CHALMERS

How to Support and Facilitate Knowledge Flow in Product Development at Volvo Group Trucks Technology

SINA GHAEDIAN

Master of Science Thesis in Quality and Operations Management

BO CHEN

*Master of Science Thesis in Innovation and Industrial Management**

Department of Technology Management and Economics
Division of Quality Sciences
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SE-412 96 Gothenburg - Sweden
Telephone + 46 (0)31-772 1000

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Abstract

The notion of “Knowledge value stream” promoted from Lean Product Development brought knowledge to the fore-front of Product Development area as a core value created in product development process. Managing knowledge generally is a complex area, particularly in Product Development context. However, it is not a new topic and researchers have investigated this area from different angles. This thesis research is based a real case in an organization’s Product Development department, with a purpose to figure out how knowledge flow can be improved, especially how knowledge capture and reuse can be supported and facilitated. This is realized mainly through a thorough literature review on related issues followed by twenty-seven semi-structured interviews with interviewees from various levels and functions involved in product development projects.

The researchers investigated knowledge flow in three dimensions in the organization: the explicitness of knowledge; the reach of knowledge flow in the organization; and knowledge management lifecycle. Current status and improvement areas are identified in the above-mentioned three dimensions. How to achieve the improvement is however looked into from following three areas, around which conclusion is drawn: 1) What methods and mechanisms can enable knowledge flow; 2) What organizational structure can support knowledge flow; 3) What cultural factors can facilitate knowledge flow. Recommendations to the case organization are given by presenting what works well? What does not work well? What can be done both in strategic level and actionable level? respectively in knowledge capture, Share and Reuse. Finally researchers review the research by criticizing the model employed in the research and look at empirical data more from organizational learning perspective. Future research areas are discussed.

Keywords: knowledge management, Knowledge flow, knowledge capture, knowledge share, knowledge reuse, product development, Lean Product Development, organizational learning

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The two researchers would like to express their gratitude to all those who have made this thesis project possible.

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We would like to thank two supervisors from school, Rick Middel from School of Business, Economics and Law, University of Gothenburg and Sverker Alänge from Chalmers University of Technology for their highly professional guidance both on producing a good paper and extending our thoughts without limiting our view. Neither of them hesitated in spending extra effort and time into this thesis project.

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Bo Chen and Sina Ghaedian

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1. Introduction

1.1 Background

Product development has been regarded as the most knowledge-intensive function in an organization. Liu, Chen and Tsai (2005) in their study have established positive relations between knowledge management and new product development performance. Kennedy, Harmon and Minnoch (2008) in their book about lean product development have emphasized that knowledge value stream is the core area which Product Development should focus on, versus product value stream. Relationship between knowledge value stream and product value stream is shown in figure 1 below.

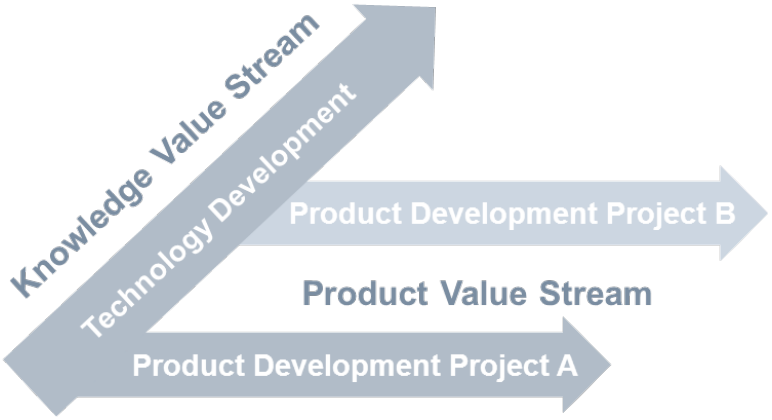

Figure 1: The knowledge value stream and product value stream (Kennedy, Harmon and Minnoch ,2008)

˝The methods and practices of knowledge management significantly affect how effectively an organization generates, stores, accesses, recombines and mobilizes what it knows about NPD-both technically and processually" (Pitt and MacVaugh, 2008). The discipline called Knowledge Management is a continuous strategy of getting the right knowledge to the right people at the right time, and help people share and act on information to improve organizational performance. In other words, knowledge has to be converted into value and profits, by flowing right knowledge to the right people at the right time (Holm, 2001).

This research project is based on a real case problem in Volvo Group Trucks Technology. In the following, a brief description of the problem and discussions about its possible reasons is covered; moving towards research areas related to the problem and finally the focus of the research.

1.2 Problem formulation

Company Background

Volvo Group Trucks Technology is a worldwide entity supporting the Group Trucks and Business Area's within the Volvo Group. Group Trucks Technology´s Scope of activities are:

- Product Planning
- Projects & Range Management
- Advanced Technology
- Complete Vehicle
- Powertrain Engineering
- Vehicle Engineering
- Purchasing

(From Volvo Group website)

Organization Context of this research project

This research was initiated under a progamme in Previous Volvo 3P (which is incorporated into present organization Volvo Group Trucks Technology), called "Lead Time Reduction Programme" which is a three year's initiative until end of 2012.

Reducing lead time in projects is a strategic objective for Volvo Group. It has been shown that research and development costs and times are too high within the Volvo-group and to improve upon that lead time in our projects has to be decreased. (Volvo Group website)

In product development of the organization, it has been realized that there could be improvement in terms of learning from mistakes, bringing the knowledge into organizational level, and reusing the existed knowledge. Various issues have been identified that can be possible reasons behind the problem:

- Difficulties in utilizing learning from the projects
- Not efficient standardization
- Not enough time dedicated to reflection
- Higher focus on quick fixing and firefighting, than finding root causes of a problem
- Difficulties in handling non-codified knowledge
- Not efficient conditions to assure smooth knowledge flow, such as weak Interactions between projects and line
- No accountability and structure to support knowledge flow
- No supportive knowledge repository

Two main themes appear by synthesizing above sources: knowledge management and organizational learning. The problem is abstracted that knowledge and learning are not managed efficiently. The question in concern is not only learning from past mistakes, but also to manage knowledge flow in product development in a way that the organization can achieve a knowledge-based product development, in which learning is the core element.

Focus of the research

Knowledge management lifecycle includes knowledge creation, knowledge capture, knowledge storage, knowledge share/transfer, and knowledge application (Nissen, 2002; Alavi and Leidner, 2001). In a product development organization, new knowledge is created from activities in all the stages such as concept selection, design, detailed development,

testing and so on. It might be captured and resides in different forms such as documentations, database, codified knowledge in system, tacit knowledge imbedded in individuals. However, “as organizations create new knowledge and learn, they also forget” (Alavi and Leidner, 2001), which means part of knowledge is lost without being captured. Due to the distributed nature of knowledge, knowledge needs to be shared and transferred to those who need it. Furthermore, the captured and shared knowledge does not necessarily results in the application of knowledge (Alavi and Leidner, 2001). The organization has found it challenging to learn from the newly acquired knowledge, keep it and building it into organizational competence. In other words, knowledge is scattered, is not flowing smoothly and efficiently and formulating the complete loop of Knowledge management lifecycle. Consequently, how to capture the newly created knowledge from the projects and make sure both the existing and newly captured knowledge are brought into the new projects becomes the focus of this research.

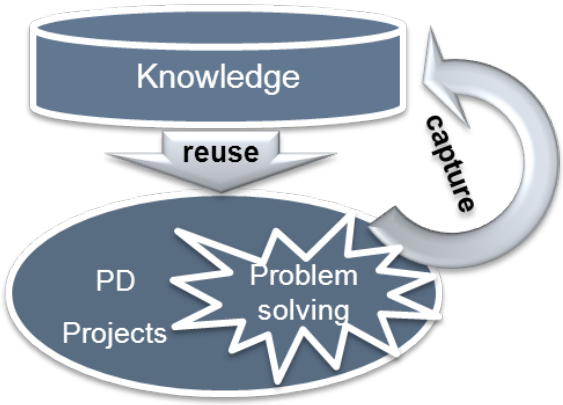

Figure 2: Illustration of the research focus

1.3 Purpose and research question

The purpose of this research is to find out how to improve capturing and reusing knowledge in Product Development projects, in order to achieve efficient knowledge flow in product development at Volvo Group Trucks Technology.

Research questions

The purpose of establishing supportive conditions for effective and efficient knowledge capturing and reusing knowledge, leads the project team to the following research question:

How to support and facilitate knowledge flow in PD at Volvo Group Trucks Technology?

A supportive structure, methods and mechanisms and culture for capturing and reusing knowledge is critical for efficient knowledge flow to ensure that organizations avoid suffering from reinventing the wheel (Morgan and Liker, 2006). As a result of reviewing literature, the main research question is divided into following sub-questions:

1) What methods and mechanisms can enable knowledge flow
2) What organizational structure can support knowledge flow
3) What cultural factors can facilitate knowledge flow

1.4 Delimitations

Considering the convenience of acquiring resources, this research only looks into development site in Gothenburg, implying that the issue of managing knowledge across geographic locations and cultures is not taken as a viable. Rather this research stands on a general level which is assumed to be able to generalize over geographic locations and cultures. It is not within this research's scope as well knowledge creation in the knowledge management lifecycle and the related issues to knowledge creation. Furthermore, the authors do not intend to include how to establish knowledge management system. Finally, the detailed implementation plan is not included, though in section 6.2.3 a few suggestions are given about implementation in the organization.

2. Methodology

This chapter describes strategy and methods this research employs, including research strategy, research design, methods for data collection and analysis together with illustration how the research is conducted in order to achieve the research objective.

The goal of the research is to understand how knowledge flow is currently in the organization and how to increase the efficiency, which is embodied in the research question **"How to support and facilitate knowledge flow in Product Development at Volvo Group Trucks Technology?"** This goal is agreed jointly by discussion among the two researches and supervisors from both school and organization. Before and during discussion, researchers have done preliminary literature review in order to understand the problem that the research intends to investigate into. After the goal of research and research question is formed, further literature review was conducted which decomposed main research question into three sub-questions:

1) What methods and mechanisms can enable knowledge flow
2) What organizational structure can support knowledge flow
3) What cultural factors can facilitate knowledge flow

The research was executed from two lines:

1) Theoretical framework established from literature review for developing theoretical understanding of problem in order to guide the strategy and method of collecting data, as well as guiding development of interview questions.
2) Data collection in order to understand the current situation and the associated issues

These two lines met in the analysis where they were compared and analyzed to form analysis and conclusion section.

2.1 Research strategy

Research strategy is a general orientation to the conduct of research. The difference in the general orientation is differentiated into two distinctive strategies: quantitative strategy and qualitative strategy. Quantitative strategy is more oriented to deductive approach by testing theory, emphasizing quantification in data collection and analysis. On the contrary, qualitative strategy is more oriented to inductive approach by generating theory, emphasizing the individual's role in interpreting and constructing the reality (Bryman and Bell, 2007). The problem that this research is investigating into is around knowledge management and organizational learning, which decides the nature of the research entails extensive perception, opinion from the organization members how they construct the situation. Consequently this research assumes qualitative strategy, in which the theory is

neither tested or generated, but utilized to guide which areas should be looked into and what answers can be expected to the main and sub research questions.

- **Literature review and theory's role in the research**

Literature review plays important role both in the early phase of the research for finding the focus and throughout the research to guide which areas the researcher should look into. In the early phase before the goal of the research is agreed, researchers reviewed literature in product development including lean product development, knowledge management and organizational learning to form the research question. During the research, more detailed literature review was conducted to find which areas are critical to look into. The source of literature is chosen according the following keywords: knowledge management, Knowledge flow, knowledge capture, knowledge reuse, product development, Lean Product Development, knowledge based product development, organizational learning. Appendix III shows theory and framework the researchers have read and considered, from which the tangible result of literature review is formalized into chapter III "Theoretical framework", serving as foundation of interview questions.

2.2 Research design

Research design incorporates framework of data collection and analysis. Case study applies when the research aims to provide an in-depth and unique elucidation on an object of interest in its own right which falls into an idiographic approach (Bryman and Bell, 2007). Since the problem that the research intends to investigate is in a single organization which requires detailed and intensive examination of the current status and the organization members' perception of the problem, case study is chosen as the appropriate research design.

2.2.1 Research method

Research methods is the techniques the researcher utilize to collect data. Qualitative methods such as unstructured interview, participant observation are often connected to case study since these methods support generating intensive and detailed examination of a case (Bryman and Bell, 2007).

- **Data collection**

As Bryman and Bell (2007) solicited that due to complexity of some organizations and probable conflicting interpretations from different sources, multiple research methods are sometimes encouraged to ensure the completeness of data. Particularly in this research, researchers start from the main research question and break down the main research question into three sub-questions, which were further broken down into more sub-questions, each of which guides researchers with sources to collect data (as shown in Appendix II). The sources include primary data, which is collected first-hand by semi-

structured interview, casual and random talks with employees; and secondary data, which is collected by reading documentation, checking organization website. Qualitative interview is more suitable in qualitative research when there is more interest in the interviewee's point of view and more detailed and richer description (Bryman and Bell, 2007). Since the research area is in knowledge, which is rather subjective depending to a big extent on the organization members' perception and views, semi-structured interview is utilized with a series of questions formed from both literature review and requirement from the organization about what are the ranges of issues around the problem that the research intends to study on. However, the sequence of questions is changed and further questions are followed up in different interviews in accordance with different interviewee's role, level and specialty in their function. Each interview lasts from 45 minutes to 100 minutes. During the interview, leeway is particularly given to interviewees as to how they understand the importance of different issues around research topic. A pilot interview was conducted with one interviewee from whom the feedback was used to adjust the introduction of background and interview questions. At the same time secondary data was collected from different sources. The researchers studied organization's policy and norm which is related to knowledge and learning and attended several seminars related to lean methods. How product development is conducted in process was studied and discussed with company supervisors. The collection of secondary data and collection of primary data through random talks were conducted throughout the research project. On the contrary, the collection of primary data through semi-structured interview was conducted intensively within a short period of time according to availability of interviewees. However, follow-up talks with some of the interviewees were conducted for further clarification after interviews were done. Altogether, twenty-seven semi-structured interviews were conducted

- **Sampling**

In order to reach a not only in-depth but also a rather representative study in the organization, sampling was chosen in a structured way which covers vertically different stratified group and horizontally different function groups. Both operational level in projects (engineer level) and project management level are included in samples, however with project management level as the main interviewees. Managers from line organization are also included to avoid possible bias that majority samples are from project organization. In some stratified group and function group, two to three people were interviewed to decrease possible variation in different samples. According to Bryman and Bell (2007), theoretical sampling is a tool connected to grounded theory used to decide what data to collect next and where to find them during the process of data collection, coding and analysis. In the late phase of the research project, Interviewees from engineering level and from line organization were identified for further interview since the theoretical saturation in data was not fulfilled. Below table 1 summarizes number of interviewees in different roles.

Interviewees' position	number of interviewees
After-Market Project Manager	1
Chief Project Manager	4
Product Development Project Manager	5
Global Manufacturing Project Manager	1
Process manager (Lead Time Reduction Program)	1
Manager Product finance	1
Project Assurance Manager	3
Product Development Project Manager - CAB	3
Purchasing Project Manager	3
Project Senior Consellor	1
Line Manager - CAB	1
Line Manager – Chassis	1
Engieer - CAB	1
Director Volvo Group Institute Project Management	1

Table 1: Interviewees' position and number of interviewees

2.2.2 Data processing

The interviews were transcribed by two researchers and notes were taken from transcript without taking into account theory from literature review. This was done by coding different concepts into categories. Further these notes were grouped in accordance with theory to form the empirical data. Data from secondary source was used to complement the primary data in empirical data section.

2.2.3 Data analysis

In this research project, grounded theory was applied for analyzing data as well as for collecting data as illustrated previously. Grounded theory entails iterative process of conducting data collection, analysis in tandem which is helpful in capturing complexity of context (Bryman and Bell, 2007). The analysis begins with trying to find patterns in empirical data followed by connecting correlation between different concepts and categories. Hence, the main issues in analysis section are guided by different sections in theoretical framework however not following the same structure.

2.3 Validity and reliability of qualitative study and case study

2.3.1 External validity

The main concern on criteria for evaluating case study research design is the centered on external validity (generalizability) beyond the unique case context. A case study's findings

cannot be easily generalized and be representative to other cases (Bryman and Bell, 2007). It is not the researchers' intention to generalize findings of this research out of the organization in study. However, the theoretical framework chosen for the research can shed light on what areas future research in the similar areas can look into.

2.3.2 Internal validity

Internal validity of qualitative study relates whether the theoretical ideas researchers develop match with the researchers' observation (Bryman and Bell, 2007). The theories and models chosen for this research is reviewed, at the late phase of the research project, whether they limit researchers' perception of the data collected. The review shows that the model employed for knowledge flow brings preference of knowledge management domain over organizational learning domain, resulting interpreting data mainly from knowledge management perspective. The result of this review is discussed more in detail in section 6.3 "Criticizing on the model for knowledge flow".

2.3.3 External reliability

External reliability concerns the extent to which the research can be replicated (Bryman and Bell, 2007). In this study, external reliability is more in relation to the data collection and sampling. As described in data collection section, samples of interview are confined in management level excluding engineering level. Furthermore, interviews are limited to the employees from project team and the data from the line organization is rather second hand than first hand. Hence if the research is replicated in the same manner however including people from engineering level and from line organization, the findings is not guaranteed to the same.

2.3.4 Internal reliability

Due to involvement of a great deal of subjective judgement in qualitative study, under the circumstance that more than one researcher is involved, internal reliability should be examined whether researchers agree on what they see and hear, how is the consistency in their decision, for example what are the related issues, how to categorize data (Bryman and Bell, 2007). In this research, two researchers agreed on most of the interpretation on the empirical data. However, due to the large amount of empirical data, two researchers had different opinions on what is more important issues to lift up and be analyzed more. For example, it has been mentioned by many interviewees that high turnover rate is a big barrier that organization/department loses competence and knowledge is lost. Finally it is agreed by the two researchers that it is more related to competence building than knowledge flow (specifically knowledge capture and reuse), which can be left for the future research.

3. Theoretical Framework

This chapter reviews literature on current research topics within product development and knowledge management, as well as touching upon organizational learning. It begins with an introduction of two kinds of product development process: conventional process and Lean PD; followed by the emphasis of knowledge in both kinds of PD process. The second section presents concept of knowledge, knowledge flow and its management. The third section provides an overview of evolving issues to support and facilitate knowledge flow in product development, specifically, three areas in managing knowledge and learning: 1) methods and mechanism; 2) organizational structure and knowledge management structure; 3) cultural factors.

3.1 Product Development

3.1.1 Product development process

"Product development is the collective activities, or system, that a company uses to convert its technology ideas into a stream or products that meet the needs of customers and the strategic goals of the company." (Kennedy, 2003). Product development is considered to be the source of sustained growth and competitive advantage for organizations. Hence how to effectively manage the product development process becomes the focus both in academia and business.

There are basically two different process models implemented in product development:

1) Conventional process with commonly used stage-gate model as leading model, and
2) Lean product development process.

Conventional Product Development process

Stage-gate model provides both conceptually and operationally tool to manage, direct, control the process of developing idea to new product launch (Cooper, 1990). As shown in figure 3, the process of product development is divided into several stages separated by gates.

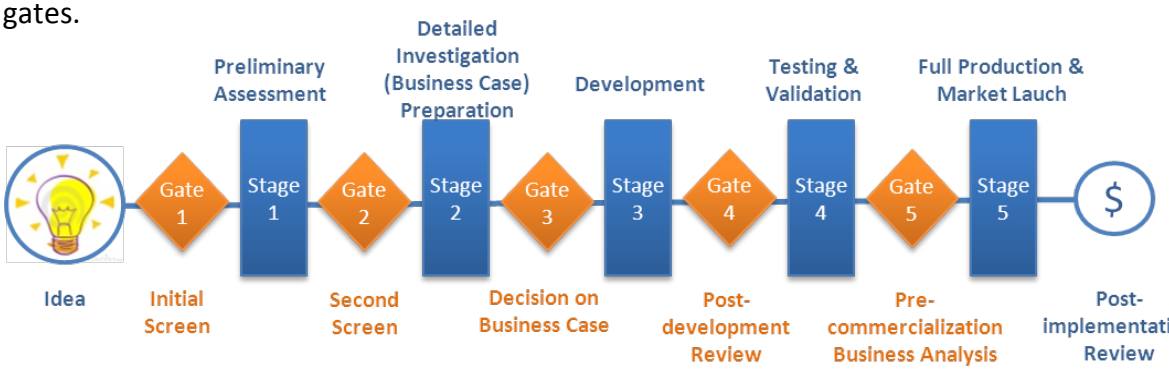

Figure 3: Stage-gate model (Cooper, 1990)

Stages show what work is done in each stage and a gate is a checkpoint whether the quality of previous stage is sufficient enough to move to the next stage.

The stage-gate model has been made by analoging from production process, with quality control and risk reduction as focuses by making sure that all deliverables in each stage is fulfilled before entering next stage (Cooper, 1990). It is designed to be a tool for planning various activities and tasks during the product development process. It is implied that the output of product development process is new product with the information how the product is manufactured, marketed, sold, used and serviced (Catic, 2011).

