find it because the search found too many other things. Thus, there will be mistakes made and problems repeated that are well documented in the search-based KM system.

8. Recommendations

Recommendations in this chapter are provided to achieve a best tailored system for Volvo GTT based on the achievements of the thesis.

The subsequent step is to make a specification for how to create Check Sheets for different components and train the employees in how to use them. The methodology can be based on the Check Sheet in the thesis, which can function as a guideline for how to capture ones knowledge in a compressed format. As seen in the synthesis, links to other documents are used in the Check Sheet. Therefore it is important to map the knowledge in different databases as a support for the link feature connected to the generic rules.

When a Check Sheet is accurate enough, it is of biggest interest to validate it. Letting a design engineer design with the use of the Check Sheet can validate it. It will provide vital insight about the features and the content.

When the Check Sheet is validated and proven to work, it should be incorporated into daily company activities - which also can be seen as a step for testing it in “real-life” situations. With the incorporation, track the usage of the Check Sheet is interesting. It will give a clear picture of how well the implementation is succeeded or not. Parallel to this, measurements of quality and productivity must be done to see if it really is facilitating the work for the design engineers. Finally, it is interesting to track the return on the investment.

Table 3: ***Recommendations on further developments.***

Further Steps to Consider
Further development of the trade-off curves.
Optimize the Check Sheet through validations and case studies.
Validate the ownership structure.
Programming the Check Sheet, i.e. a software.
Bring the insights from the thesis, along with other KM initiatives, and implement the optimal solution tailored for Volvo GTT.

9. Conclusions

During this thesis we have realised that competing through product development capabilities is very important for companies in general and for the automotive industry in particular. Having a well-functioning KM structure is crucial when cutting product development lead times. Therefore, the major challenge is to retain and develop the knowledge within the company.

As the current situation in the Climate group and Volvo GTT in general looks like today, the employees are dependent on asking experts or other colleagues when they experience knowledge gaps. Since four different truck manufacturers are included in the Volvo GTT, it is also of interest to transfer knowledge between the different companies to achieve a cross functional synergy effect. Going back to chapter 1.3, the purpose of the thesis was:

> *"To create a KM tool which captures the core knowledge for components providing the design engineers to make knowledge based decisions upon designing. It should also include a respective ownership structure to keep the knowledge up to date and maintained."*

The purpose was broken down into three research questions in order to make it more manageable:

1) Where is the knowledge find in the Climate group today?

2) In which system shall the knowledge be captured, stored and distributed, in a way that is suitable for the design engineers?

3) What are the prerequisites for the created system to be maintained and support the design engineers in their decision making?

We have discussed the different research questions and our findings will be summarized and analysed based on the different research questions. Considering the first research question, the knowledge flow within the Climate group is relatively scattered. There is no particular KM system the mechanical designers are using today. However, there are mainly seven identified data, information and knowledge sources but the pure knowledge content is poor. When knowledge gaps appear in their working process, they are dependent on asking their colleagues. The STS has a lot of experience and knowledge regarding the components in the climate system hence making that person hard to replace. An important part of our synthesis has been to involve the STS into the development of our KM system.

Examining other departments within the Volvo GTT to compare the knowledge flow shows that Volvo Powertrain uses a KM system called DVG. The format is relatively user-friendly but the mechanical designers have no incentive to use it in projects. It is a disadvantage and a major reason why the system has stagnated in development.

Continuing with the second research question, we are convinced that the Check Sheets and trade-off curves will, from a KM point of view, give the mechanical designers a good base. The trade-off curves will visualize trade-offs between design variables which will make the decision making more efficient and the Check Sheets will keep the knowledge in an easy format. However, the challenge is to not make the content too detailed neither too general. One of the Check Sheets advantages is its checks enabling to check off each point hence ensure that the knowledge embedded in the Check Sheet will be taken into consideration. We believe that an integration of the Check Sheets into the GDP structure will force the design engineers to check off before each release, which will increase the incitement to use the Check Sheets but also put effort to maintain and update the content.

Moving to the third research question, we realised the importance of a well prepared KM ownership and maintenance structure early in the study. Without any incentives to keep a KM system alive, it will sooner or later stagnate in development. Our first draft of an owner and maintenance structure sets well-defined roles for the involved engineers in tasks to reuse and update the knowledge in the Check Sheet.

To conclude this section, we have seen that being able to collect, distribute and reuse knowledge is far from easy. There are many variables that matters but getting the employees involved in the KM process is a vital aspect to consider. Spending time and effort in improving systems for capture, store and reuse engineering knowledge should be seen as an investment from the company’s point of view with the potentially high returns. To achieve this, the cultural aspects must be taken in consideration together with the KM technology.