Lean Product Development

"Lean" is a concept from the book "The Machine That Changed the World" (Womack, Jones and Roos, 1990) which describes how Japanese automobile manufacturers, especially Toyota, produce with a much higher productivity and efficiency than the western manufacturers by using TPS (Toyota Production System) incorporating several "lean" concepts. Later it is widely accepted that Toyota's success is more derived from its product development system which shares "lean" concepts from the production system. Lean product development (Lean PD), or knowledge-based product development as Kennedy, Harmon and Minnoch (2008) call, is believed to be a process for product development with high focus on knowledge and learning, which can leads to higher efficiency than conventional approach. A comparison between Toyota PD and conventional PD shows the difference in the efficiency of product development. Compared with conventional PD, Toyota's PD has:

- 4x increase in development productivity
- 2-3x decrease in development cycle time
- 2-3x decrease in development cost
- 2-10x increase in innovation
- 2-5x decrease in development risk (Kennedy, 2003)

There are some commonly agreed lean principles regardless of production or product development such as:

- Customer and value focus: process should deliver value for end-customer (the next step in process is also customer for the current step)
- Continuous improvement: root cause is identified, created learning is used to accomplish a continuous improvement by standardization
- Focus on flow: deliver the downstream the right quality at the right time, reduce waste
- Knowledge focus: continuous learning as core for knowledge capture and reuse (Swan and Furuhjelm, 2010); (Morgan and Liker, 2006)

3.1.2 Focus of knowledge in Product Development

> "The methods and practices of knowledge management significantly affect how effectively an organization generates, stores, accesses, recombines and mobilizes what it knows about NPD-both technically and processually"
> (Pitt and MacVaugh, 2008)

Knowledge-based theory argues that the critical input and source of value is knowledge since all human activities are knowledge dependent (Grant, 1996). In product development, it is widely accepted that it is the most knowledge-intensive function in organization hence how to manage knowledge and learning in product development attracts much attention. Following this attention appears different researches centering on various areas in managing knowledge and learning, such as what methods and mechanisms can be applied, what structure is needed, what culture factors facilitate or impede knowledge management. A review of the researches in these areas of knowledge management and learning will be presented in section three.

Compared with the conventional product process, Lean PD emphasizes that the key for product development is the created knowledge which is reusable during the process. At the same time, the value that product development creates is the manufacturing systems and usable knowledge (Ward, 2007). It is apparent from the perspective of both the above-mentioned Lean PD cornerstones and Lean PD process, that knowledge creating, reusing and learning are critical for efficient product development. Kennedy, Harmon and Minnoch (2008) in their book about lean product development points out that product development has two value streams (as shown in below figure 4):

> "Lean development's goal is learning fast how to make good products".
> (Ward, 2007)

1) Product Value Stream – to develop new products, including all activities and tasks in the development process
2) Knowledge Value Stream – to capture knowledge and reuse it for current and other projects

Versus Product Value Stream, which is the focus of the most organizations' product development function, the Knowledge Value Stream is the core which ensures the continuous development of product value stream.

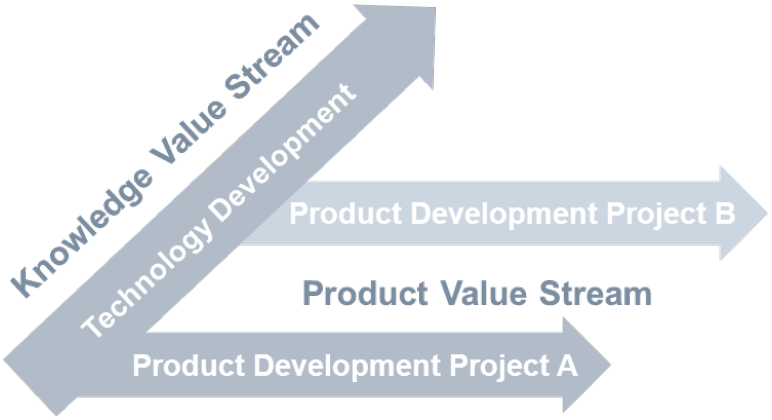

Figure 4: Knowledge Value stream and product value stream in product development (Kennedy, Harmon and Minnoch, 2008)

Knowledge developed in product development projects needs to be fed into Knowledge Value Stream and to be brought into projects. In Lean PD, a knowledge "pull" system is used to deliver right knowledge to the right person at the right time. "Pull" means the individual engineer knows what knowledge he or she needs and where to get it, thus extract the knowledge when he or she needs it (Morgan and Liker, 2006).

Hence in Product Development, knowledge management is about capturing right knowledge efficiently to be reused at the right time by the right people. As a starting point it is important to visit the basic concepts of knowledge, knowledge flow and the management of knowledge flow in the following section.

3.2 Knowledge flow

3.2.1 Knowledge

Teece (1998) argues in new economy the competitive advantage of organization rests on the ability to manage knowledge astutely, specifically, the ability to build and deploy knowledge assets. Different types of knowledge have different characteristics which bring different implications for management (Grant, 1996). According to Davenport and Prusak (1998), the types of knowledge decide the relative difficulty of capturing and transferring knowledge.

Polanyi (1966) classifies knowledge into tacit knowledge and explicit knowledge. According to him, tacit knowledge is based on the subjective insights, intuition derived from experience, values, emotion. It is context-specific thus not easily expressed, formalized and communicated. While explicit knowledge is the knowledge that can be transmitted in systemic language orally in written or in electronic form. (Polanyi, 1966); (Kakabadse, Kouzmin and Kakabads, 2001). Further, Polanyi (1966) believes there is no sharp distinction between tacit knowledge and explicit knowledge and all knowledge has tacit dimension. Goffin et al. (2010) give example of tacit knowledge and explicit knowledge and difference in their nature in NPD as shown in below table 1.

	Explicit knowledge	Tacit knowledge
Nature	• Intrinsically incomplete • lacks context and requires interpretation	Difficult to articulate
Typical examples	• Information • Know-what	• Intuition and insights • Practical intelligence, skills • Know-how and heuristics • Rules of thumb • Mental mode and beliefs

Table 2: Difference between tacit and explicit knowledge and examples in NPD context (Goffin et al. 2010)

3.2.2 Managing knowledge flow

The primary objective of knowledge flow is to "enable the transfer of capability and expertise from where it resides to where it is needed-across time, space and organizations as necessary" (Nissen, 2002). This requires knowledge flow to be perceived between different levels and reaches. Nissen (2002) integrate knowledge flow in different levels and perspectives into the extended dynamic knowledge flow model (as shown in figure 5) which looks at knowledge flow in three dimensions:

1) In the dimension of explicitness: Knowledge converts between the continuum between tacitness and explicitness;
2) In the dimension of reach: knowledge flows between individual, group and organization;
3) In the dimension of knowledge management lifecycle: knowledge flows in a continuous cycle through organization as six phases: creation, capture, storage, share/transfer, and reuse.

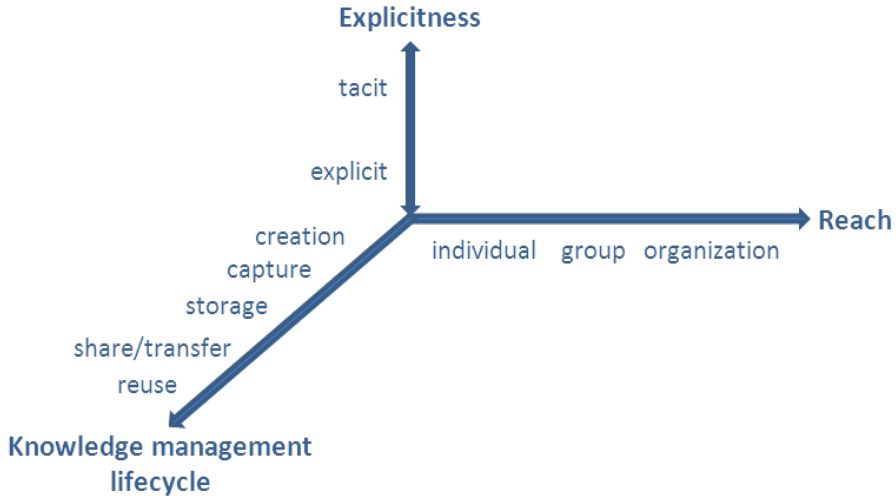

Figure 5: Extended model of knowledge flow (Nissen, 2002)

3.2.2.1 Knowledge flow in dimension of reach

Knowledge exists in different levels such as individually and collectively (Nonaka, 1994), thus the dynamic of knowledge flow happens between individuals, groups and the whole organization.

Organizational knowledge is formed in different ways:

- Individual knowledge shared between all the members in the organization (Grant, 1996)
- Bring individual's knowledge together and integrating individual knowledge (Grant, 1996); (Gold, Malhotra and Segars, 2001)
- Knowledge developed by individuals in groups and socially constructed through the inter-personal relationships, which results in a collective knowledge in comparison to individual knowledge (Spender, 1996).

Bring individual's knowledge together and integrating individual knowledge in organization is the key in managing knowledge in organization (Grant, 1996). Compared with individual knowledge, collective knowledge is more strategically important since individual needs to draw on the organizational knowledge for decision making and problem solving (Mentzas et al., 2001).

3.2.2.2 Knowledge flow in dimension of explicitness

In Product development, key issues for knowledge flow of explicit knowledge and tacit knowledge are different. For explicit knowledge, key issues are managing knowledge creation, storage, retrieval and motivate employees to produce good documentations. For tacit knowledge, key issues are recognizing people as the source of knowledge, thus it is important to create conditions for network, informal interactions and build up trust, as well as encourage sharing tacit knowledge so it is not lost (Goffin et al., 2010).

Nonaka and Takeuchi in their famous book "The knowledge-creating company" (1995) propose four modes of knowledge conversion based on the two types of knowledge: tacit and explicit. The fours modes are (as shown in figure 6):

Socialization: is the sharing process of tacit knowledge between individuals in which the experience is the key, since the abstraction of information from its associated emotion and context in which experience is embedded only captured explicit part of knowledge. Examples of socializations include apprentice system, on-the-job training. Socialization requires adequate design of space and time to encourage communication between individuals (Curado and Bontis, 2011).

Externalization: is a process of converting tacit knowledge into explicit concepts by using metaphors, analogies, concepts, models etc. A typical example of externalization is concept creation process in which, for example in product development, metaphors and analogies are used to articulate tacit images of a desirable product into explicit concept. Externalization makes it possible that individual knowledge transforms to collective

knowledge. It requires putting down the knowledge into documents so that it can be captured by others in the organization (Curado and Bontis, 2011).

Combination: is a process of reconfiguration existing explicit knowledge to create new explicit knowledge between individuals through the media such as documents, meetings, telephones, networks enabled by ICT. This mode of knowledge conversion is more and more supported by networks and large-scale databases.

Internalization: is a process that individual converting explicit knowledge in the organization, in the form of documents, manuals or oral stories, into his/her tacit knowledge mainly by "learning by doing". "Internalization" means individual creates own experience, or shared mental model from others experience or technical know-how. It is also a process that knowledge comes from collective level to individual level.

These four conversion modes provide means of communication between the two types of knowledge: tacit and explicit knowledge.

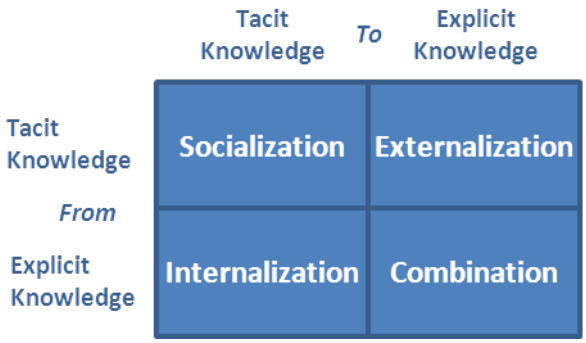

Figure 6: Four modes of knowledge conversion and creation (Nonaka and Takeuchi, 1995)

3.2.2.3 Knowledge flow in process view of knowledge management lifecycle

Nissen (2002) synthesizes different knowledge management lifecycle model into an amalgamated process which includes: knowledge creation, knowledge capture, knowledge storage, knowledge share/transfer, knowledge reuse.

More specifically in product development, Harris (2009) identifies four activities as focus of knowledge management:

- Knowledge identification: identification of knowledge required to develop new product, including product specifications, tooling, and material capabilities.
- Knowledge capture: capture, store and retrieve the knowledge created in product development process.
- Knowledge formalization and presentation: formalize and present knowledge to ensure it is used in present and other projects.
- Knowledge utilization**:** integration of the knowledge which is identified captured and formalized into products and decision making.

Nevertheless as also what Harris (2009) points out, since project is often time bound, people and knowledge are dispersed when project ends, leading to knowledge fragmentation and loss of organizational learning. knowledge management system or tool proposed by many knowledge management literature tends to manage explicit knowledge in the form of documentation, the context and process behind the documentation is lost, not either helpful for tacit knowledge capture and encouraging knowledge reuse. Specifically in product development as a creative process characterized by high level of uncertainty and variation, knowledge is unevenly distributed, much of it in tacit form and much located in the minds of comparatively few expert staff, which brings more challenge for managing knowledge flow and learning in an efficient way (Pitt and MacVaugh, 2008).

> "The success of Toyota, and the companies applying Lean Product Development could be explained by the fact that they work more systematically with knowledge capture and reuse."
> (Swan and Furuhjelm, 2010)

This research focuses on **knowledge capture** and **knowledge reuse**, with the aim of efficient knowledge flow to retain any knowledge that is created so that knowledge is accumulated in the organization level to develop organization knowledge, which, would be available whenever the organization needs to use it. Thus in the context of this research, knowledge capture refers to retain and accumulate the knowledge created, found in product development; knowledge reuse refers to the application of the knowledge captured. Knowledge share and transfer are partial steps towards knowledge reuse (Alavi and Leidner, 2001); consequently Knowledge share and transfer are in the scope when there are factors related to capturing and reusing.

3.2.2.4 Organizational learning and knowledge management

"Learning is the process of experiencing, analyzing, communicating the knowledge previously generated by others." (Spender, 1996) In product development, learning is the way to create useable knowledge (Ward, 2007). Argyris (1991) separates learning into Single-loop learning and double-loop learning. Single-loop learning involves error correction and problem solving, while Double-loop learning entails finding root cause and questioning and changing the operating norms.

The terms of Knowledge management in organizations and organizational learning have been used sometimes interchangeably in literature. King, Chung and Haneya (2008) provide three ways to see the intersections between organizational learning and knowledge management: 1) Organizational learning is complementary to knowledge management; 2) Organizational learning can be seen as the goal of knowledge management; 3) Organizational learning is one of the ways by which organization can utilize knowledge.

Organizational learning includes following process: information and knowledge acquisition; dissemination; interpretation and development of organizational memory (Martínez-León and Martínez-García, 2011). Specifically in NPD (New Product Development) process organizational learning involves identification and correction of errors with the final step of

capturing and storing generated knowledge (Ruy and Alliprandini, 2005). According to Chiva and Alegre (2005), on one hand, organizational learning is a process concerned with growth and change of organizational knowledge; on the other hand, organizational knowledge is a key component of organizational learning.

Consequently in this research, though bearing a research question in knowledge flow with a focus in knowledge capture and reuse, includes concepts, models, methods and critical factors in organizational learning.

3.2.2.5 Preconditions for efficient knowledge flow

It is necessary for organizations to identify and assess preconditions which are indispensable for knowledge management effort to be successful (Gold, Malhotra and Segars, 2001). There are two aspects of conditions to ensure efficient knowledge flow: from knowledge side and from the people side. From the knowledge side, knowledge needs to be transferrable, accessible and up-to-date (Grant 1996; Gold, Malhotra and Segars, 2001; Nissen, 1999). From the people side, individuals need to have capability for acquiring existing knowledge and processing knowledge (Grant, 1996).

Knowledge capture

Organization must acquire the ability to make knowledge useful for others and for future application, which means the organization knows what it knows and have systematic routine for locating and retrieving the knowledge. Knowledge capture happens when people are aware of what they learned and what aspects of the learning would be useful in the future and for others. Both tacit knowledge and explicit knowledge needs to be captured, since without contextual detail of the knowledge, the effective reuse of the knowledge will be compromised (Alavi and Leidner, 2001). There could be different strategies to capture tacit knowledge and explicit knowledge respectively, codification and personalization, as will be mentioned in Section 3.3.1.3.

Knowledge distribute (share/transfer)

There are two prerequisite for knowledge share and transfer: 1) the recipient should be able to digest the knowledge; 2) appropriate technique and media should be selected. Both informal ways (such as informal seminars, coffee break) and formal ways (such as training) can be used as share and transfer channels. The difference in transferability between tacit knowledge and explicit knowledge decides the mechanisms for sharing and transfer should be different. Personal knowledge transfer such as apprenticeship and job rotation might be more suitable for tacit knowledge, while knowledge repositories are more preferable for explicit knowledge transfer (Alavi and Leidner, 2001).

Knowledge reuse

The awareness of others knowledge and perception of the value of it decides whether knowledge will be reused at the first place (Magnusson, 2004). An efficient knowledge retrieval mechanism needs to be in place to make knowledge visible and accessible in the

organization (Gold, Malhotra and Segars, 2001; Davenport and Prusak, 1998; Alavi and Leidner, 2001). On the other hand, even when knowledge is accessible, application of the knowledge is to a large extent depending on people's perception on role of knowledge in organization. Hence a knowledge-intensive culture is needed to encourage employees proactively seeking, sharing, capturing knowledge (Davenport and Prusak, 1998)

Knowledge reuse can be seen in a process view which includes the previous stages of capturing (or documenting) knowledge, distributing knowledge, reusing knowledge (Markus, 2001). For reusing knowledge to happen, people first need to recall the knowledge (where the knowledge is), then recognize knowledge (the knowledge meets the users' need) and finally applying the knowledge. The knowledge which is captured and codified is often decontextualized. Thus it is critical to recontextualize, which entails analyzing general principles against a specific situations.

3.2.2.6. Barriers for Knowledge flow:

There are various barriers in organization for efficient knowledge flow. The main barriers that many organizations are confronted with can be as follows: (DeFillippi and Arthur, 1998; Love, Fong and Irani, 2005; Dworman, 1998; Söderberg and Alfredson, 2009)

1) Ignorance: Particularly in large companies usually the source of knowledge is not aware that someone is interested in the knowledge he/she has and the recipient of knowledge does not know either that someone else has the knowledge they require.
2) Not efficient communication between the source and the recipient of knowledge.
3) Difficulties in retrieving captured knowledge: difficulties in both finding the needed knowledge documents and finding the knowledge needed within a large collection of documents, due to not efficient documentation system; for instance, not organized and easy to find documents (lack of search ability), or long documents that can take a long time to get the useful knowledge from it.
4) Context-specific knowledge and learning make it difficult for other projects to get benefit from past experiences.
5) Uncertainty on validity of the captured knowledge.
6) Lack of "natural" mechanisms of learning, since projects mostly are judged on hard facts such as quality, time and cost; projects have a rather short-term orientation with a focus on immediate deliverables which does not facilitate learning and knowledge management which needs a long term approach.
7) Employee turnover
8) Lack of management support: Knowledge management-activities is often neglected in project management practices, since the outcome of KM is not easy to be measured and quantified, and this is one of the main reasons that causes lack of support and commitment from management team.

Section 3.1 and 3.2 have reviewed concepts of product development, knowledge and managing knowledge flow and learning in product development, including in Lean Product Development. Discussion around preconditions and barriers for efficient knowledge flow points to questions for managing knowledge and learning in product development, with the purpose of ensuring the preconditions are met and barriers are overcome:

1) *What needs to be in place? What methods and mechanisms can be used?*
2) *Who should be responsible for knowledge flow? How the organization is structured and the implication of it on managing knowledge?*
3) *What are critical cultural factors for achieving knowledge-intensive culture?*

These questions will be discussed in following section 3.3

3.3 Three areas critical for managing knowledge and learning in product development

Various factors in different areas have been identified as critical to support and facilitate knowledge management process for achieving efficient knowledge flow. Gold, Malhotra and Segars (2001) point out that technology (embodied in various tools and methods used in the organization), organizational structure and culture are the preconditions and infrastructures for managing knowledge. If there is no supportive structure, methods, mechanisms and culture for capturing and reusing knowledge, organizations suffer from reinventing the wheel (Morgan and Liker, 2006). Consequently, in following section 3.3.1; 3.3.2; 3.3.3, the areas which are critical for effective and efficient knowledge management that an organization should consider to achieve knowledge based product development are discussed. The areas are:

- Methods and mechanisms to enable knowledge flow
- Organizational structure to support knowledge flow
- Culture factors to facilitate knowledge flow

Each sub-section frames a particular issue in managing knowledge and provides set of ideas for efficient knowledge flow throughout product development.

3.3.1 Methods and mechanisms

Problem of learning from development projects is examined in many literatures, pointing out the complexity of PD. Many different people are involved in development projects under set of activities, during different periods of time. As stated by Clark and Wheelright (1992), organizational learning is not a natural outcome of development projects and most organizations are not good at learning from their own experiences. Capturing the right knowledge and reusing existed knowledge within an organization is a real challenge that many companies are dealing with. (Clark and Wheelright, 1992)

Different methods and mechanisms that can facilitate continuous learning and managing knowledge in PD are discussed in following sections:

3.3.1.1. Learning cycle: The importance of Reflection and Standardization

Learning cycles can play a big role in improvement processes. PDCA cycle as introduced by Deming is a learning cycle which constitutes four different phases as follows (Bergman and Klefsjö, 2003):

- Plan: Understanding the problem and thorough planning on how it can be solved, changed or improved.
- Do: Implementing the plan.
- Check: Evaluating the result of the implementation and check the gap between expected outcome and actual result and the reasons
- Act: Reflecting on the implemented solution and its result, in addition to standardizing the solution.

Reflection and Standardization are the functions that are highlighted in knowledge works, in order to solve the problem robustly and permanently (Kennedy, Harmon and Minnoch, 2008).

Systematic approach can help organizations to avoid "rubbish in-rubbish out" and make the captured solutions permanent. By having a continuous learning culture, reflection and standardization, people lift themselves above the world of present events, aiming at using the developed knowledge for other projects as well. Solving a specific problem with a specific solution, without generalizing that solution to be reused and without eliminating root cause of the problem cannot contribute to the organizational learning.

Standardization can make the knowledge usable in organizational level, so the whole organization can get benefit from a good change, an improvement, a solution by bringing the developed knowledge from the learning process into standards. (Alänge, 1994). Below figure 7 shows how learning cycle and standardization can work as the base of continuous learning and continuous improvement.

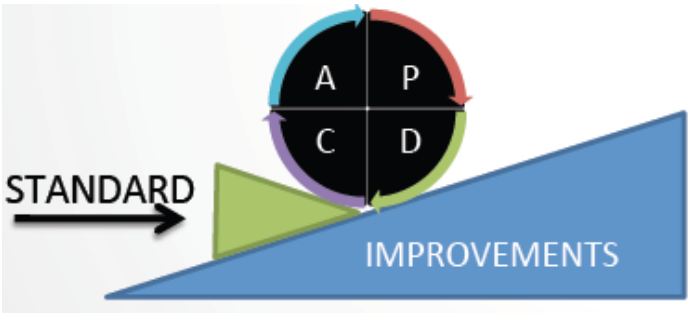

Figure 7: Standardization and continuous learning, as the base for continuous improvement (Bergman, 2003)

In a PD organization with ideal knowledge flow, valuable knowledge from current projects is systematically identified through reflection process and is made applicable for other projects through standardization. Updating Standards through a systematic knowledge capture in projects can assure that best practice is always applied (Swan and Furuhjelm, 2010); (Mian, 2008).

3.3.1.2. Lessons learned and post project learning

In order to capture the most important knowledge created in PD projects, Lessons Learned workshops can be seen as an extremely useful method. Reflection and reviewing critical events in a project is necessary to help the project team to discuss upon their own understanding of the project, and also to make the learned knowledge available for the entire organization, by capturing the learning in documents or by following other suitable methods to capture and share the knowledge. Lessons learned method helps transforming temporary knowledge into permanent knowledge that can be retrieved and reused in parallel projects and in future projects as well.

Post project reviews can also help organizations to update existed standards and processes accordingly. Post project learning aims at capturing key project experiences which can be used or improved in future projects. Sharing this evolved knowledge with others and recommending changes that would help other projects- future and current- can be considered as the main outcomes of Post project reviews (Schindler and Martin, 2003). However, post-project reviews considered as being of limited use as they failed to capture tacit knowledge and tended to become somewhat disconnected from the situations they are intended to support. There are problems in maintaining the dynamics of knowledge sharing in order to complete the Knowledge Management process for each project. When a project ends, team members leave for other projects, there are difficulties to recall experiences and lessons learned during the project and communicate them efficiently. Consequently, it is crucial that key experiences gained during a project be captured right after each milestone in process, not after termination of the project. (Swan and Furuhjelm, 2010); (Schindler and Martin, 2003); (Söderberg and Alfredson, 2009).

Focusing on learning from mistakes and finding root causes of a problem can improve the organization continuously and facilitate achieving a learning organization (Crossan, Lane and White, 1999). On the other hand, potential for learning can be found not only in things gone wrong, but also in successful projects and best practices as well. A PD organization has to capture the successful projects' knowledge and learning, and make it available throughout the whole company to be used.

3.3.1.3 Two Knowledge management strategies- codification and personalization

According to Hansen, Nohria and Tierney (1999), there are mainly two strategies for knowledge management: codification and personalization. Codification strategy refers to codifying and storing knowledge in database with a focus of reusing them. The personalization strategy is based on the assumption that knowledge is tied to the person so

the person-to-person contact is necessary for knowledge flow. In some companies, competence database is established to help employees find correct people to connect. Codification brings individual knowledge to organizational level by capturing knowledge in documentations and database as a consequence facilitating sharing between individuals (Magnusson, 2004). One of the main implications is that codification strategy is more suitable for managing explicit knowledge while personalization strategy is more suitable for managing tacit knowledge. However, tacit knowledge flow can be aided by codification that certain aspects of tacit knowledge can be converted into explicit knowledge, making it possible to articulate and capture (Goffin et al., 2010). Different mechanisms are identified for capturing and sharing explicit knowledge and tacit knowledge, as shown in below table 3. The adoption of personalization strategy often resulted in organization's efforts to build up access to experts, while adoption of codification strategy often leads to the efforts to build up access to codified expertise (Markus, 2001).

	Explicit knowledge	**Tacit knowledge**
Mechanisms for capturing and sharing	• Codification • Documentation • Databases and search engines Blogs, wikis, intranets	• Practice • Personal and team reflection • Drawing mental maps • Apprenticeships • Social interaction and mentoring • Story-telling and metaphors • Converting some elements of it into explicit knowledge

Table 3: Mechanisms for capturing and sharing explicit knowledge and tacit knowledge (Goffin et al., 2010)

3.3.2 Organizational structure and knowledge management structure

In Product Development organization, products and processes are developed in projects. A matrix structure, with permanent functions and temporary projects organization pulling out people and resources from different functions to deliver new product in project, is a typical way that PD organizations adopt to organize their activities. These multi-functional teams have to deliver projects' targets and develop their functional departments as well. (Bresnen et al., 2003). In the following, first four different types of organizational structure for organizing product development activities are introduced with their implication for managing knowledge. This is followed by description of three types of Knowledge Management structure connected to the different types of organizational structure. Finally, how knowledge management is organized in Lean PD in relation to organizational structure is illustrated for contrast.

3.3.2.1 Organizational structure in Product Development organization

The basic structure of the development organization includes the formal organization as well as responsibilities. These structural elements influence the nature of interactions across functions and consequently how knowledge is captured, shared and reused (Clark and Wheelright, 1992). There are four types of structures around which product development project activities can be organized. These four types stand in the continuum ranging from loosely linked set of vertical organizational functions to an independent and integrated team cut across the organization horizontally. Characteristics of these four types of structure are described from Clark and Wheelright (1992)'s book as below and shown in below table 4.

Functional team structure, in which the work is completed and coordinated in each function and over time the primary responsibility for the project passes from one function to the next. In functional structure, naturally the functions capture the prior experience to keep the depth of the knowledge within that function and apply knowledge over time and across projects. However, this structure brings problem that there is lack of systematic approach to achieve cross-functional working and smooth interactions across functions in order to deliver common and shared solutions in projects.

Lightweight team structure, in which "light weight project managers" who coordinate the work across different functions, facilitate moving the organization toward more cross-functional working. However, project managers called light-weight since they have little influence on the function organization since the key resources are under control in the respective functional managers. Basically lightweight structure has the same strength and weakness in managing knowledge as in functional structure. Nevertheless, due to the project managers, there is improved communication and coordination that people are kept aware of cross-functional issues and what is going on elsewhere in the project.

Heavyweight team structure, in which project manager takes full responsibility of the delivery of the project and the work of all those who are involved in the project. Project manager has rather heavy influence over function department with the same level as functional managers or sometimes outranks functional manager. Compared with lightweight team structure, heavyweight structure enables improved communication among the team members and different functions, higher focus on cross-functionality and integrated problem solving.

Autonomous team structure, in which team members are fully and formally assigned and dedicated to the project team, and the team is solely accountable for the final result of the project. The project manager has full control over the resources from different functional groups and very often has priority in selecting team members compared with other project structures. Such project team promotes cross-functional integration in the most effective way.

	Functional	Lightweight	Heavyweight	Autonomous
	Work is completed in the function and coordinated by functional managers	A coordinator works through liaison representatives but has little influence over the work	A strong leader exerts direct, integrating influence across all functions	Leader has full control over all resources, team members are fully assigned and dedicated to the project
Project leadership	Functional managers	Lightweight, Jr. Level project manager	Heavyweight, Sr. Level project manager	project manager has full control over the resources
Functional representation	Within functional group	Part time by liaison representative	Full time by team members	Full time by team members
Team leader organizational authority	Only within functional group	Coordination between functions only	Across groups, same level or outranks functional managers	has priority in selecting team members
Resources and task assignment control	Functional Managers	Functional managers	Team leader	Team leader
Team reports to...	Functional Managers	Functional managers	Team leader	Team leader
Physical location	In functional areas	In functional areas	Often co-located	co-located
Accountability for results	Functional managers, responsibility passes sequentially	Functional managers, responsibility passes sequentially	Team leader, dedicated core group	Team leader and the whole team

Table 4: Characteristics of four types of organizational structure in product development (Clark and Wheelright, 1992)

3.3.2.2 Three typical types of knowledge management structure

How knowledge management structure is in line with the organizational structure influences effectiveness and efficiency of knowledge dissemination and behavior. Three typical types of structure for knowledge management in PD are discussed as follows referred to Söderquist (2006)'s article:

KM as a central strategic function: A central KM function where a team of specialists are in charge of KM-related activities in all development projects (as shown in figure 8).

A Chief Knowledge Officer (CKO) is leading the KM function. A central unit as a KM supporting functions, provides an excellent overview of problems that projects are faced with, and enables capturing the best solutions that are applied in different projects. Capturing and aggregating solutions is one of the main strengths of this centralized KM structure, that can be fed in projects as Best Practices (Söderquist, 2006).

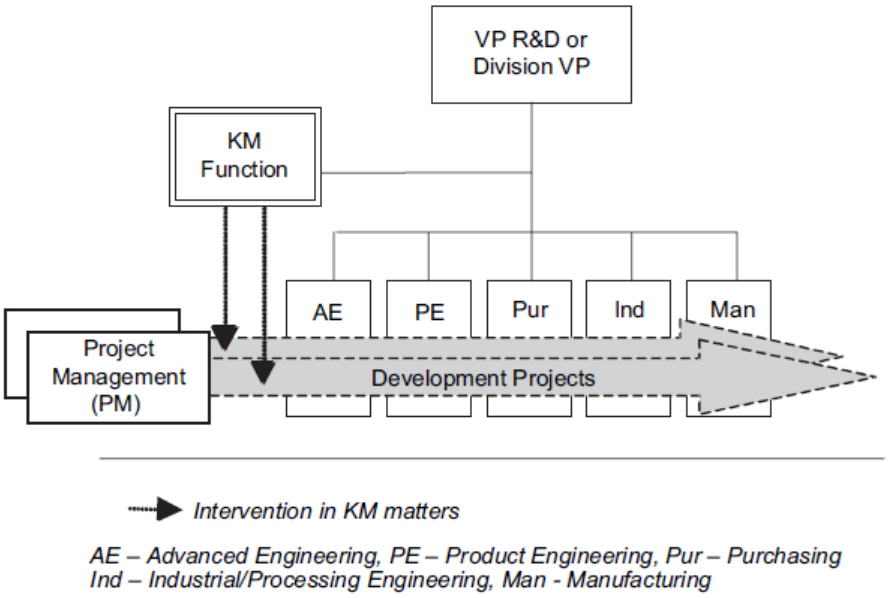

Figure 8: KM as a central strategic function (Söderquist, 2006)

KM as a decentralized task force: KM is internal to individual projects, where the responsibility for managing knowledge is internal to each development project. KM activities are followed on the project level, under the ultimate responsibility of the project manager; responsibilities included documenting, conducting lessons learned and post project reviews. Focusing on the operational needs of each project is the main advantages of this type of structure, in which KM activities are strongly oriented towards each project. The project-decentralized structure strongly supports transfer and sharing within a project, but lacks mechanisms and incentive that facilitate knowledge sharing to parallel and new projects (Söderquist, 2006).

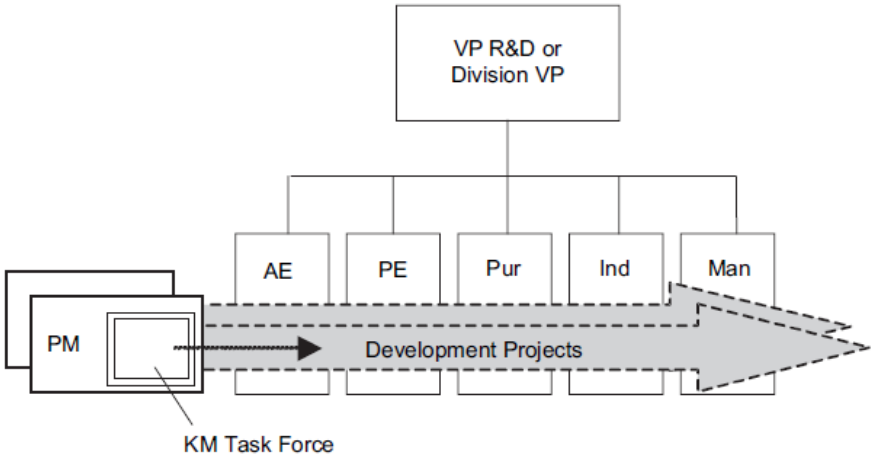

Figure 9: KM as a decentralized task force (Söderquist, 2006)

KM as specialized functional departments: The specialized functional area departments have the responsibility to manage KM works (as shown in figure 10). An individual or a small

team within the functional department is responsible for taking the useful related knowledge into the function as well as making the functional-specific knowledge available to the whole organization. These functional KM cells can facilitate the functional knowledge flow into the project if there is efficient interaction between functions and projects.

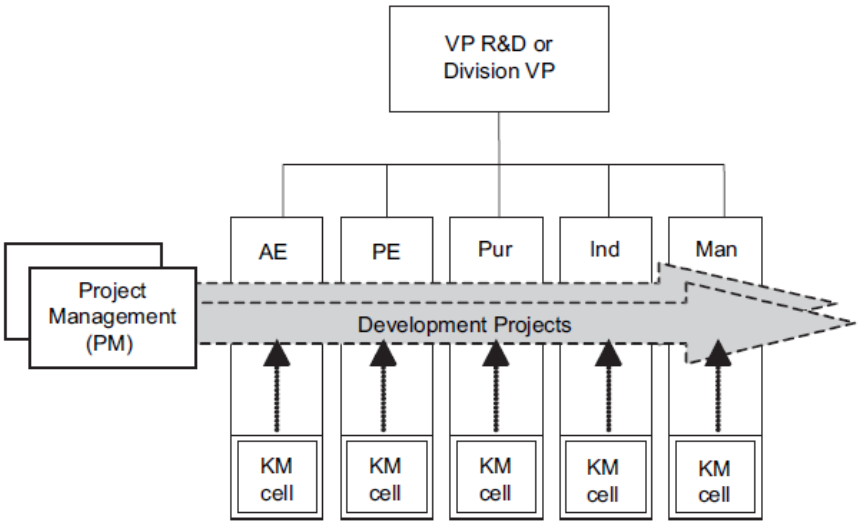

Figure 10: KM as specialized functional departments (Söderquist, 2006)

None of the discussed structures can be seen as an ideal one, for managing product development knowledge. There is no one best way of taking care of knowledge and always situational factors have to be considered, in order to achieve the best KM structure according to each specific organization. Comparison of the three mentioned structures is shown in table 5 below (Söderquist, 2006); (Ferrari and Toledo, 2004); (Bartezzaghi, Corso and Verganti, 1997); (Linder and Wald, 2010); (Morten, 1999).

Dimensions Analysed	KM Structure		
	Central KM Function	Project-Decentralised KM Task Force	Functionally Located KM Cells
Mission Clarity of KM Activities	• Clear responsibilities and clear guidelines for KM processes and actions. • Strong alignment between KM efforts and NPD strategy. • The KM imperative for effective NPD is well understood and people commit to KM processes and actions.	• Pragmatic perspective grounded in operational work and driven by the needs of each project. • Facilitates the understanding about what KM practices, tools and methods pay off "in the field". • Loose coupling of KM activities to R&D strategy. Vision and mission subordinated to those of each individual project.	• KM vision and mission subordinated to the priorities and politics of the specialised departments • Conflicting priorities for KM imposed by different functional managers
Positive Impact on Knowledge Transfer and Sharing	• Very good overview of project needs and individuals' knowledge. • Rapid transfer of knowledge between similar problem-solving activities, from team to team, from project to project.	• Structure strongly drives inter-functional knowledge sharing. • Highest potential for supporting transfer and sharing of tacit knowledge.	• Focus on state-of-the-art knowledge in deep fields of expertise. • Strong transfer within the product engineering function, i.e., transfer of engineering knowledge between product families.
Frictions Engendered in Knowledge Transfer and Sharing	• Loss of momentum in the knowledge sharing process due to lack of expertise of KM staff. • Post-project reviews risk remaining disconnected from the operational reality of projects. • Hierarchical distance between KM staff and project staff.	• Risk of project isolation, i.e., knowledge is not transferred well between projects, let alone between product families. • Lack of project portfolio overview.	• Poor incentives for inter-functional knowledge dissemination. • Poor coordination of different Knowledge Management efforts.

Table 5: Comparison of the three structures for KM in PD (Söderquist, 2006)

3.3.2.3 Structure and roles for knowledge and learning in Lean PD

In Lean PD, taking Toyota as example since Toyota does all pre-development in functional groups, project is only pulling knowledge from line organization to deliver product according

to customer needs. Due to the maturity level of pre-development, projects know what to deliver and how.

There is no central role for managing knowledge and learning. However, there is rather clear separation of roles for knowledge. Chief engineer, as the project leader, is responsible for the product value stream, while the line manager is responsible for generalizing captured knowledge; build up knowledge base in their functions for future use.(Swan and Furuhjelm, 2010); (Morgan and Liker, 2006); (Kennedy, Harmon and Minnoch, 2008). By setting up a PD process utilizing learning mechanism involving everyone, learning and continuous improvement is embedded in the normal daily work, which collectively formulates a "lean" learning culture (Morgan and Liker, 2006).

3.3.3. Cultural factors

3.3.3.1 Culture definition and its role in knowledge management

Culture has been identified by many researchers as a significant factor deciding effectiveness and efficiency of knowledge management initiatives, and efficiency of learning in organization (Eskerod and Skriver, 2007; Alavi, Kayworth and Leidner, 2005-6; Sabri, 2005; Park, Ribière and Schulte Jr, 2004; McDermott and O'Dell, 2001). The emphasis has transferred from technology which enables knowledge management to the values, norms and practices which shape the behaviors and make up a company's culture. Below figure 11 shows how culture impacts knowledge activities by shaping people's behavior.

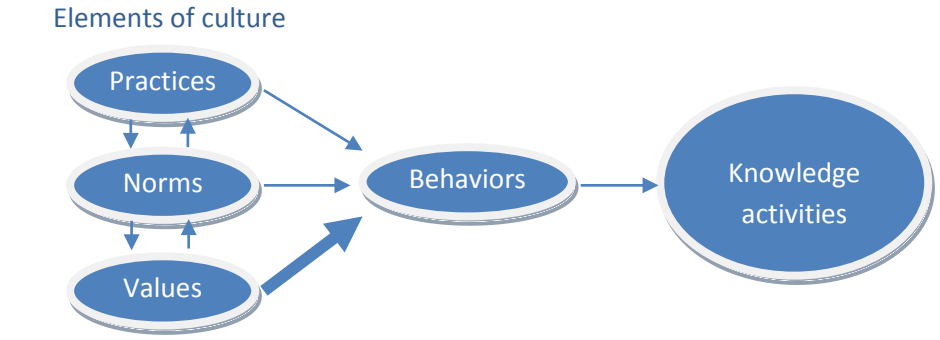

Figure 11: Culture Elements Influence Behaviors (De Long and Fahey, 2000)

Many researchers who investigate on the culture's role in knowledge management or organizational learning derive their view of culture from Schein (1992). He defines culture as "a pattern of basic assumptions-invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration-that has worked well enough to be considered valid and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems" (Schein, 1992, P.9). Further, Schein (1992) classifies organizational culture into three levels: artifacts,

espoused values and basic, underlying assumptions. Artifacts represent visible culture at the surface of the organization including things such as technology, visible behavior patterns, language, rituals, ceremony etc. Espoused value is embodies in articulated organizational value and strategy. It visibly identifies what is important for a certain culture group and is consciously aware by the members. Basic, underlying assumptions is the deepest level of culture, which is invisible and unconsciously rooted in people's beliefs, perception, thoughts and feelings which form how people behave in organization (Schein, 1992; McDermott and O'Dell, 2001). Among the three levels, however, the basic, underlying assumptions influence more than the other two levels on behavior (Schein, 1992). Different levels of culture are shown in cultural iceberg in figure 12:

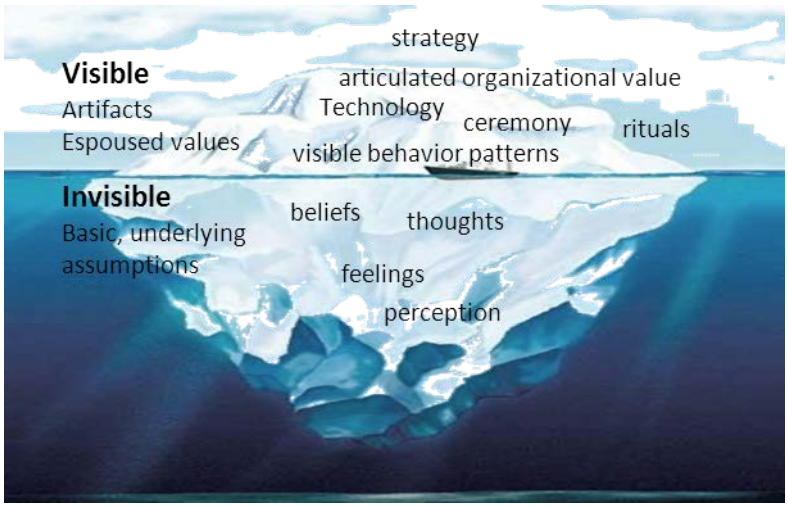

Figure 12: Cultural iceberg

Researchers research the role of culture in knowledge management in organizations departure from different conceptual dimensions and levels of culture.