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Appendix I – KM in other companies

An important part of the result has been to investigate how other companies in comparison to Volvo GTT are working with KM in product Development. Companies of different sizes which are operating in different industries could give interesting inputs to the final result. The interviews were held at companies which have their research and development offices in the Gothenburg area. One of the companies is validating and testing components in cooling system for e.g. the automotive industry. The other two companies are a manufacturing company and an aerospace company. The idea was to see how the companies are working with capturing, re-using and storing knowledge. The interviews took place at each of the companies' offices and took approximately 45-60 minutes each. We have not been able to triangulate the answers but we believe the extracted material from the interviews gave useful inputs for the thesis. Though, it was relatively hard to elicit information which could be useful for us in the end. The interviews were more of a general nature in a KM perspective. One of the interviews took place relatively early in the project which resulted in a general content since the frames of the project were, on that time, rather vague.

Manufacturing company

The manufacturing company is a multinational company with around 50 000 employees worldwide which around 3000 are working in Sweden. The manufacturing company is, like Volvo GTT, represented on many different markets worldwide and has also research and development departments in India, China and in two other European countries. The person we interviewed worked a couple of years as a design engineer at the company.

In general, the interview's group is developing specific product which is only developed in Gothenburg. On the company's other sites in Europe, they are developing different products. They are for instance developing the company's future products or helping customer to customize the company's products into their applications. In the daily work, mutual communication is between the colleagues is the most common way to transfer knowledge within the organisation. The company uses one database storing drawings and other data which is the company's document management system. The company, as well as Volvo GTT, performs plenty of validations and tests of their products. The test results are stored in a separate database and each validation report must be approved by a proof reader before it is stored in the base.

They have also a third database where knowledge is stored in terms of designing guidelines with useful related links to other databases. This database is relatively recently implemented at the company and works fine. The knowledge in the database is made searchable by relevant search words, which the creator decides. The database is accessible for all the personnel and everyone is able to store documents, which also are a challenge because the personnel cannot see if any documents have been updated. It is also relatively easy that duplicates are created when no one is maintaining the database.

There are no continuous knowledge transfer between the site in Sweden and the other European sites. However, they have access to the designing guideline database, since many documents are written in Swedish; the knowledge transfer could therefore be unstructured.

Consulting company

The consulting company is a big Scandinavian technical consulting company with around 2000 employees. The company is operating on a couple of locations across Sweden. In Gothenburg, they are specialized in developing, testing and validating components in climate system for different applications.

Since they are relatively few personnel at the Gothenburg research and development department, the knowledge transfer happens orally between the personnel. Although, they are following a template while documenting projects. These documents are processed in software which works as a tool for sharing, organizing and discovering information.

The site in Gothenburg is in an initial stage in embracing the tool and the usage of the software is more up to each employee. Hence, there is some documentation personnel have to do in projects. The main crucial advantage of using the software is to, by looking at relevant projects executed earlier, get an idea of the time and costs for a project. Although, any direct knowledge is not provided – rather information.

Aerospace company

The international aerospace company has around 400 employees in Sweden where they are manufacturing computer systems, antennas and microwave electronics. The company has no thorough strategy regarding KM. They are trying to implement it by incorporating a reorganisation.

Today the personnel are divided up in areas of expertise and they are experiencing barriers between the divisions. No direct collaboration are being exchanged rather the departments are, when they have fulfilled their tasks, handing over the project for the next department to take over. Seeing one's own department as separated from the rest inhibits the knowledge distribution and creation.

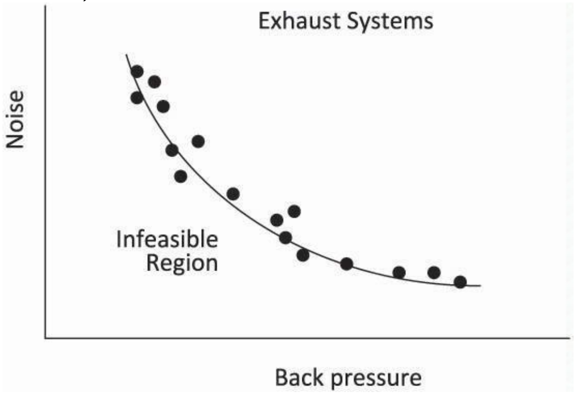
The idea with the reorganisation will be to separate the departments and create new ones with a variety of expertise in each group. The company hopes that this new way will give room for discussion between the diverse expertises thus promote creation of new knowledge and provide a holistic view for the participants. It will also allow responsibility for the project as whole for every employee - from start to finish. Going from an expertise separated into a project separated approach can also affect the reorganisation negatively by reducing the communication between experts from different projects.