Some researchers such as McDermott and O'Dell (2001) have drawn implications from Schein (1992)'s three levels of culture on knowledge management that the knowledge management initiatives will only be successful when they are in line with all these three levels of organizational culture, particularly the deepest level: basic, underlying assumption.

Rivera-Vazquez, Ortiz-Fournier and Flores (2009) describe macro level and micro level of culture. Macro level culture refers to more general level of culture which includes elements such as collectivism, femininity, future orientation. Culture at micro level refers to organizational culture. Company needs to combine these two levels of culture to create the environment which is more prone to knowledge production and sharing. At the same time, culture barriers at both levels need to be identified and overcome if the company wants to be effective in producing and sharing knowledge (Rivera-Vazquez, Ortiz-Fournier and Flores, 2009)

Another dimension of culture is national culture compared with organizational culture. From Hofstede (1980)'s view, the organizational culture is believed to be nested in national culture

(Rivera-Vazquez, Ortiz-Fournier and Flores, 2009). For Alvesson (2002), organizational culture is engraved by national culture, class culture and professional culture.

An important question in terms of level of organizational culture is whether researchers take integration or differentiation perspectives of organizational culture (Alavi, Kayworth and Leidner, 2005-6). According to Meyerson and Martin (1987), integration perspective looks at organizational culture as a collective values held by diverse group of organizational members. While differentiation perspective looks more realistically into the organizational culture that it is a mix of various local cultures and values. Under this perspective organization can be seen as collections of the subculture. This view is more realistic nowadays in big organizations considering their cross-culture operation (Alavi, Kayworth and Leidner, 2005-6). However, in this research, since it is only looking into the Product Development in Gothenburg, Sweden and taking into account that there is underlying dominant organizational culture and value embodied in organizational profile such as Volvo Way and Volvo's value, the authors take the integration perspective of organizational culture and blurred the geographical cultural influence.

3.3.3.2 Cultural factors critical to knowledge management practice

Dwelling on the above-mentioned research, several cultural factors from different levels have been identified to be decisive to facilitate or impede knowledge capture, sharing and reuse.

Trust

Davenport and Prusak (1998) state successful knowledge transfer happens only when the knowledge is transmitted, absorbed and used. While lack of trust of the source of knowledge is one of the major reasons that someone understand and absorb knowledge while not use it. He, Fang and Wei (2009) in their research look at the important role of "trust" in knowledge-seeking behaviors. Under the circumstance that knowledge capture and reuse is not happening directly between two people but mediated through system or mechanism, the trust issue is even more complicated. It goes beyond the interpersonal level of trust and stands at the generalized, collective level, which influences knowledge-seeking intention (He, Fang and Wei, 2009). Rather it is trust in the whole setting that knowledge captured will be useful for other people and projects, subsequently be useful for the whole organization. At the same time, it is critical that the knowledge source in need is trustworthy for knowledge seeker no matter who update it.

Holste and Fields (2010) look into the effect of below two forms of trust on tacit knowledge sharing and use:

1. affect-based trust, which is grounded in mutual care and concern between co-workers and value of the reciprocated relationship.
2. cognition-based trust, which is grounded in perception of co-workers' reliability and competence

And found both affect-based trust and cognition-based trust are positively related to tacit knowledge share and use. In addition, affect-based trust has greater influence on willingness to share while cognition-based trust plays greater role in encouraging using tacit knowledge. On the other hand, the trust that the knowledge shared and transferred will be used by others in an appropriate and professional way is necessary for the sharing and transfer to happen.

Incentive

The norms and practices determine to what extent employees will seek and build on the existing knowledge. The culture that values individual creativity more than leveraging on past experience discourage behavior of reusing knowledge (De Long and Fahey, 2000).

Davenport and Prusak (1998) see the Status and rewards go to knowledge owners as one of the major frictions of knowledge transferring and sharing. They propose the performance evaluation to include how people share knowledge and introduce incentives based on that. Menon and Pfeffer (2003) explain why often external knowledge is more preferred than internal knowledge that employees sometimes ignore internal knowledge to avoid the painful implications of comparison with the internal knowledge owner thus loose advantage in competition for reward, status and promotion to internal competitors.

Benbya (2010) further proposes consideration in incentives for promoting knowledge activities in below different dimensions:

- Individual vs. team-based incentives

Incentives reward individual performance on generating individual pieces of new knowledge lead to “hoarding knowledge” instead of sharing. People rewarded on the team-basis share knowledge the most.

- Contributors’ vs. Users’ incentives

Knowledge contribution and knowledge reusing are two distinct behaviors which are subject to different motivations. Organizations tend to reward knowledge producer and contributors rather than those who consume knowledge due to the cultural bias toward inventing new things.

Oosterwal (2010) describes “firefighting” as a universal and common syndrome in product development projects partly due to the preference of the project leader to fix things themselves. At project level, “firefighting” is justified due to the complex and competitive environment in which Product Development works in. At individual level, firefighting is considered as heroic behavior and is rewarded. Also, managers rather respond to problems when they become emergent and apparently important than preventing them (Clark and Wheelwright, 1992). Rewards shape how people behave by indicating tangibly what the organization values (Issa and Haddad, 2007). Hence at both levels, fixing problems at late phase rather than preventing problems are encouraged.

The other barrier for creating incentive of capturing knowledge is employee's reluctance to admit mistakes, which limit the possibility of capturing lessons learned from mistakes. Hence how mistakes are treated impact the behavior of leveraging knowledge (De Long and Fahey, 2000).

Motivation

Senge (1990) describes gives "shared vision" as the discipline for creating a learning organization, meaning building together a collective vision in a shared process. Little, Quintas and Ray (2002) relate Senge's five disciplines to knowledge management and interpret "building shared vision" in knowledge management as "moving personal knowledge into team knowledge and ultimately organizational knowledge".

Rivera-Vazquez, Ortiz-Fournier and Flores (2009) find "protection of own position and specialization" and "lack of sentiment that the knowledge that one possesses may be useful for other people in the organization" as cultural barriers of knowledge transfer.

De Long and Fahey (2000) describe how culture mediates the perceptions of relationship between individual knowledge and organizational knowledge. When the norms advocate and reinforce individual's ownership of knowledge, hoarding knowledge as a source of individual power is supported, as a consequence knowledge sharing is compromised or sacrificed.

Perception of value, time; concern about past, present and future; priority of task

Davenport and Prusak (1998) make a notion that "Knowledge is not much valued at all" in some companies. Though no company would admit it, it is represented in various situation listed below, in which some are articulated while others are underlying norms.

- Discourage reading and talking on working time (Davenport and Prusak, 1998)
- Promotes the results but not the sharing of knowledge (Rivera-Vazquez, Ortiz-Fournier and Flores, 2009)
- Only product is perceived as final deliverable of PD project

The value of what work is "real" work relates to the perception of time, which is regarded by Schein (1992) as an important part of organizational culture. Typically time in a project is perceived as scarce, limited and "project dependent" with a tight schedule (Eskerod and Skriver, 2007). Project members' focus is much concerned on not wasting time with a hard pressure to meet project deliverables. The importance of time is also highlighted in the classic triangles of project performance evaluation "quality, cost, time", when time is an important criteria for evaluating project and team's performance, it decides how team members prioritize work.

Following Schein (1992)'s claim that perception of the past, present and future shed light on the organizational culture, Eskerod and Skriver (2007) also found project members' perception of relationship between the past experience, the current task and the future needs of knowledge to be critical in people's behavior in using past experience for the

future. Since people are more focused on the current task, and the very near future, they do not consider it a high value to dwell on the past experience compared with the task on hand.

3.3.3.3 Organizational culture and knowledge management initiative

- To change culture for knowledge management initiative or adapt knowledge management to culture?

Alvesson (2002) mentions that culture can be used as a navigation aid in which the emphasis is on the deep values and basic assumption-the deepest level of culture claimed by Schein (1992). In the approach, it implies that the concern is more about enlightening the practical relevance by identifying what is difficult or impossible to accomplish in managing knowledge.

Researchers take different views on the relationship between culture/organizational culture and the knowledge management. Davenport and Prusak (1998) evaluate cultural differences, for instance Japan and America, to prove that methods of knowledge transfer should fit the national and organizational culture. McDerott and O'Dell (2001), after investigating best practice companies in knowledge management, conclude that the approach of knowledge management should be adapted to fit the exiting organizational culture. In particular, organization can find an existing core value in culture to tie the knowledge management initiative with. On the other hand, Eskerod and Skriver (2007) proposed possibility of working on the deepest level of culture – underlying assumption to improve knowledge transfer.

In Appendix III, a figure shows theories and framework the two researchers have read and considered, which are related to the research topic. The theory and framework outlined in this chapter "Theoretical framework" are chosen by the researchers due to their relevance to the main research question. The chosen theory and framework as well form the three sub research questions.

4. Empirical Data

This chapter presents findings from empirical data, which is collected mainly through two methods: 1) organization information in external and internal websites and databases 2) the semi-structured interviews.

First the organization where the thesis project is conducted is introduced. Then the empirical findings are presented beginning with an overview of how knowledge flows currently in the organization, with the focus of knowledge capture, knowledge share/transfer, knowledge reuse. This is followed by the detailed description of the three areas critical for knowledge flow, i.e., what methods and mechanisms are used, how organizational structure has impact on knowledge flow, what cultural factors are influential in knowledge flow.

4.1 The organization

Volvo Group Trucks Technology is a worldwide entity supporting the Group Trucks and Business Area's within the Volvo Group. Group Trucks Technology´s Scope of activities are:

- Global Product Planning
- Advanced Technology & Research
- Range & Project Management
- Complete Vehicle
- Powertrain Engineering
- Vehicle Engineering
- Purchasing

Product development is realized in PD (product development) projects, which forms a typical matrix organization. When there is a new project about new product, the project defines what to deliver and when to deliver. The line organization assigns resources and proposes technical solutions (budget and headcount) to the project. The project is finished and resolved when the new product is delivered. PD projects are supposed to follow a common process guideline (GDP) with indicated phases separated by gates with the purpose to execute projects in a structured manner. A detailed description of the structure of product development and product development projects are presented in section 4.3.2.

4.2 Overview of knowledge flow

In PD organizations, a lot of knowledge in different types is generated; the knowledge about product itself, the process of developing the product, and the knowledge about running the project. The organization is adept at creating knowledge and solving problems, while on the contrary not mature enough in capturing knowledge and reusing knowledge. A general statement from the interviewees is that the created knowledge is not channeled to where it

is needed and when it is needed. At the same time, knowledge is rather separated pieces than consolidated.

> Knowledge is within individuals.
> - One interviewee

There are several findings to support this general statement. First of all, most interviewees agree that very often knowledge remains in individual, for example, there are a lot of knowledge kept in personal computer or emails and stay there. Quite a lot of knowledge does not come to group level to form a collective knowledge. As interpreted by one interviewee "Volvo as a group knows, but it does not mean everyone knows". The interviewee exemplifies that too much focus is put on the knowledge about improvement in product, sometimes the common sense about how the product is operating is missing, which leads to major loop back in design work in the project. The common sense mentioned is often knowledge in experienced engineer which is not included in product design specification and not possessed by new engineers. For example, a truck should be able to mount snow plow (or something else) in the front, as a feature of the product. However it is not mentioned in the prerequisite for design. Experienced engineer know this so and it is taken for granted that everyone knows. What could happen is that young engineers don't necessary know and design mistake could happen, then corrected by experienced engineer at some point in the project resulting in big change in the late phase. Product knowledge is captured in different documentations and databases, however, there is a lack of knowledge pool with good documentation of the complete product knowledge.

> Volvo as a group knows, but it does not mean everyone knows.
> - One interviewee

The reason why knowledge stays at individual level varies with different individuals, but some overall identified reasons are:

- Not enough awareness that one has created some new knowledge since there is no efficient reference of existing knowledge;
- Not enough interest to share it with others or it is not prioritized;
- Not enough awareness or habit to put down knowledge in a specific context in a logical, reusable and traceable way. Consequently whoever gets hold of that knowledge is not able to know whether that knowledge can be applied to one's own situation;
- No dedicated people and well-defined process to consolidate knowledge;
- Difficult to capture and share experience (tacit knowledge), thus this kind of knowledge stays in the individual's mind and difficult to write down;
- High turnover rate with insufficient handover period deteriorates the situation because people leave their position before their knowledge and experience can be captured and stay in their positions.

The same phenomenon exists in the other direction of knowledge flow that is from collective knowledge to individual knowledge. In the organization, there is lack of a protocol of how to pull knowledge, such as: Where can I find the knowledge? In which database? Or Who can I talk to to get knowledge? When I find knowledge (for example in a database) how can I

apply? People have to learn this by working long time in the same position. The consequence is that even there is knowledge existing somewhere in a database, a white-book etc., individuals do not necessarily know where the knowledge is, and neither how to use it even when it is found.

The same notion as “knowledge is within individuals” is that knowledge stays very much in each project, not flowing to other projects efficiently in a systematic and structured way. Each project is rather a silo organization which focuses only on its own deliveries. Additionally, “there is a wall between projects and line organization” as one interviewee describes the interaction between projects and line organization. This notion is agreed by many interviewees in the way that they illustrate how “strong” the line organization is compared to projects. Specifically, the line organization owns all resources including budget and headcount. Project is only a temporary organization which transforms the resources assigned from the line into the deliveries. However, when it comes to where the knowledge is, different views appear about different knowledge. The knowledge about product, especially the technical knowledge, resides in line organization. Projects are consuming knowledge from line organization to deliver product. Nevertheless, some interviewees expressed that often projects are the ones which is in the front line of new technical knowledge while line organization is only maintaining existing activities. Compared with product knowledge, not much of other knowledge created in projects goes to line organization except in the form of white book.

Knowledge flow in terms of technical knowledge about product is in a better situation than project knowledge and process knowledge, partly because the technical knowledge is flowing between line organizations and projects naturally in engineering level where there is not clear separation between line and projects. Engineers develop their technical knowledge and expertise in their areas while delivering tasks in different projects, and then use that knowledge and expertise in following projects. They develop product knowledge by updating engineering specification and attending group meeting and discussion in their function groups. Nevertheless, since it is difficult to put down experience in document, muck of it stays in each engineer’s head. It has been identified that the most important thing to keep knowledge is to keep experienced people in their position so their knowledge will be available.

It is notable that knowledge flows rather efficiently among individuals by personal network, due to a good knowledge sharing culture in the organization. Almost all interviewees mention network as the most important channel for getting knowledge. A lot of interviewees mention “someone” to search and get knowledge from. “If I need some knowledge during the project, I might know someone who has run a similar project before, or had come across similar problem before, then I will talk to him/her how it was done and see what I can take/learn from it, or I will ask someone who might know someone else who has done it before”. The similar pattern exists for knowledge flow at the project level (between projects). Generally, there is no formal and structured communication and

exchange between projects. Rather, the communication and exchange are often arranged by those who happen to find similar projects and make people exchange knowledge. For instance project managers who are responsible for several small projects, called Intro Block CPM, can find similar problems in different projects and identify potential needed knowledge transfer across projects. In some positions people who have the same role involved in different projects have formal meetings to share what is happening in other projects considering their scope, but it is not the case in all the levels and is not mature enough in the whole organization.

In terms of tacit knowledge and explicit, when explained what kind of knowledge is tacit knowledge (for example experience of how to interpret data, how to do things), most interviewees believe there is not much awareness and focus on this kind of knowledge. The most common tacit knowledge- experience, how to do things- resides deeply in individual's head. At individual level, tacit knowledge is not documented. Tacit knowledge is lost quickly especially when the knowledge flows from individual to the group, or from one employee to another employee when the context is missing and only facts are left.

4.2.1 Knowledge capture

There is a lot of knowledge created in projects while not all created knowledge is captured. This is sometimes due to no-awareness that it is something new one has created, sometimes due to no incentive to capture it. Especially when employees don't know who will use it they don't feel motivated to write down what they learned. "So much knowledge is in inbox". For example, the decision making sometimes is conducted in emails back and forth within a group of people, when the decision is made, in very few cases that the reasoning behind the decision making is put down other than stays in the emails. Hence the knowledge cannot be considered in possible future applications. At the same time, individual's performance is evaluated by making deliveries and finishing tasks, capturing what one has learned and created is considered to be an extra task hence not prioritized. The competence of capturing knowledge is also an influential factor, for example people are at different levels of making good documentations.

At project level, knowledge is to a high extent captured only for the project. A well-recognized way of capturing knowledge in project is by writing white book log during project and a complete white book at the end of the project. Writing white book log by conducting workshop is regarded as a good way of learning and capturing what the team members have learned. Even though as mentioned by several interviewees, there are difficulties in capturing the discussions from the workshops. Moreover, the learning and knowledge are more used to build up each individual's experience. There is less knowledge spilled over to other projects. Project knowledge is encapsulated in white book and stays there. There is no clear path where and to whom the knowledge can be handed over.

Context of knowledge is not fully captured even at individual level. For example very often the concepts of product are chosen while the reason why to choose some concepts and why to reject other concepts are not well documented. “We not only don’t know why we choose some concepts, but also don’t know why we refuse some concepts”. Consequently, for the next project, people need to do the same process again for selecting concept. It is as well difficult to pick up the rejected concepts when the reasons for rejecting them are not valid any more.

Many interviewees mentioned that knowledge from the retiring people and those who change position is not captured, thus easily lost especially when there is very short handover time, which is a common case throughout the organization.

There are several barriers for people to capture knowledge in the organization: no time and budget. People don’t spend time on capturing knowledge since they are not paid to do so. They are paid to make design, do test, solve problems etc., but not capturing what they have learned.

Finally looking at the captured knowledge, it is not consolidated in a common platform where people can retrieve easily, which makes reusing knowledge difficult.

4.2.2 Knowledge share/transfer

There is a good knowledge sharing culture recognized in the organization. Most interviewees reflect that colleagues are open and ready to share their knowledge. However this openness to share does not mean they proactively share with others, but only when they get request for their knowledge. Thus the knowledge needs to be pulled when knowledge owner doesn’t initiate sharing knowledge. Knowledge sharing between projects occurs only on demand when project management team sees the necessity. Good sharing culture is actually only good “ready to share” culture in the organization.

Personal network plays an important role in knowledge sharing and transfer. People share knowledge mainly by informal ways such as talks, preferably with close colleagues. When people share with non-close colleagues, they tend to share only facts, without the context. Some interviewees claim that more face to face communication is needed when there is email culture in the organization that everything ends up in emails.

4.2.3 Knowledge reuse

At the individual level, many interviewees think there is no time to stop doing the task and search for knowledge, thus trying to reuse other’s knowledge is not preferred to doing it by themselves. The fact that captured knowledge is not consolidated, not easy to access, not easy to search brings difficulty for employees to retrieve knowledge. Due to this reason sometimes people just give up trying to find knowledge and spend time and effort in

recreating knowledge which already exists. On the other hand, sometimes it simply does not occur to some employees that there might be answers for their question somewhere in the organization. Not collocating in the same building creates a natural barrier for employees to communicate easily, resulting in less awareness of other's knowledge. Generally, reusing knowledge is not on focus in the organization. Firefighting syndrome deteriorates the situation by attracting organization's attention to solve problems when they arise instead of using existing knowledge to prevent problems from occurring.

There is no supportive culture for reading documents to get knowledge; consequently knowledge is reused more by informal ways. Since experience most resides in people's mind, the common way of reusing this kind of knowledge is by asking around colleagues or searching the potential knowledge owner through personal network. For example, in some occasions team members from one project invite the author of a white book of previous project to present the lessons learned to grasp the experience together with the factual knowledge documented in white book.

At the project level, it is not clear where the knowledge from projects ends with. There is no clear flow of knowledge from project to the line organization and/or to other projects. Rather projects try to reuse knowledge by looking for similar projects which recently finish or parallel running project and talk to people who were/are involved in those projects. A more structured way of reusing knowledge from previous projects is that each new project is supposed to read lessons learned in white books of relevant projects. However, the knowledge in white book is not consolidated and built on the knowledge of other projects (white-books), it is difficult to judge whether the knowledge contained in white-book is updated. Even white book itself is sometimes not accessible, it is difficult as well to know which white book contains the knowledge which is needed by a new project.

Network plays a critical role in reusing knowledge. Yet there is no good structure for employees to build up their network, especially for newly recruited employees. For example some project managers mention they get a lot of request from other department or functions who in his/her can answer a question because the knowledge seekers only know the project manager maybe from organizational chart. Knowledge flow is stuck or slowed when knowledge seekers do not have a network with those who can provide knowledge.

4.3 Three areas critical for managing knowledge and learning in Product Development

4.3.1 Methods and Mechanisms

White-book and Lessons learned:

Lessons learned workshops is actually linked into white-book writing process in the organization within PD area. This is why both concepts are discussed together in this section.

White-book is the main tool and the standard way of capturing the learning from projects, used in PD projects. A white-book is a documentation that is written and delivered after a project ends, sometimes through conducting lessons learned workshops after each gate in GDP, aiming at capturing learning that has achieved during the whole project life time. However, workshops are often only about two hours long. Furthermore, it is very much up to each project how to write a white-book, even there are specified headlines mentioned as a white-book template that has to be filled out, the quality of white-book tends to vary between projects.

In some projects especially in big projects, white-book log is written after each gate in product development process and different white-book logs in a project are considered as inputs for final white-book that is delivered in the end of the project. In big projects, time between two gates can be as long as several months or even one year. White-book log is a simple excel-sheet with some headings, aiming at capturing main learning in each phase, asking such questions as what has been wrong? What has been doing well? What has been learnt? to address highlighted learning and experiences from both positive and negative aspects. Ideally, in a few projects, meetings within the project team are organized to reflect on the project and the discussions could be used as a base for further improvements in next step of that project; part of the outcome of these meetings is documented in white-book log.

In smaller projects, project members sit together and do brainstorming and discuss main learning that has been gained. As mentioned before, the outcome of these discussions are documented in the white-book. However the discussions in these meetings are broader than what is fed into the white-book. Addressing issues to be more efficient in that project is discussed, but not captured in white-book. There is difficulty to capture and document the discussions, especially on soft aspects, such as why we did this, what is the context of the decision we made. As lessons learned workshops are supposed to be team reflection, due to low participation from team members (often engineers don't attend project team reflection workshop, they participate more in their group discussion in function group), sometimes a white-book survey is conducted to collect more detail inputs from project members. Then the result of the survey is a good start material for discussion in lessons learned meetings.

The activities during a project on writing a white-book are only focused internally to be as efficient as possible within that specific project; some actions that need to be done or be improved in next steps of the project are discussed. There is no enough attention and no structured way of bringing the knowledge into white-book in order to share and be used by other projects. Consequently, not much time spending on the packaging the document and the knowledge to be easy to access, understand and reuse. It is up to each project team how good they deliver their documents.

White-books are stored in a database, but actually sharing the white-book with other projects is not done in an efficient way. It is stated in the company standards (GDP) that finding related white-books and reviewing them need to be done in start of a project to

reuse the knowledge from previous and parallel projects, but practically, a lot of those who read white-books do not find it as beneficial as it is expected, considering time and effort they spend on. The problems can be related to the two stages of white books: the writing and delivering of the white book; the use of it in other projects. These two aspects are obviously strongly interdependent.

Difficulties:

1- Not enough time and budget to put on reflection and lessons learned meetings
2- Project focus as barrier to conduct lesson learned workshops and reflection
3- No time to spend on writing a white-book with high quality
4- In big projects, time between two phases is rather long, even if lessons learned workshop is conducted after each gate, since it is not documented properly, it is hard to remember details to feed into final white book.
5- Lack of motivation on reflection and writing a white-book as well, since the value of it in not seen clearly and also it is not clear who is/will be the customer (recipient) of it
6- Difficulties to capture discussions in the lessons learned workshops
7- No time to read white-book
8- Not easy to access white-book (due to confidentiality issue)
9- Not easy to find the right white-book; not searchable and not categorized according to project name, project type, project number etc.
10- Not easy to get the needed (right) knowledge in a white-book
11- Since white book is written at the end of project, knowledge captured might be outdated when people try to reuse
12- Concerns on validity of the knowledge
13- Not easy to reuse the knowledge found in a white-book due to not knowing whether the knowledge is applicable to new situation

Data bases:

There are several knowledge databases in use in Volvo that used in product development context, but like the white-books they are not providing the support for knowledge flow that is intended. In Volvo, each database is containing a type of knowledge; a database with focus on engineering knowledge (technical knowledge), a database with focus on project knowledge, etc. In a typical PD project, all the databases are used, by project members, considering different roles, but the efficiency of the databases varies in respect to different type of knowledge and different contexts. Different type of knowledge is created in projects and it is not clear enough how to take care of that knowledge, in terms of where to store, how to store, how to keep the knowledge in database updated, how to make it accessible to people who need that specific knowledge, etc.

In projects, there are team places as well where a lot of information is stored , including best practices and bad practices. A team-place is another tool that can be considered as a

knowledge container within that specific project. Nevertheless it is not easy to be found and understood by other projects. There is no clear protocol as who can have access to which team place. If someone is interested in a team place (for example, team place of another related project), he/she can ask those who are responsible for the team place for access. The Problems that make databases not working as satisfactory as they should be are:

1- Not easy to access
2- Not easy to find the right knowledge; not searchable
3- Not easy to apply the knowledge found in a database
4- Concerns on validity of the knowledge

Informal Communication (network):

Searching and finding the right knowledge in documents is not working well, and the concern on the validity and freshness of the knowledge in databases makes informal meetings and talking to each other more useful and efficient, since it is continuous knowledge transferring and sharing. Contacting people and invite the right person to discuss their learning is the main way of getting the knowledge. However, there is no structured way to find the right person and similar projects; it is done through personal network to set up informal meetings and discuss with others in order to get the needed knowledge. By searching name in the organization's intranet, employees can find other colleagues about their position and reporting hierarchy. However, the description of each individual is edited by themselves so there is no clear map who has which competence and experience.

Formal Meetings:

During project lifetime, there are many meetings in which people discuss problems and the progress of the project, to handle the short term tasks in that project. The focus of these meetings does not go beyond that specific project and all the meetings generally have benefits only within that project. According to interviews, when it comes to the long term development of functional knowledge, people from different projects but within the same function sometimes meet and try to share what is going on in different projects. The effectiveness and efficiency of these meetings varies considering the roles and the function. These meetings, for instance among all Project Assurance Managers, can support across project learning to a great extent, but the difficulty comes in when there is no protocol that secure these knowledge sharing happen regularly, among same roles who are involved in different projects.

4.3.2 Organizational structure and knowledge management structure

Product development organization has matrix structure. Line organization is permanent organization consisting of different functions and different commodity sections developing their own in-depth technical knowledge and excellence. Product is developed in projects, which are formalized temporarily according to each development project requirement and

utilizing resources and technical knowledge from line organization to achieve project target. The structure of matrix organization is shown in below figure 13. Projects are organized differently according to the size (which is basically how much budget the project is assigned), strategic importance, competence within the organization etc. However, generally projects are differentiated into big projects and small projects. Projects for important quality issues are called Red Card projects, taking priority in the organization over all other projects in terms of availability of resources and attention from the management team. The team leader holds full responsibility and control over the team, together with the team bearing full accountability for the result.

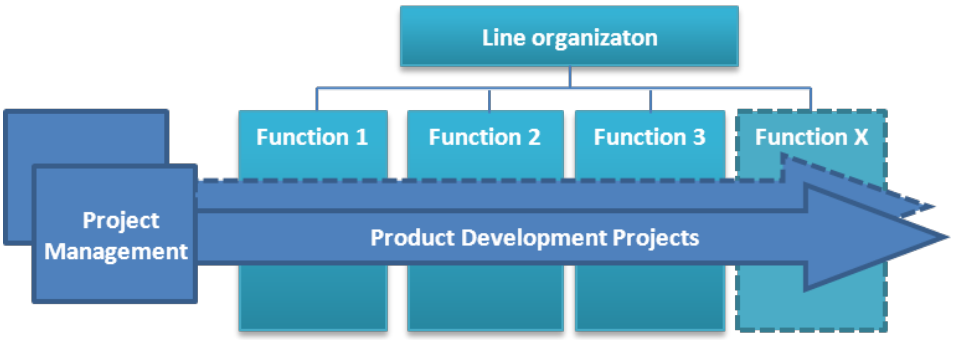

Figure 13: Matrix organization in Product Development

The organizational structure within Product Development project is outlined in below figure 14:

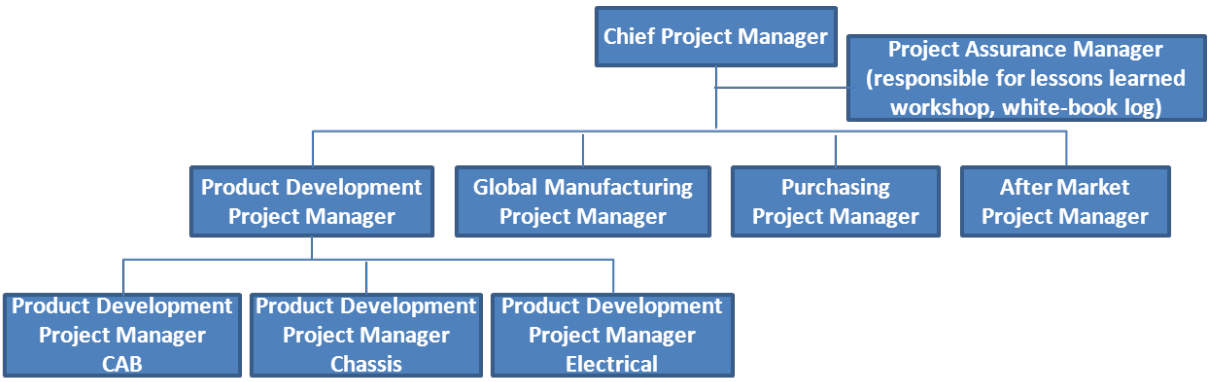

Figure 14: Organization structure within Product Development Project

A Chief Project Manager is assigned to big projects, as team leader, who is taking overall responsibility of the project with a core project team supporting the project activities. But at engineer level, it is common that engineers sit in their own function department and do task assigned to them. Chief Project Manager has less control on the resources (head count) assigned to the project than line managers. Different functions, such as Purchasing, Product Development, Manufacturing and so on, are involved in a development project. The mentioned functional project managers are the links between line organization in their

functions and projects in management level, who are responsible for how to run the projects in the best way considering their functions. At the same time, they are also supposed to bring the knowledge back to their function and make sure that the learning is shared within that function. While it is different in different projects whether each function representative is part time or full time involved in one project. Almost in all projects, the authority on resources is mainly owned by line managers. Within the project team, normally core group team report to the project team leader while people in engineer level report to their functional manager.

Technical solutions are owned by functions and are fed into PD projects. Accordingly the knowledge is developed both in projects and line organization. As mentioned by most of the interviewees, line owns the resources and the technical solutions (Who and How), but projects decide on What and When (Planning according to expected deliveries). Projects are very dependent on line in terms of solutions, resources etc.

There are several influential roles in project management level, in terms of knowledge works. Chief Project Managers (CPM) who are the main responsible role for the whole project including capture the learning developed in the project. In bigger projects, a specific role is assigned to the projects as called Project Assurance Mangers (PAM), who has a supporting role to CPM, to secure that the project deliver what is planned and expected. PAM works with Project Assurance Plan where it is specified which criteria a project needs to fulfill before opening a gate and secure that the project knows what to do in different gates to deliver expected results. Conducting lessons learned workshops and taking care of white-book is usually considered as part of PAMs' responsibilities that is delegated from the CPM of the project. According to interviews capturing knowledge from projects is realized very hard for them and sometimes it is lost in huge amount of other responsibilities. Even though there is a formal responsibility, it is still depending on the project manager and the members of the project if lessons learned meetings is conducted, with how much effort and time, and with what level of quality. Responsibility of knowledge works falls into project managers when it comes to smaller projects, since there is no project assurance manager assigned in such projects.

Line organization seems to be stronger than project organization and steer the projects, and the knowledge developed in projects is not utilized in a structured way. According to interviews, line managers are not involved enough in projects and their involvement is based on project demand. It is mostly up to each project what to do with their learning and how to make sure that the learning is transferred to the rest of the organization. Systematic communication across projects and between projects and line organization can be improved to a great extent. There is no demand on projects from line in terms of knowledge and learning. It is up to each PM to feel a need to capture the knowledge. What knowledge to capture, how to capture, share the knowledge and to whom is up to each individual as well. Interactions and connection between projects and line are weak, so it is not clear enough for the project managers to whom they should hand over the developed knowledge. The

impression is that there is no dedicated and structured way to take care of knowledge, which is gained during project life time.

Not strong connection between projects and line organization causes some gaps between process managers' perspectives on the projects, and how the projects are actually run. For instance, processes that are supposed to be applied in the projects do not necessarily connect to how the project works in reality. As mentioned by several interviewees, if process managers want to have the knowledge how to use the process in a best way, then they should be more involved and interested in projects, instead of only considering the outcome of the processes. Process managers should involve, support and should look forward the feedbacks from projects in order to improve the processes and make sure that the processes are updated.

4.3.3 Culture factors

There is general agreement that the organization is good at creating knowledge and solving problem. However, capturing knowledge and what people have learned in project is not in focus in the daily work, neither is reusing knowledge that already exists. Also, people often see capturing knowledge as extra work. Employees normally don't find time to capture knowledge or to search for knowledge for reuse. Especially when the captured knowledge is not for their own future use and they don't know who would use the knowledge and benefit from using it, it is difficult to be motived to create something which they don't see the direct customers for that knowledge. Firefighting culture is strong especially in manufacturing department and in the late phase of PD project. Firefighters are considered somehow as heroes who save the project and are rewarded by prestige.

There is a good knowledge sharing culture in the whole organization. "Knowledge is power" is not a general phenomenon except in some expert positions. People generally are willing to share their knowledge. On the other hand, people only share when they get request from their colleagues, which means they don't proactively share what they have learned. One reason is that very often they don't know whether they have created some new knowledge and don't know who can benefit from it.

When asked about how employees get knowledge, most employees claim that they mostly get knowledge from their network while less inclined to search knowledge in databases and read documentations. This approach is reinforced by the good knowledge sharing culture mentioned before. As long as one can find the correct person to talk to, one can get a lot of knowledge.

An interesting factor arouse from the interview is that that there is "no blame" culture in the organization, which is supposed to bring positive effect for learning. However, "no blame" culture results in not learning from mistake, for example, some white book is classified because the project is a failure and there is concern that if the white book is open there

could be finger-pointing to the people involved in that project. Several interviewees mention that there is lack of atmosphere in the organization that it is ok to make mistakes so that mistakes can be lifted up and discussed hence people can learn from it. Only speaking about good things is very common in the organization.

Team members do not necessarily relate their own work to the complete product (truck) that sells in the market. It is not rare to hear “we VS. they” between different functions or different departments (commodities). The value that the projects deliver is considered to be the developed product, not the knowledge about product. Employees’ performance is evaluated mainly by whether they deliver their task, which does not include how much they learn. The project performance is evaluated in two dimensions. Firstly in the short term, project is evaluated by how it achieves QDCF (Quality, Delivery, Cost and Feature). Secondly in comparative long term, it is evaluated how well the project sells in the market. A good selling product which brings high profit can cover some failure of the project such as over budget. Though the “continuous improvement” is one of the cornerstones of “Volvo Way”, it is difficult to see how it is lived by each employee in the daily work.

5. Analysis and Discussion

In this chapter, the empirical data and theoretical framework are compared and evaluated against each other to find the critical themes for improving efficiency of knowledge flow. Six critical themes are identified and analyzed with consideration of the three areas (methods and mechanisms, organizational structure, cultural factors) and related issues. Therefore this chapter is structured around the identified themes, with the three areas and related issues discussed interwoven in each theme. Due to the importance of cultural factors in shaping individual and organization's behavior, it is analyzed more in detail in a separate section as a standing alone theme. The analysis's purpose is to provide an understanding of potential improvements on knowledge capture, share and re-use in Product Development projects, which serves as foundation of the next chapter: Conclusion and Recommendation.

5.1 Focus on Knowledge Value Stream towards collective knowledge

The primary objective of knowledge flow, is to "enable the transfer of capability and expertise from where it resides to where it is needed-across time, space and organizations as necessary", pointing to the process of upgrading individual knowledge to organizational knowledge (Nissen, 2002). As mentioned by Ward (2007), a project should have two deliveries: the product and useable knowledge. Knowledge value stream, promoted in Lean PD concept, requires both efficient sharing of individual knowledge and integrating fragment of knowledge. In this sense, building up knowledge value stream aims at upgrading knowledge from individual level to organizational level as well. It is by capturing, integrating and sharing individual knowledge that individual's knowledge generalizes to organizational knowledge (Grant, 1996); (Spender, 1996); (Gold, Malhotra and Segars, 2001). The other way around, it is by reusing organizational knowledge that organizational knowledge helps individual make decision and solve problem (Mentzas et al, 2001).

Collective knowledge is built up by three ways: sharing individual knowledge throughout the organization; integrating individual knowledge; develop knowledge in groups and socially construct knowledge (Grant, 1996); (Spender, 1996); (Gold, Malhotra and Segars, 2001). As shown in empirical data, knowledge mostly resides in individuals and there is lack of a collective knowledge in the organization. The reason can be analyzed from the above-mentioned three ways of building up collective knowledge. First of all, it seems from the empirical data that people are sharing knowledge frequently thanks to a good sharing culture. However, people don't initiate sharing while mostly they share when they get request for knowledge. At the same time, there is lack of supportive structure to facilitate building up network with people from different levels and different functions. It can be concluded then knowledge sharing can be improved by connecting potential knowledge owner and knowledge users across different levels and functions. Secondly, empirical data shows that knowledge about a subject is kept within different individuals, in different parts

or different databases in the organization. There is no dedicated people or process to integrate segmented knowledge. Thirdly, several interviewees mention that in the organization there is lack of mechanism through which people can build up knowledge by a common ways of doing things, especially across-functionally.

High focus on delivering products, without enough attention to learning in Product Development projects, hurts knowledge capture and reuse. As it has been viewed in the organization, performance measurement of individuals and projects is only on delivering what has been planned. This lack of attention to knowledge value stream does not support knowledge flow in the organization. As mentioned by several interviewees, people do what they are measured on, and currently developing learning and making useable knowledge available to the organization is not part of the evaluation. Management role is so influential to create the appropriate mindset in the organization from learning perspective and to bring awareness and interest on knowledge value stream. Considering long term perspective on the organization performance, emphasis on developing collective knowledge is as important as the delivery of the products.

5.2 Reflection and Standardization

5.2.1 More frequent reflection during life time of a project

Reflection is a base for continuous Learning from best practices as well as learning from mistakes. Most of the literatures have discussed that the lessons learned from every development project have to be captured, in order to be reused in future product development projects. However, transferring the developed knowledge from a project into ongoing projects should be considered as crucial as using the knowledge in future projects.

This lack of focus on capturing, sharing and reusing knowledge across running projects is one of the main reasons that the projects postpone reflection to the very end phase of the project hoping that the captured knowledge will be reused in future projects, instead of having a continuous reflection and sharing mechanism throughout the project life time. A side effect of not having enough attention on parallel projects is creating unnecessary and not reusable documents, mistakenly justified by saying that it will be reused in a project in future.

As discussed in empirical data, the developed knowledge in projects is not captured efficiently during life time of a project, because there is not enough focus and time to spend on reflection during the project. A few reflection sessions conducted during some projects are designed to only give benefits to that specific project and probably provide some inputs into final white-book that is delivered after the project ends. Consequently, even if the knowledge is captured, it remains within that specific project and not being available and useable to other projects. The current knowledge management structure in the projects-

decentralized KM structure- dose not promote across projects knowledge flow either, which could discussed further in section 5.5.

5.2.2 Reflection on facts

What to reflect on? If it is not clear on what we should reflect, it will be too easy to neglect conducting reflection meetings. As pointed out by several interviewees, discussions on lessons learned workshops is hard to be captured and usually people leave the meeting, thinking whether the meeting was useful and what they have got from the meeting to bring with themselves. There are several reasons that can hurt the efficiency of reflection activities, and can make people unmotivated to do reflection. Reflection has to be on facts and historical data. Only by this way, we can secure that reflection meetings are value adding. Since there is no frequent reflection during the project, people forget what actually happened in the project. Therefore, when there is no data and facts available, reflections can only be based on people's impressions and feelings that is not accurate, not easy to be captured and consequently not easy to be used for improvements. As it is been said: "You cannot improve it, if you can't measure it" .

5.2.3 Standardization

As stated by Bergman and Klefsjö (2003) a learning that leads to an improvement should be made permanent and reusable to the whole organization. As seen from the empirical data, there is currently no structured way/process for making these improvements within the functional organization. It highly depends on individual initiatives to make a change requests and how much time and effort he/she put on to follow-up the proposal. According to the interviews, processes are applied in projects, and people involved in projects have a good insight on how the processes is actually be used in projects and what are the gaps between the defined process and what is followed practically. However, projects do not have the authority to improve the processes when a beneficial change is identified, and it is not either within the scope of project organization to update process according to the potential improvement.

Identified improvements should not only be applied in that specific project, but give influence on functional organization and related processes. A rapid and constructive feedback from the projects to process managers/owners is what is currently not functioning well in the organization. Even though GDP states that recommendations for changes should be presented in the white book, but since improving process is something out of the projects scope, there is no guarantee that these type of recommendations are mentioned in white-books. Furthermore, there is no well-defined process for handling these recommendations to update processes and make sure that the whole organization gets benefit from it.

5.3 Knowledge Pull for continuous knowledge flow

The projects have found it difficult to find out who are the potential users of the developed knowledge and to find out which team/project has interests on that knowledge. Consequently, it is not clear for the source of the knowledge what to capture, in which style and context, because the recipients of knowledge is unknown. As described both in theory and empirical data, there is no motivation to capture/document knowledge that no one use. Without having an efficient pull system, the company suffers from recreating the knowledge that is already generated and even captured in a project, but stays within that specific project and not shared or used to update process.

Due to having many projects running at the same time and so many people involved in projects, specifically for big companies like Volvo, it is challenging for projects to find the knowledge they need at the right time, as well as the potential recipients of the knowledge they create. By having knowledge pull system, communications and learning across projects becomes smoother. Individuals/teams involved in KM works should have a good overview on PD projects, to enable effective knowledge transfer between projects and achieving an efficient knowledge pull that is needed. It will be further discussed in the section 5 how a knowledge management structure can be supportive of knowledge pull.

5.4 Personalization and codification strategy: complementary and supportive each other

As outlined in theory, there are mainly two strategy of managing knowledge: codification and personalization (Hansen, Nohria and Tierne, 1999). Codification strategy is more suitable for managing explicit knowledge while personalization is more suitable for managing tacit knowledge (Goffin et al, 2010). In the organization, both strategies are applied for capturing, sharing and reusing knowledge. However, empirical data shows there is different inclination in using different strategy. The difference exists both in different levels (organization level and individual level) and for different types of knowledge (tacit knowledge and explicit knowledge).

Codification Strategy

As empirical data shows, in the organization various documentations are used to document different learning and knowledge. Technical knowledge about product such as test report and simulation report are readily codified knowledge which is stored in databases. Knowledge and learning created in different phases in project such as from concept selection, problem solving involves both tacit knowledge and explicit knowledge. Nevertheless, there is no distinction in the organization between how tacit knowledge and explicit knowledge should be captured. Every employee decides how to capture and codify

knowledge though there is sometimes a basic template for guidance, for example what sections to include in white book.

It is the organization's consciousness to capture them in the codified manner. The requirement that white book should be read at the beginning of the project in order to reuse knowledge from previous projects and the requirement that white-book should be written for each project in order to capture knowledge in the project reflect organization's intension of utilizing codification strategy for managing knowledge and learning. Nevertheless, there are various problem and barriers in using this strategy. At the individual level, employees are not clear how the knowledge should be captured, for example to which extent of detail they should write and how much personal experience they should put down. Moreover, employees don't invest sufficient effort and time in capturing and consolidating knowledge.

As discussed in empirical data, there is not enough time spent on producing a high quality white-book. This relates to two issues. Firstly, working on knowledge is not perceived real value of work. Secondly, employees don't find it worthwhile to write down what they learned if they don't know the knowledge they capture will be reused. Neither do they know what detail they should capture without a potential customer of the knowledge in mind. There is less trust in the knowledge capture-reuse circle by codification strategy. Even if they are required to do so, they tend to capture explicit knowledge which is only facts without context. Knowledge is decontextualized when employees find it difficult to capture tacit knowledge especially when it is unknown to whom the knowledge is targeted. Outcome of discussions and decision making result are more important in order to continue delivering tasks, reflecting as well organization's less attention to tacit knowledge in codification strategy. The contexts of knowledge, experience, reasoning of decision making are seldom codified.

Empirical data reveals that codifications strategy is often only for purpose of codifying the knowledge, not with the final aim of applying it. Integrating individual knowledge to organizational level is the key for individual to draw on organization knowledge for application (Grant, 1996); (Mentzas et al., 2001). Combination, the process of reconfiguration existing explicit knowledge is the way to achieve this integration (Nonaka and Takeuchi, 1995). When the knowledge is codified in fragment instead of consolidated by combination, there is less possibility that employees can find and reuse them. Consequently, when trying to reuse knowledge, employees don't find database and documentation to be useful enough when they need knowledge. Knowledge in documentation and database is not searchable according to different themes, even not often accessible. Even if they find the knowledge, since it is probably already several years old and sometimes captures too little context it is difficult to judge whether it can be applied to the knowledge seeker's situation. A vicious circle evolved that less and less knowledge is captured, shared and reused by codification strategy.

Personalization Strategy

The interview results show that there is a desire from individuals to access the knowledge that has been documented, but they have a hard time doing so. This relates both to how the documents are stored, which makes them hard to search, and to what is documented and in what way they are documented, making it hard to apply knowledge from the documentations. What is observed from empirical data is that at individual level, employees are more inclined to use personalization strategy for sharing knowledge and retrieving knowledge for reusing. When they feel they need knowledge, they try to ask around close colleagues, if not successful then extend to other colleagues by using network. This process may take some detour but proven to be efficient as long as the knowledge seeker find the right person to talk to.

Employees find personalization strategy particularly useful since when they communicate directly, they have better understanding of each other's ability of digesting the knowledge they are sharing, which results in a better effect of sharing and reusing knowledge. Especially in the case tacit knowledge is in need, spontaneous socialization, i.e. sharing of tacit knowledge between individuals, happens rather frequently within close colleagues. Socialization requires adequate design of space, time and mechanism, such as apprentice system or planned on job training (Nonaka and Takeuchi, 1995); (Curado and Bontis, 2011). However, there is no supportive foundation to facilitate this process in the organization. It is done by talks between colleagues in reality.

Using network has been identified as the most important way to get information and knowledge especially for getting tacit knowledge such as experience, how to do things and explanation around explicit knowledge. There is more trust between employees when the knowledge flows face to face, which makes people feeling more comfortable with knowledge they get by personal communication than by reading documents. However, this means that efficiency of knowledge flow is heavily dependent on several factors. First of all, people need to be available to provide knowledge when the knowledge is needed. It has been identified that knowledge flow is compromised often because people are away for business trip, holiday or just too busy with other tasks, thus cannot provide knowledge in a timely manner. Secondly, people need to build up network with colleagues in different levels and functions so that they are aware of others knowledge. Yet there is no systematic way helping people building their network. It is mainly developed by long period working in the organization, which left newly employed people less advantaged in using others' knowledge. "Reinventing wheels" happens sometimes just because people don't know whom to ask. Thirdly, the problem of high turnover rate needs to be addressed so that team is stable enough for network to function. Unexpected turnover without enough handover time has caused loss of knowledge in the position where the successors have to recreate knowledge again. People lose the track of team members' competence when the turnover happens frequently in the same project team.

As can be seen from above-mentioned analysis, the mismatch in different inclinations for the two strategies in organizational level and individual level is caused to a large extent by the barriers and difficulty that employees encounter when they try to managing knowledge in codification manner, both in capturing knowledge and reusing knowledge, as well as the perception that it is difficult to manage tacit knowledge in codification strategy. When there is barrier and difficult in one approach and the other approach works, it is natural to resort to the easier and quicker approach. However, if the codification approach can be improved, whether personalization approach should be strengthened further entails more discussion.

Two strategies support and complement each other

As suggested by Goffin et al (2010), tacit knowledge flow can be aided by codification. The example that one project invites authors of white book of related previous projects to present lessons learned in white book and discuss together is a good way in the organization to combine personalization strategy and codification. It also helps team members to get in touch with people who were involved in other projects, hence extend their network for future.

Codification and personalization strategy is not mutually exclusive, on the contrary they can support and complement each other. Personalization can help capture and reuse tacit knowledge which is difficult to manage by codification. By capturing knowledge in documentation and database, codification strategy provides the platform and basis for knowledge sharing, enabling both reusing tacit and explicit knowledge. The implication is not centered on whether organization should promote codification strategy or personalization, but how the barriers and difficulty in both strategies can be addressed so that the balance between these two strategies can be reached for the maximum knowledge flow efficiency.

For codification strategy to be more effective and efficient for knowledge flow, the trust needs to be built that the knowledge employee captures will be reused. This trust is established by making knowledge accessible, searchable, updated and consolidated, capturing more context, resulting in a better knowledge database. Knowledge needs to be abstracted from fragment in documentation. For example, there should be dedicated people to read white-book in different themes and integrate the knowledge in each theme. A clear protocol for documenting knowledge is necessary. For example, when writing a document, writer can go through the following checklist:

- For whom am I writing the document?
- In which form should it be?
- How much detail should I write?
- How much context and my own experience should I write? Or should I only write hard facts? If I write down my experience, would that be misleading in readers' new situation?
- What can readers do on reading the document?

Using the last question to rethink the previous questions helps writer create documents in a user-friendly way.

For personalization to be more efficient, organization needs to help employees build up network and create environment for informal knowledge flow. There needs to be easy way to know who possibly has the knowledge one seeks. An initiative to codify network is to build up competence map and publish every employee's specialty. However codifying competence is only the first step which makes network and competence visible. A robust personalization strategy entails personal interaction so that people are comfortable enough and interested in contacting others proactively for knowledge. When barriers in both strategies are addressed, organization can connect codification and personalization in a more efficient way.

Affect-based trust, which is grounded in mutual care and concern between co-workers, has great influence on willingness to share tacit knowledge. Cognition-based trust, which is grounded in perception of co-workers' reliability and competence, is influential in encourage people to use tacit knowledge (Holste and Fields, 2010). It is evident from empirical data that when people share knowledge with non-close colleagues they tend to share only facts with less context and their own experience. It is implied then that to help employee increase affect-based trust, for example by creating opportunities for informal communication, will improve the sharing of tacit knowledge. While keeping employee aware of each other's competence is beneficial for tacit knowledge to be reused because it boosts cognition-based trust. As a prerequisite for achieving this, awareness of others' tacit knowledge can realized by using codification to convert tacit knowledge into explicit form and relate it to its knowledge source then make it visible in the organization is critical for keeping tacit knowledge alive and accessible in the organizational level. This could shorten the time of seeking who might have the tacit knowledge in need than by only asking around colleagues. In this way, combined strategy of personalization and codification strategy could be facilitated.

Practically, which strategy to use is as well related to whether the knowledge is for reusing in parallel running projects or for future projects. As explained previously, since each project is taking care of knowledge mainly only for the project itself, there is less in-time spillover of knowledge in codified manner to the simultaneously running projects. Consequently, in order for the knowledge created in one project to flow to other projects more quickly, personalization strategy needs to be strengthened. Smooth communication on what is going on and who is doing what in current projects keep people updated what they can learn from each other.

5.5 Knowledge flow across projects and knowledge flow between line organization and project organization, considering organizational structure in PD

Knowledge Management structure and KM responsibilities cannot be considered independently from how the overall structure of the organization is. As discussed by Clark and Wheelwright (1992), these structural elements influence the nature of interactions across functions, across projects and between line and project organization, the intensity of completeness of communication, and consequently how knowledge is captured, shared and reused.

As described in empirical data, product development organization has a matrix structure. Line organization is permanent organization consisting of different functions and different commodity sections developing their own in-depth technical knowledge and excellence. In this sense, product development is organized with its basic systems, skills, practices and mechanisms being functional. On the other hand, product is developed in projects, which are formalized temporarily according to each development project requirement, utilizing resources and technical knowledge from line organization to achieve project target. According to empirical data about how projects are organized, the characteristics are highlighted in the table 6 below that shows the organization has some elements from lightweight structure and some elements from heavyweight structure.

	Functional	Lightweight	Heavyweight	Autonomous
	Work is completed in the function and coordinated by functional managers	A coordinator works through liaison representatives but has little influence over the work	A strong leader exerts direct, integrating influence across all functions	Leader has full control over all resources, team members are fully assigned and dedicated to the project
Project leadership	Functional managers	Lightweight, Jr. Level project manager	Heavyweight, Sr. Level project manager	project manager has full control over the resources
Functional representation	Within functional group	Part time by liaison representative	Full time by team members	Full time by team members
Team leader organizational authority	Only within functional group	Coordination between functions only	Across groups, same level or outranks functional managers	has priority in selecting team members
Resources and task assignment control	Functional Managers	Functional managers	Team leader	Team leader
Team reports to...	Functional Managers	Functional managers	Team leader	Team leader
Physical location	In functional areas	In functional areas	Often co-located	co-located
Accountability for results	Functional managers, responsibility passes sequentially	Functional managers, responsibility passes sequentially	Team leader, dedicated core group	Team leader and the whole team

Table 6: Highlighted characteristics of organizational structure in product development (based on Clark and Wheelright, 1992)

Considering the three typical KM structures, discussed in chapter of Theoretical Framework, heavyweight organizational structure is more supportive to de-centralized KM structure, in a way that project managers who are overall responsible for the project including knowledge works have the authority and focus on capturing knowledge in projects and share it with other projects and respective functions. Functional and Light weight organizational structure is more supportive to functional KM structure, when knowledge resides and is developed in line organization. As described in empirical data, most PD projects are organized in the matrix structure that strides between light weight structure and heavy weight structure. Further the organization has not explicitly defined its KM structure. KM is partly decentralized, where the responsibility for managing knowledge is internal to each development project. Due to being more light-weight in overall structure in product development, there are difficulties to get benefits from the developed knowledge in projects, since KM activities are followed on the project level.

In the organization, KM of PD projects is under the ultimate responsibility of the project manager, which is delegated to PAMs in bigger projects, keeping KM initiatives focused on the operational needs of each project. Even so, it is not mature decentralized KM structure since KM works easily go under many other tasks and is not prioritized. There is no evaluation how well KM activity is conducted and what benefit is achieved from KM activity. Even though it is articulated as a part of tasks for PAMs and CPM, apart from finishing the tasks (for example writing white book), it is not guaranteed good knowledge flow results from those KM activities.

KM structure in functions in line organization is vague. Even though, in engineering level the influential roles in KM works such as PD PMs, are naturally involved in projects and functional works but there is no clear KM structure and responsibilities clarified and stated. The organization has got partly benefits of decentralized KM structure when it comes to project knowledge and benefits of functional KM structure when it comes to engineering knowledge. As discussed, not clear definition of responsibilities in KM decrease the efficiency of interaction between projects and line to a great extent. In line organization there is no clear and structured knowledge ownership and in projects there is no protocol on what to capture and why, as well as to whom knowledge is delivered. This makes both functional knowledge flow into the projects and project knowledge flow into functions not smooth. Consequently, people involved in projects may not be even aware that the knowledge they need is already somewhere in the organization; If they are aware in the best case, they need to look for someone who has the knowledge they need, starting from their close contacts to find the right person/team. However, very few persons/teams put time and effort to find a team who are interested in the knowledge they developed.

According to interviews, project managers explained it could be difficult in practice to put thoughts and efforts for packaging and sending the developed knowledge to other projects. As it is mentioned, the project-decentralized KM structure cannot provide an overview of the firm's portfolio of projects and the potential needs and opportunities of inter-project knowledge transfer (Söderquist, 2006). However, as mentioned in empirical data, an exception is that CPMs who are responsible for a group of projects can have a good overview on which projects can communicate to get knowledge from each other.

This is the biggest frictions in knowledge capture that also comes from the unclear structure which cannot support capturing right knowledge and transferring it to the right people. KM works in PD should be guided to favor knowledge application (knowledge reuse). As discussed by Ferrari and Toledo (2004), it is remarkable that a complex knowledge flow in NPD is not something to avoid and it can also be crucial for advancing the process and product, but consequently difficult to manage. Different knowledge management organizational arrangements that are interdependent on overall structure have influence on how efficiently knowledge is managed in projects and line and how knowledge flows throughout the whole organization.

5.6 Cultural factors

Trust

Importance of trust factor appears rather differently in interpersonal level and collective level. Trust also plays different role in knowledge capture, knowledge share and knowledge reuse. As explained by He, Fang and Wei (2009), when knowledge flow is mediated through system or mechanism at collective level instead of happening face to face at individual level, trust issue becomes a barrier. It is concluded from the empirical data that when employees get knowledge from another colleague, they do not have issue in trusting the knowledge source. However, they generally do not trust the knowledge source stored in documentation and database. For example, the knowledge stored in white-book is not trusted sometimes since it is already old knowledge when white book is released and the knowledge is not searchable by topic or themes. The knowledge is not updated and consolidated. This distrust impedes employees from seeking knowledge and reusing it. When it comes to knowledge capture, since most employees do not trust that the knowledge they capture by documenting it and storing in system will be reused by others, they lost the motivation to put down what they have learned. Therefore when employees do not see who is the source and recipient of the knowledge, they are not motived to capture what they learned and search for knowledge from database and try to reuse it. On the other hand, due to the good knowledge sharing culture in the organization, both knowledge provider and recipient trust each other, the trust among employees further strengthens knowledge sharing culture. No interviewee has ever come across the situation that the knowledge providers do not share because they don't trust colleagues who are seeking knowledge.

Hence when the knowledge flow is mediated by intermediate instead of shared directly, trust is more critical for a smooth and frequent knowledge flow. Due to the lack of trust of the knowledge intermediate, people are more inclined to get knowledge from network instead of searching in database. Knowledge at individual level is more trusted than the knowledge at organizational level in the documentation and database.

Affect-based trust, which is grounded in mutual care and concern between co-workers, is important for people to share tacit knowledge. When people share with close co-workers, contextual part is also shared, however when they share with other colleagues, they tend to share only facts and left out context. By contrast, cognition trust which is grounded in perception of others' reliability and competence has indistinct effect on knowledge flow.

Incentive

There is cultural bias toward inventing new knowledge instead of reusing knowledge since the organization is in a technology-intensive industry and the organization is good at creating new solutions and solving problems in product development project. This perception is shared by almost all interviewees. As a result more focus is on solving problems instead of searching for similar solutions which were created before. Firefighters who solve the

problem at the late phase of project get rewarded in prestige as “heroes” who saved projects. Since rewards, including intangible rewards, shape how people behave in accordance with what they perceive what organization values (Issa and Haddad, 2007). This norm sends the signal to the employees that recreating solution (corrective action) is more preferred than reusing knowledge proactively (preventive action), as a consequence discourages reusing existing knowledge.

There are few incentives encouraging people to capture what they have learned. Consequently even though new solutions are being invented in problem solving, knowledge from the problem solving is more often lost than captured. This situation deteriorates inclination of searching for exiting knowledge. As indicated by De Long and Fahey (2000), how to treat failure decides how efficiently the organization learns from mistake. The organization has “no blame” culture trying not to put fingers on those who made mistakes. However, the action of hiding mistakes (such as make some white books of failed projects confidential) in order not to point fingers to employees has an adverse effect that people don’t feel it is ok to make mistakes and failures should be lifted and discussed in order to learn from it.

Motivation

Product Development project is delivery oriented. At the project level, project performance is evaluated by how it achieves QDCF (Quality, Delivery, Costs and Feature) which is later somehow adjusted by the market performance of the product developed in the project. No dimension about how knowledge is developed is included in the performance evaluation. At individual level, team member is task oriented. They normally see the achievement of their work as delivering parts or product, not the knowledge about product and how to develop product.

Employees don’t necessarily relate what they deliver to the complete truck which is sold in the market and used by the customer. Furthermore, people still have silo mentality within their own departments or functions, impeding them from developing common ways of working with other departments or functions. Individuals lack the sentiment that knowledge they have might be useful for others in the organization. They are not motivated to capture what they learned when they don’t know whether knowledge they capture will be used or who will use it.

Contrary to the theory about “hoarding knowledge”, rarely do employees keep knowledge to themselves in order to protect their position and power. However, the segmental mentality brings obstacles to create a shared vision that the whole team should develop collective knowledge about how to develop product. Consequently, both at project level and individual level, there is no motivation of building up knowledge about product.

Perception of value, time, concern about past, present and future, priority of task

Since the product is perceived as the ultimate value that the product development project created, at the same time, time in project is considered scarce, all focus is on developing product. Any work related to developing product is considered as real work, while work related to knowledge and learning is considered as extra task instead of the main work which drives task in developing product. This is opposite to what Lean Product Development promotes that knowledge is the real value which is created by product development, as a result knowledge value stream is the source of product value stream. This perception of value in the PD organization decides following behaviors:

In concept selection, once a concept for a product is selected, the knowledge created during the selection process is not captured and consolidated since the task of selecting concept for that project is accomplished. Hence when the following project starts, it is difficult to reuse the existing knowledge about the concept.

Time and resources spent on finishing tasks, solving problem are perceived as more eligible than that spent on building up knowledge. Newly employed, inexperienced engineers are not much welcomed in projects because they don't deliver as much as other experienced engineers. Though most interviewees agree there is a lot of knowledge in retiring people, not enough resource is used to capture knowledge within the organization. There is very short handover time when people are retiring or leave the position. Ultimately, resources spent on delivering tasks are perceived more valuable than only spent on capturing knowledge.

Writing and reading white book are considered more as a task to finish required by GDP than as the tool to learn and build knowledge. Even though the white book log is updated during lessons learned work shop in project and through the process team members learn from what happened in the project, the underlying purpose is to learn in order to deliver for that project.

Since finishing task is the most important element of performance. Result itself is more important than how the result is achieved. This is reflected in many norms and behaviors. For example, very often only outcome of meeting, discussion and decision making are documented, or sometimes not documented when the results are used to continue working. When people come across a similar situation, it is hard to find the previous occurance. Employees do not consider it higher priority to dwell on existing knowledge and past experience than to finish task on hand.

To sum up, the organization is not in a learning mode, employees are more driven by task and delivery. The mistake is hidden so there is less opportunity to learn from the mistake. As one interviewee describes "People don't learn because they don't relate the consequence of their action to their action". Continuous improvement as one of the cornerstones of "Volvo Way" is neither connected to learning nor connected to the daily work of each individual.

6. Conclusion

This chapter, dwelling on the chapter "Analysis and Discussion", summarizes findings which shed light on how knowledge flow can be supported and facilitated. This chapter has two sections. The First section illustrates conclusion on current focus in knowledge works in the organization and identified improvement areas, using a knowledge flow model (Figure 15).
The second section addresses three sub research questions that pointing out how to move from current situation toward improved state, consequently answering the main research question.

6.1 Current focus in knowledge works and improvement areas

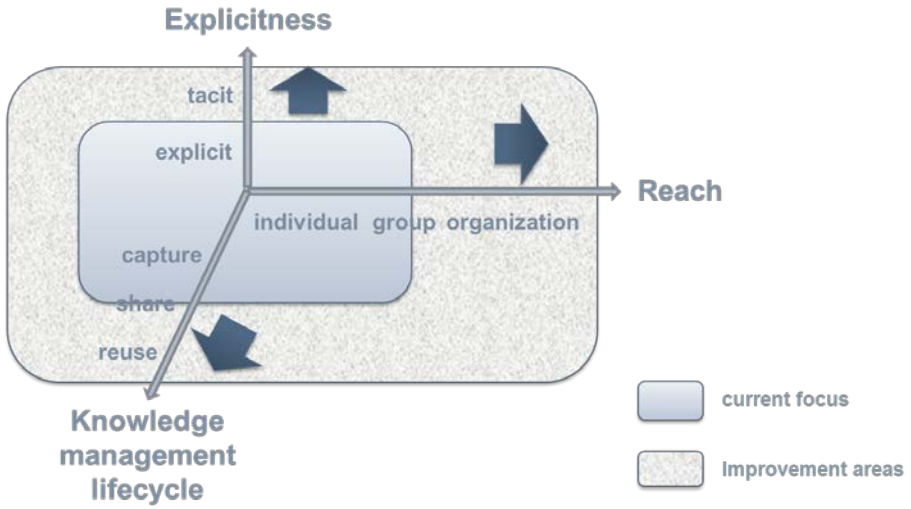

Figure 15: Current focus on knowledge works and the improvement areas

Continuous Improvement in Knowledge works can mean continuous learning and continuously capturing knowledge for reuse in ongoing and future projects. Capturing knowledge is a prerequisite of how the organization applies what it knows. However, codifying knowledge in documents and databases sometimes is taken as synonym of knowledge capture mistakenly. Consequently, in the organization codifying knowledge is on higher focus than it should be, in comparison to capturing knowledge in a way that can be reusable. There is a big part of codified and stored knowledge that is not necessarily contributing to knowledge reuse. The final goal of knowledge works is making the organization to reuse its existing knowledge, so capturing, sharing and storing knowledge should be always channeled toward knowledge reuse, which is the area that can be improved in the organization.

It can be concluded from the analysis that the organization's knowledge is managed more at individual level. Due to a lack of understanding that developing organizational knowledge is a

base to develop products, individual knowledge is not necessarily contributing to collective knowledge. Considering knowledge value stream and product value stream, there is less awareness and sentiment on knowledge value stream. Thus, an improvement area is to make individual and group knowledge available to the whole organization.

There is less attention and focus on tacit knowledge compared with explicit knowledge, leading the organization taking codification as main knowledge management strategy, where experiences, contexts are often neglected. Capture solutions on specific problems through codifying it into documentations is a method for encoding created knowledge. However, experiences in projects are mostly un-codified and seldom transferred to other people, mainly because experiences are not captured and shared efficiently (Schindler and Martin, 2003). Personalization that is more supportive of managing tacit knowledge which can support knowledge flow is more initiated by individuals in the organization, but not promoted efficiently on organizational level. The organization can improve getting benefits from both strategies to achieve efficient knowledge management, not only in explicit knowledge but also in tacit knowledge.

6.2 How to move from current situation toward improved state

6.2.1 What methods and mechanisms can enable knowledge flow?

Reflection, Standardization

The organization uses reflection workshops in projects for team members to learn from past experience. White-books are used to document the learning and capture knowledge created in the process, but it is not efficiently used to improve subsequent projects. More frequent reflections and standardization can enable learning through capturing knowledge, updating processes and sharing it across ongoing projects. As discussed on previous section (Analysis and discussions), a big potential improvement for the organization in terms of knowledge works is going through a full learning cycle and focus on the Act phase (reflection and standardization) in the PDCA cycle. Through reflections in shorter intervals than it is currently in the organization, ongoing projects can also get benefit from learning gained in one specific project. Consequently, knowledge become available to be able to travel to where it is needed to be reused, instead of storing knowledge in which there is always high uncertainty on reusability of codified knowledge.

Codification and Personalization Strategy

The organization needs to be more conscious on which strategy the organization is using for which kind of knowledge, more importantly is which strategy employees are inclined to use and why is that. A codification strategy is evident at organizational level that its focuses on managing knowledge by creating documentation. There should be a clear protocol and possibly training for employees how to make a good documentation such as the level of detail to include in the documentation, what context should be written. Effective storage

and retrieval system facilitates knowledge flow throughout the organization. Organizing and structuring knowledge should be in a way that makes it easy to access and use within the organization.

A customer-oriented mindset helps creating documents which are easy to reuse. More focus needs to be put on capturing tacit knowledge, for example the context of lessons learned, the process of decision making recording reasoning and constraint. Another suggestion is to make it visible how a documentation of knowledge is used and appreciated, to make it clear for the organization that how much benefit people get from the documentation. No interaction and communication between source and user of the knowledge is a critical issue that makes codification approach less efficient. The one who makes a document usually has no idea who will read it through, when and how much the document will be beneficial and useful. Consequently, lack of motivation is an identified common phenomenon when it comes to codifying knowledge. Providing high motivation to codify knowledge can only achieved when it is shown to employees how their time and effort putting on documenting create values and appreciation. Considering the situation deeply, this is one of the biggest barriers in codification strategy that leads employees to follow personalization approach naturally, in which the time gap between sharing knowledge and knowledge reuse is not visible and sensible, due to interactive nature of direct communication.

Since employees are more inclined to use personalization to learn and get knowledge they need, there needs to be a supportive structure and design of network for employees to establish connections with each other so people can find the right people to talk to quickly. For example, for new employees, give them a list of twenty important people both in their own function and in other functions and levels which could become an important network for their work. For all employees, it is important to make interaction happen by designing meeting place wisely so people stay and talk to each other. Creating efficient ways to connect people and guiding them to interact, leads to more-effective collaboration and better learning environment, which can facilitate knowledge flow both in terms of explicit and tacit type of knowledge. The organization should connect each person's profile in intranet, including their respective competence, to their contribution to the knowledge repository, it is ensured to the largest extent that people can access knowledge and knowledge source, as well as the possibility to get tacit knowledge from knowledge source. Good sharing culture identified in the organization can as well be strengthened by competence mapping that enables tracking knowledge sources throughout the whole organization and facilitates developing network to find the right people and the needed knowledge.

Based on the above understanding of the two strategies, they can be designed to complement and support each other. Personalization can aid codification in capturing and reusing more tacit knowledge. Codification can be used to support networking and competence mapping.

6.2.2 What organizational structure can support knowledge flow?

Due to uniqueness and short-term orientation of product development projects, after a project is finished the knowledge is lost easily. In contrast, line organizations where departments and groups act as knowledge cells can play a role as organizational memory. The line organization has technical knowledge and the knowledge is recycled inside each department, but a project does not have such an opportunity due to being temporary and focusing on deliveries. However, in order to maintain the knowledge developed in projects, efficient and close interaction is required between influential roles in the line organization and the knowledge management task force responsible in projects, to make sure that knowledge flows smoothly across project and line organizations.

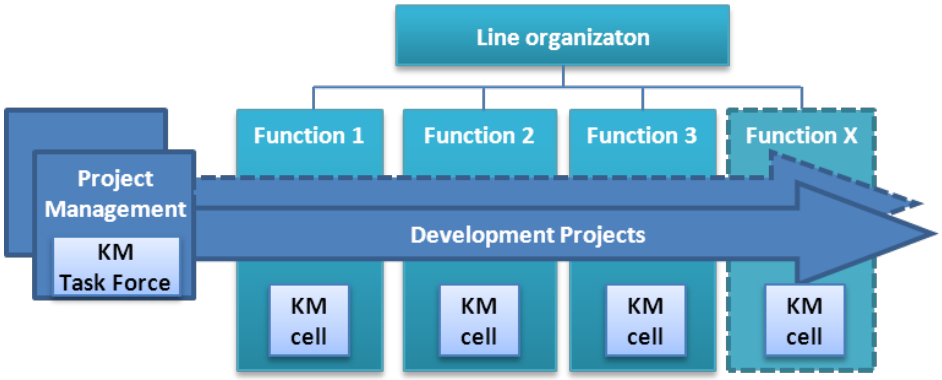

Figure16: Knowledge Management Structure

In the proposed illustrated Knowledge Management structure (Figure 16), KM cells located in functions, in which influential roles are involved (has to be clearly defined by the organization) can enable the organization to rapidly collect useful knowledge and feed it into projects when it is needed. Since people in KM cells move from team to team and from project to project, they are able to find similar problem-solving activities and consequently immediate transfer of knowledge between projects. The knowledge Management task force (De-centralized structure) boosts inter-functional knowledge sharing, since project members come from different functions and can support standardizing practices and getting high benefits of lessons learned during projects. Valuable learning could be easily captured, if there is enough involvement from KM cells into projects and good communication, since people in KM cells have an overall view on different product development projects. Through close and efficient interaction between KM cells and KM task forces in projects, transferring knowledge between projects and line can be facilitated, which secures that the whole organization have access and get benefit from captured knowledge in the projects.

6.2.3 What cultural factors can facilitate knowledge flow?

Cultural factors, such as trust, incentive, motivation, especially the underlying perception about value, shape how employees behave in the organization. Since the knowledge in some databases and documentation is not updated, not searchable, not consolidated and does not contain context, employees have lost trust in the knowledge repository as

intermediate while resort directly to the knowledge source to get knowledge. This to a large extent explains why personalization strategy at individual level (using network) of managing knowledge is preferred rather than codification strategy at individual level. Due to the fact that there is not sufficient support in helping people establish network easily and get to know others' competence, especially with those who are not closely collocated colleagues, capturing, sharing and reusing knowledge is compromised. The situation is worse with tacit knowledge, which relies greatly on awareness of others' knowledge and interest to share. Consequently it is indispensible to make the knowledge repository alive and encourage more contribution and reusing of knowledge.

Generally speaking, there is little incentive in the organization towards knowledge work. More in detail, lack of sentiment that knowledge one person has created might be useful for others, stops people from capturing what they learned for others, for example write it down in documents. This can be improved by combining personalization strategy and codification strategy as described in previous section, to increase awareness of what is happening in other functions or projects. Rewards giving to the firefighter implies that the organization values more quick-fixing instead of finding root cause and preventing problem. Incentive is needed to remove the bias toward inventing new things, to create a mindset of utilizing existing knowledge. An important issue is to create an atmosphere where mistakes and failures are lifted up and discussed in order to learn from the mistake and prevent it from happening again. People need to relate the consequence to their action. Following the same argument, on the other hand, the organization can calculate the benefit from reusing knowledge to prevent "reinventing the wheel" so the benefit is more visible.

However, the most influential factor is the underlying perception of value in the organization. In contrast to what Lean PD promotes, that knowledge is the value of product development, in the organization the product itself which brings profit is considered as the ultimate value of product development projects. This has resulted in the norms and practices in the organization which undermines all knowledge activities. As long as tasks and product can be delivered, knowledge activities can be put aside. Consequently, the main focus is on the current task, without much consideration of the past (or others') experience, which can be dwelled on to reuse, and the future, for which the knowledge should be captured. To address this, more time dedicated to learning and managing knowledge is necessary. Ultimately the management's role is decisive to shape the perception and mindset which is favorable for knowledge work. This then falls upon designing correct incentives to create motivation for capturing and reusing knowledge.

7. Recommendations for the case company

This section both highlights the recommendation discussed in section “6. Conclusion” and presents some recommendation more in a detailed and actionable way for the case organization, aligning knowledge flow in dimension of explicitness and reach into the process of knowledge capture, knowledge share and knowledge reuse, as shown in figure 17.

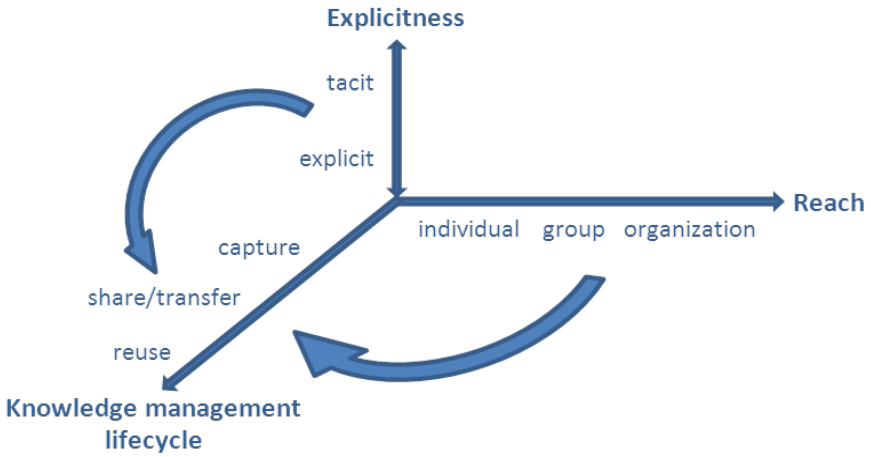

Figure 17: Aligning recommendation on knowledge flow in dimensions of explicitness and reach into dimension of knowledge management lifecycle

7.1 Recommendations respectively for knowledge capture, knowledge share, knowledge reuse (figure 18)

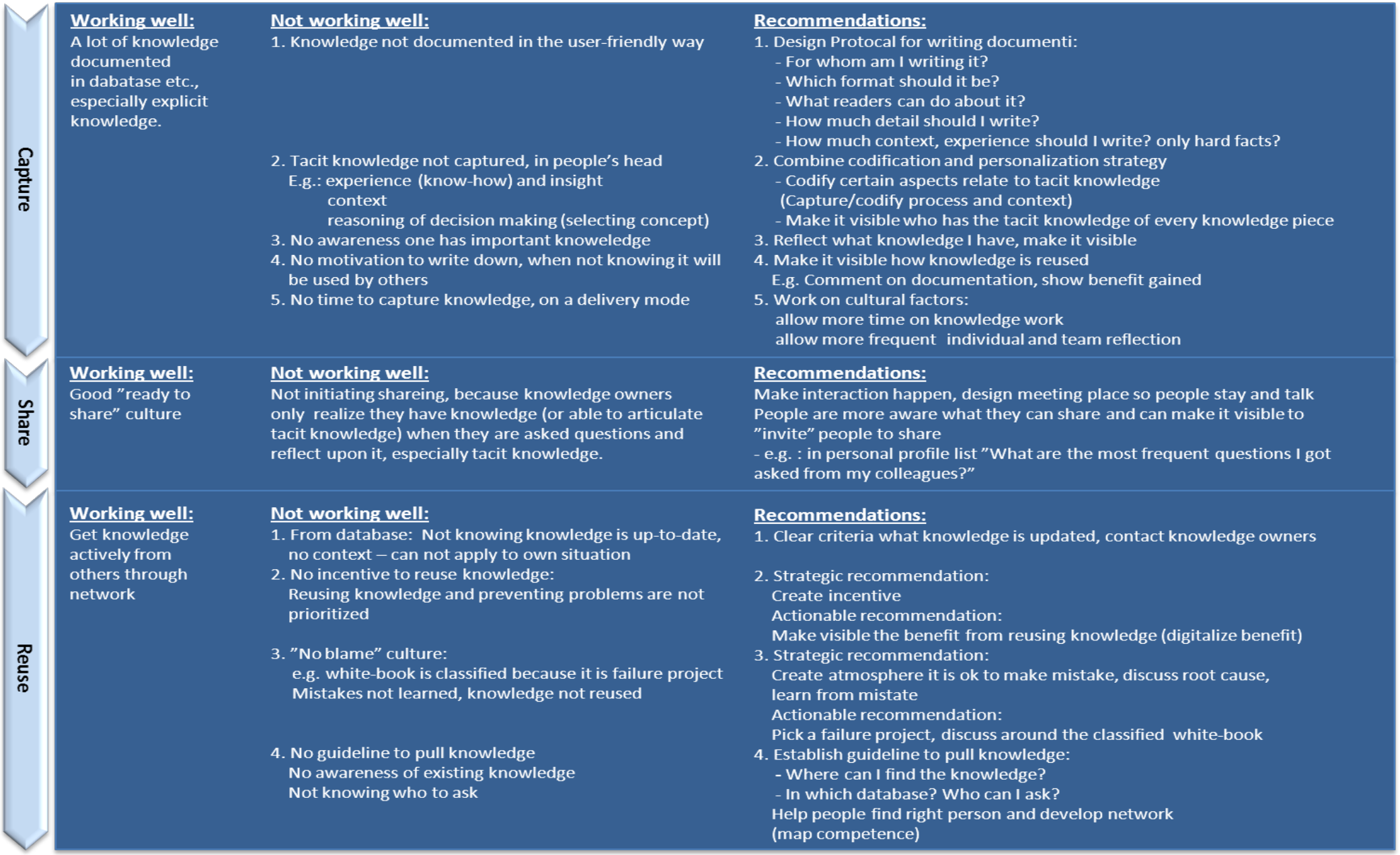

Figure 18: Recommendations respectively for Knowledge capture, share, reuse

7.2 Other recommendations

Other recommendations which do not fall into any specific process in Knowledge Capture, Share, Reuse include:

7.2.1 More frequent reflection

Reflection should be more frequent than after each gate in project. The frequency can be various but should make it possible that team members have fresh memory of what is happening and still keep the original facts and data. In the implementation, good frequency of reflection should be found.

7.2.2 Establish clear KM structure to boost interaction between projects and line organization

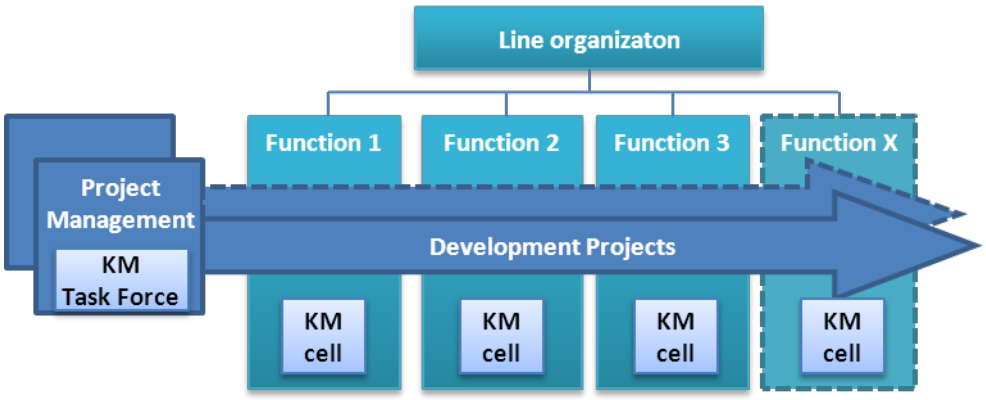

Figure 19: Knowledge Management Structure

As discussed in conclusion 6.2.2, KM task force (now CPM/PM/PAM) should:

- Keep knowledge activity alive in projects, such as frequency, attendance and quality of team reflection
- Communicate with KM cell in line organization seeking experience from other projects
- Take care of all knowledge created in project, together with KM cell in line organization (as shown in the process in figure 19)

KM cells in line organization can be function manager, group leader, feature leader or experienced senior engineers, who takes the responsibility of:

- Make sure the similar problem happen in different projects can be identified and solved in all projects
- Take over the knowledge delivered from projects, together with KM task force in projects (as shown in the process in figure 19)

7.2.3 Connect knowledge capture and reuse

It is important to check the connection between capture and reuse and make sure knowledge capture and reuse is connected to a complete loop. The following can be done:

- Investigate cost-effectiveness of captured knowledge, which might reveal how much waste the organization has in current knowledge work.
  For example: Calculate cost of writing white-book, compare it with
  - How much is reused?
  - How much benefit we got from it?
- A process to make sure all knowledge from project is taken care of and used

  1) The process to make sure all knowledge is captured and reused through line organization and fed into new projects (figure 20)

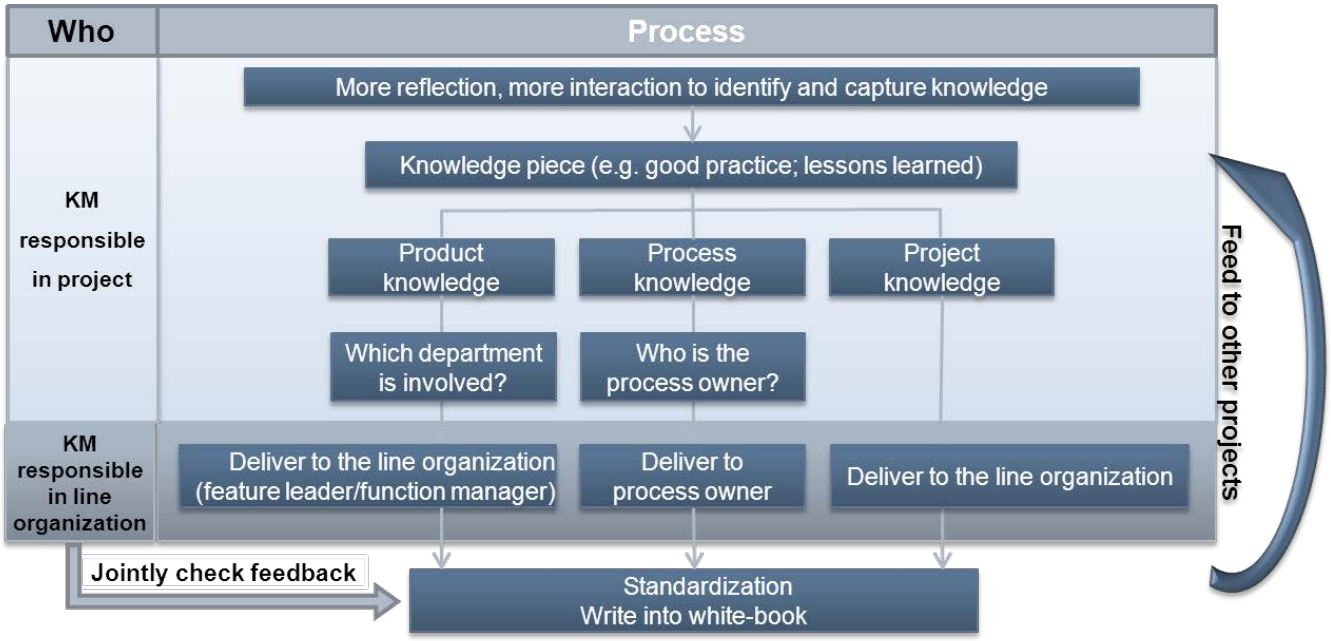

Figure 20: Process to make sure all knowledge from project is taken care of

  2) The process to make sure knowledge is shared across simultaneously running projects. (figure 21)

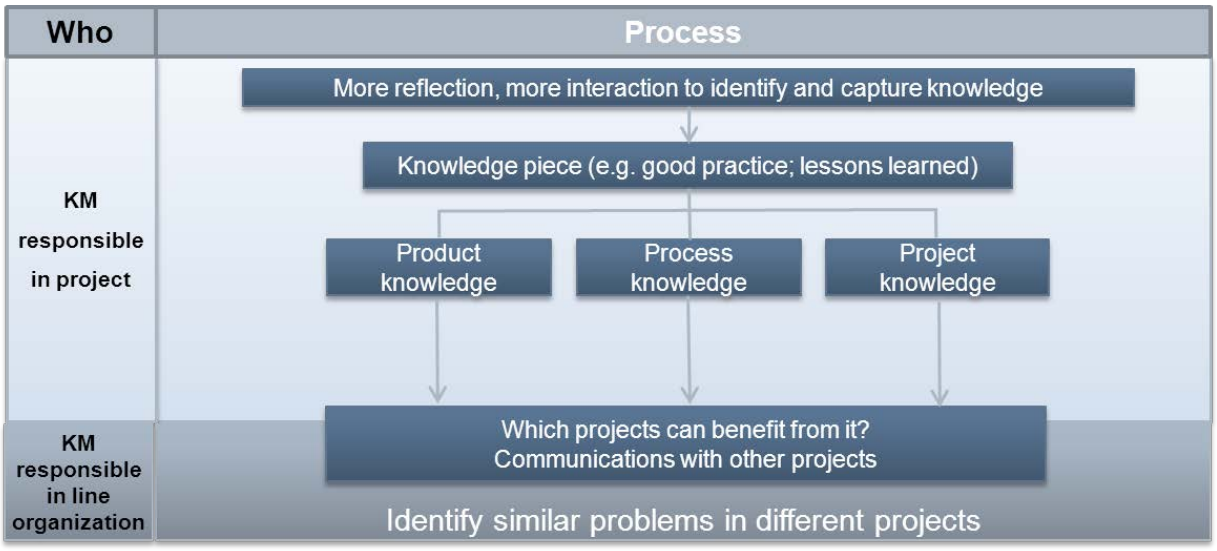

Figure 21: Process to make sure all knowledge from project is taken care of

These two processes should go parallel. Process 1) takes longer time when the knowledge needs to be delivered to line organization and made it either standardized or written into white-book in order that future project will use the knowledge. Process 2) makes sure the knowledge from one project can be shared in time with other projects, however it does not guarantee knowledge sustains after several years. This disadvantage can be overcome by process 1). Knowledge Management rolls in line organization are necessary for both processes due to their more holistic view of different projects which they are involved in.

7.2.4 Help people build network and competence mapping

It is more beneficial to use network to get knowledge not only because it is updated knowledge and with context and knowledge owner's personal experience how to interpret and utilize knowledge, but also because through interaction, people become aware what knowledge they have and can be beneficial for others. Consequently it is critical to:

- Help people build network quickly

  For example: Give new employees a list of twenty important people both in their own function and in other functions and levels which are important for their work. For all employees, it is important to make interaction happen by designing meeting place wisely so people stay and talk to each other.

- Make people's competence and knowledge visible and searchable

  For example: The organization can connect each person's profile in intranet, including their respective competence, to their contribution to the knowledge repository (database). Individual's profile can list "What are the most frequent questions I got asked from my colleagues?" to invite other people ask for knowledge.

7.2.5 Checklist for knowledge initiative

Before any Knowledge management initiative is introduced, the following checklist should be taken through:

- Who is the owner of it?
- How to make sure the owner is really responsible for it?
- Who is following up? The owner or the owner should make sure others follow up?
- How much of the knowledge is used?

For example, it is discussed in the organization maybe a white-book about product knowledge should be written separately since at the moment white-book has a tendency to include mainly project knowledge. Nevertheless, looking at the checklist bring the question whether it will have the same problem in effectiveness and efficiency as the current white-book. Without dedicated people to integrate and consolidate knowledge in different themes, without a process (such as process in figure 19) to make sure knowledge captured is taken care of with a result of standardized or shared across

organization, only introducing more tools will only create more burden for employees with little benefit.

7.2.6 Work on cultural factors

- Allow employees to dedicate more time for knowledge work and learning, including allowing more time in interaction, capturing knowledge.
- Introduce factors in Personal Development Plan how well individual is learning, which should not be limited to attending training and coursing, but also self-reflection, participating in team reflection, being active in knowledge work.
- Start to praise those who prevent problem happening and show the benefit in number (how much money is saved if it is not prevented or mistake found in late phase)
- Change people's perception on value of their work, which is not only finishing tasks and delivering product, but more importantly producing knowledge for future projects. It can be started by personal reflection such as: How much did I learn from work today? How much of it I, or my colleague can use in the future?

7.3 Suggestions on implementation and more discussion

The detailed implementation plan is not in the scope of this research project. However, it is recommended to:

- Start with the actionable recommendation and the recommendation listed in "example".
- Start working on cultural factors as early as possible since culture, for example the underlying perception of value, can't be changed in a short period of time. Consequently, considering its critical and sometimes decisive influence on other factors, the effort on cultural factors should be prioritized.
- Go over the thesis projects which have been done in the same area, pick up recommendations which have been put forward. For example, the thesis "Learning from Product Development Projects- An approach to increasing product development capability through knowledge creation and re-sue" by Niclas Rinman and Shea Wilson (2010) made the recommendation to break down white-book into knowledge articles based on subjects, which was as well mentioned in CR (Change Request) 10-37.
- It is as well valuable to think about and discuss around following questions:
  - How to build up a complete knowledge base of the product, especially how today's product is operating (as it is called "Friday truck" in the organization). Should we write it into the project prerequisite? How much does it cost if we need to build a complete knowledge base of the product? Who should write and own it? Or those knowledge should be considered as experience which young engineers should learn in their work?

- How good are we really in learning from mistake?
- What does it mean when we have high turnover rate with short handover period?

  For retiring people, in the organization, there are three ways for using expertise from retiring/retired people: 1) Call them back when there is problem; 2) Assign them 1-2 years senior counselor role before retiring; 3) By working together with others, they naturally transfer their knowledge. As described by one interviewee “It shouldn’t happen that someone works 30 years, having a lot of knowledge, while not transferring knowledge until retirement”. How frequently No. 1) happens can be used as a measurement of how No.3) is working well.

8. Criticizing on the model for knowledge flow employed in this research

This section looks at the whole research project including the empirical data from another perspective, with a criticizing view on the model employed in the research, trying to interpret empirical data in a different way.

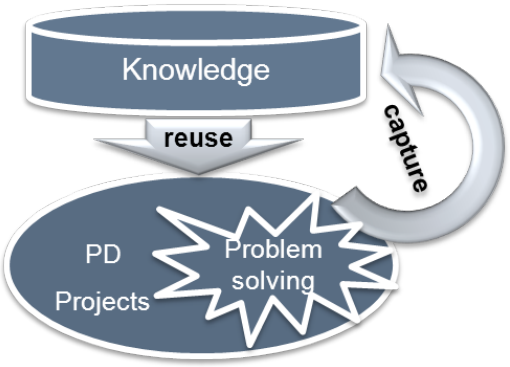

Figure 2: Illustration of the research focus

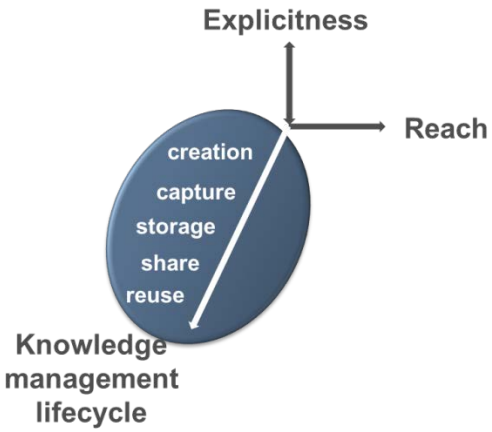

Figure 5: Extended model of knowledge flow (Nissen, 2002)

Although as described in section "3.2.2.4 Organizational learning and knowledge management" this research includes concepts in organizational learning, the research is conducted mainly in domain of knowledge management. When revisiting the model, showing the focus of the research and the model of knowledge flow in process view of knowledge management lifecycle, it is realized that the process view of knowledge flow by itself tends to objectify knowledge. The knowledge management domain, holding the perspective of cognition-possession, takes knowledge as a commodity people can possess, codify, store and transmit to others, with the exception that Spender (1996) maintains that organizational knowledge is socially constructed in a process (Chiva and Alegre, 2005). The organizational learning domain has a tendency towards a social perspective that organizational learning arises from social interactions in the workplace. In addition, the model (including the knowledge management domain) tends to perceive knowledge flow as a linear process, in which knowledge first needs to be captured, then be shared, and finally be applied.

The critique on the research itself brought the researchers to look at empirical data in another perspective. How are people learning and getting knowledge? What is working? What is not working? The answer is actually already imbedded in previous analysis and conclusion.

What is working?

People are learning by interaction through network. They get knowledge and utilize knowledge more by talking to colleagues than reading documents. Considering the knowledge stored in database and documentations, people learn how to use the database and documentation by asking colleagues as well. During interaction and reflection upon the interaction, new knowledge are created and constructed together with others, people are more aware what knowledge they have, more active in sharing their knowledge. Hence in reality often the middle steps are skipped, people create knowledge when they use it.

What is not working?

On the contrary, by documentation

- Knowledge is only partly codified into paper, then partly understood when others read it. Take the white-book as an example, it can be doubted from empirical data how much the stored (written) knowledge is actually utilized.
- Only capturing knowledge by codifying it and hope it can be used by other people and project is likely to be wishful thinking. Furthermore, codifying approach makes using the knowledge a slow process.

A conclusion can be drawn that people need to learn in interaction and knowledge flow happen instantly when people discuss and construct understanding together. Hence the organization should find ways to encourage social interaction and build system and structure to support it. The recommendation from previous section can be highlighted for this purpose as below:

- Help people build network quickly

  For example: Give new employees a list of twenty important people both in their own function and in other functions and levels which are important for their work.

- Make interaction happen

  For example: Designing meeting place wisely so people stay and talk to each other. The importance of design of workplace and meeting place for communication and interaction to happen is discussed in Thomas J. Allen's book "Managing the flow of technology: technology transfer and the dissemination of technological information within the R&D organization", and mentioned in the book "Steve Jobs" by Walter Isaacson (2011, p.431).

- Make people's competence and knowledge visible and searchable

  For example: The organization can connect each person's profile in intranet, including their respective competence, to their contribution to the knowledge repository (database). Individual's profile can list "What are the most frequent questions I got asked from my colleagues?" to invite other people ask for knowledge.

9. Future research

To the two researchers' knowledge, there has been no research in the same area which takes such comprehensive view in a structured way from three areas critical to support and facilitate knowledge flow: 1) What methods and mechanisms can enable knowledge flow; 2) What organizational structure can support knowledge flow; 3) What cultural factors can facilitate knowledge flow. This comprehensive approach has provided a holistic view on the topic, making it possible to look into the interrelationship among these three areas.

The authors believe that this research can be continued to investigate how knowledge works can/should be taken differently in different phases of product development process. Furthermore, further research can look in more detail into how lean principles can boost knowledge flow in product development. Another topic which can be researched is competence building. As mentioned in section 2.3.4 "Internal reliability", it has been mentioned by many interviewees that high turnover rate is a big barrier as organization/department loses competence and knowledge is lost. Research can be done in how organization designs competence building, probably more in Human Resource area.

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Appendix I- Interview Guide

Purpose of the thesis:

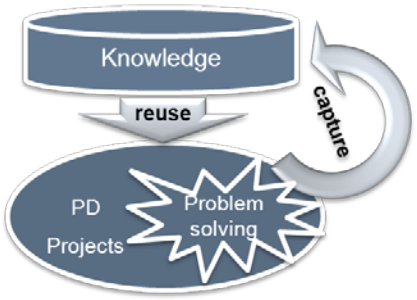
Determine how to support and facilitate knowledge flow in PD at Volvo Group Trucks Technology.

The focus is to find out how to ensure an efficient knowledge flow, specifically in

Knowledge capture: retain and accumulate the knowledge created, found in product development, so that knowledge and learning is not lost

Knowledge sharing: share knowledge within and across projects

Knowledge reuse: reuse the knowledge captured previously



By achieving efficient knowledge flow, the knowledge is accumulated in the organization level and reused by members.

For your reference, from academic point of view, knowledge can be defined as below:

- **Tacit knowledge** is the knowledge based on the subjective insights, intuition derived from experience, values, emotion. It is context-specific thus not easily expressed, formalized and communicated, for example how to ride a bicycle.
- **Explicit knowledge** is the knowledge which can be easily expressed, documented, transferred, for example technical specification documented in a report.

In product development projects, there are different types of knowledge:

- **Product knowledge**: relates to the product, for example: relations between product parameters, or design limitations of selection concepts
- **Process knowledge**: knowledge about activities, for example: how a simulation is interpreted; or policies, rules and procedures
- **Project knowledge**: knowledge about how the project is running, for example: how to manage risks and uncertainty, how to plan work, how to avoid the waiting time between tasks and activities so the work flow is efficient

You can relate these definitions and categorization to your own work.

Purpose of the interview:

We expect to have your view of how knowledge is flowing currently – how knowledge is captured, shared, reused, as well as your view on how it can be improved. The perspective from you will be used, together with view from literature, to analyze what can be done in the organization for improvement.

Thank you in advance for your time,

Bo Chen and Sina Ghaedian

Interview guide (Hand-out):

1. Please briefly describe the project you are working on and your role

Knowledge reuse

2. During the concept phase, how do team members use existing knowledge for design?
    - How do people pull the existed knowledge into the project? By which tools or methods?
    - How is the interaction between functional departments and projects, to bring the knowledge into a project? What roles are involved?
    - What difficulties/concerns are there for using the existed knowledge, even when it is available and easy to find?
3. When team members come across a problem, what is their approach to solve that?
    - Do they search for information related to similar problem happened before? Consult others? Or try to solve it themselves?
    - What needs to be in place for team members to try to reuse knowledge instead of solving a problem again?

Knowledge Capture

4. What do team members do with the knowledge created in a project?
    - How do people capture the learning developed in a project? By which tools or methods? Are they working well?
    - How people from function and projects are involved in capturing knowledge created in projects? What roles are involved?
    - Who decide what knowledge should be captured?
    - What needs to be in place for people to capture the knowledge they create?
    - What is benefit of capturing knowledge in projects?
    - How do people make the captured knowledge (solution) reusable for others? (How to generalize captured knowledge?)

Knowledge sharing – within and across projects

- How do team members share knowledge? Who do they share with? and why?
- How to share experiences embedded in learning process and tied to a person?

Overall questions for knowledge capture, sharing and reuse

- What is the value created by the projects?
- How do people perceive the initiatives in knowledge management generally (such as introducing new tools for capturing knowledge, build community of practice for sharing knowledge)?

Can we come back to you if there would be further clarifications needed?
Any other additional comments can be placed here

Interview Questions (Researchers' version):

Main Questions (in bold) in hand-out and supportive/back up questions

(Questions will be edited if the interviewee is only involved in concept phase or implementation phase)

Interviewee:

1. Please briefly describe the project you are working on and your role

Knowledge reuse

2. **During the concept phase, how do team members use existing knowledge for design?**
   - **How to pull the existed knowledge into the project? By which tools or methods?**
     - What types of knowledge is needed during early phase for concept design?
     - What part of required knowledge already existed in organization that can be reused?
     - Where to look for the existed knowledge? Is it easy to find it?
   - **How is the interaction between functional departments and projects, to bring the knowledge into a project? What roles are involved?**
   - **What difficulties/concerns are there for using the existed knowledge, even when it is available and easy to find?**
   - What types of knowledge is created in a project, during early phase for concept design?

3. **When team members come across a problem, what is their approach to solve that?**
   - **Do they search for information related to similar problem happened before? Consult others? Or try to solve by themselves?**
     - If not searching for previous knowledge, why?
     - When they reuse the knowledge created by others, do you have concern on the reliability of the knowledge source?
     - Which behavior is more valued in problem solving: fire-fighting or search for previous knowledge and reuse them?
     - What is perceived more important: only the result (for example: problem solved) or how the result is achieved?
   - **What needs to be in place for team members to try to reuse knowledge instead of solving a problem again?**
   - What types of knowledge is created in implementation phase?

Knowledge Capture

4. **What do team members do with the knowledge created in a project?**
   - **How to capture the learning developed in a project? By which tools or methods? Are they working well?**

  - Do team members document knowledge? What types of documents are developed? Are they working well? How is a good document? (what characteristics a good document has)
  - How do team members share knowledge? Who do they share with? and why?
  - How to share experiences embedded in learning process and tied to a person?
- **How people from function and projects are involved in capturing and sharing knowledge created in projects? What roles are involved?**
- **What needs to be in place for people to capture the knowledge they create?**
- **How to make the captured knowledge (solution) reusable for others? (How to generalize captured knowledge?)**
  - Is there any reflection on the learning that has developed? How and When? (During a projects/after a project ends)
  - How to update standards and processes, according to a captured knowledge? What roles are involved?

Overall questions for knowledge capture, sharing and reuse

- How the project team is built? Is it more rotating or stable team?
- What is needed for people to spend more time on capturing, sharing and reusing knowledge?
  - In projects, how much time (in percentage) do they spend on capturing and reusing the existed knowledge?
- **What is benefit of capturing knowledge in projects?**
  - Benefit to the person
  - Benefit to the project team
  - Benefit to the organization
- **What is the value created by the projects?**
- How do people in projects perceive their contribution to the line organization (functional areas)?
- How do people perceive the initiatives in knowledge management generally (such as introducing new tools for capturing knowledge, build community of practice for sharing knowledge)?
-

Can we come back to you if there would be further clarifications needed?

Any other additional comments can be placed here

Appendix II – Data matrix

Main research question: How to support and facilitate knowledge flow in PD at Volvo Group Trucks Technology?

Sub questions & Data matrix: (sub-question is not the same as interview questions)

	Primary data	Secondary data
1. What tools, methods and mechanism can enable knowledge flow		
1.1 What are different tools, methods, mechanisms used for different types of knowledge in different phases, for capture, share, and reuse knowledge? Why?	1.1.interview	1.1company info.
1.1.1. How are these tools, methods, mechanisms used? Why?	1.1.1interview	
1.1.2. What are working well or not working well? Why? (what are the advantage and disadvantage