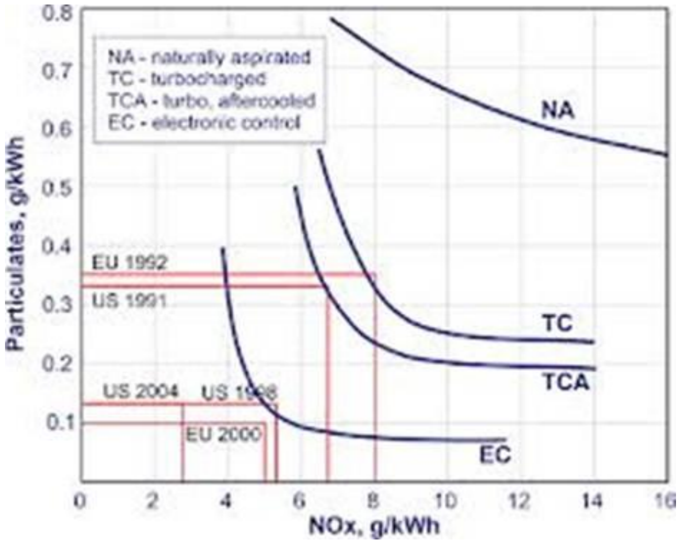
Another issue that the company experience is the knowledge capture. They do have a wiki-like database for saving and writing documents, although this is not used and maintained frequently resulting in a non-used method. Therefore, a big interest is in implementing a good knowledge capturing method. Unlike many other companies it is a little of commerce of personnel hence the knowledge stays within the company in form of tacit and the key focus are set on knowledge sharing rather than capturing - which in itself is a method providing the knowledge sharing, thus has to be managed.

Appendix II – Trade-off Survey

TRADE-OFF CURVES

With this survey, we want to get inputs in the characteristics that you believe affect other properties (see example below)





Trade-off between NOx and particulate emissions for different engine concepts

1) What properties do we want for a pipe / a hose?

____

____

____

____

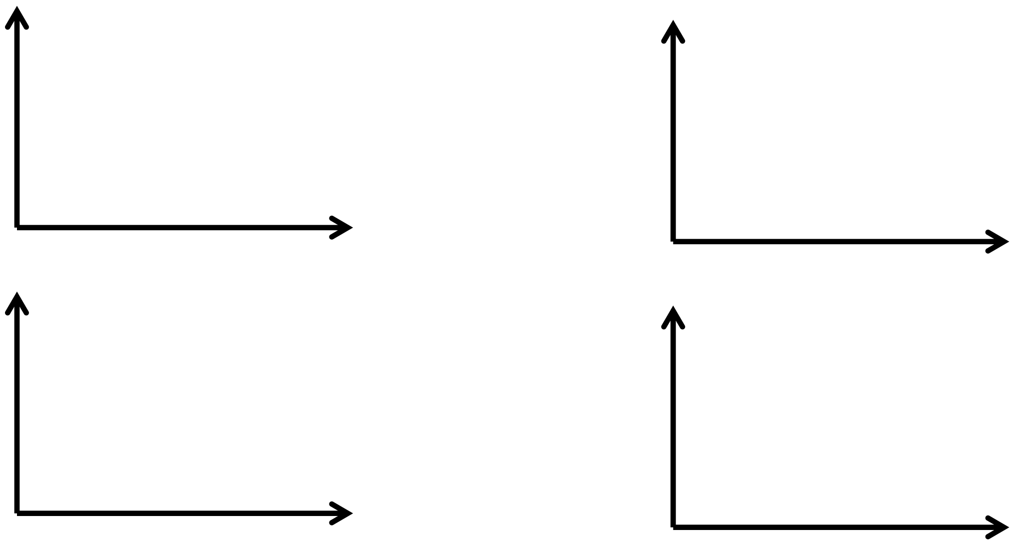
2) Which out of the above properties correlate with each other?
(In a trade-off, as described above)

____________ ⟷ ____________ ⟷ ____________

____________ ⟷ ____________ ⟷ ____________

____________ ⟷ ____________ ⟷ ____________

3) If possible, label the axes and plot the relationships in the graphs below. *Remember that no raw data is needed but this can be done on intuition.*



4) Other comments: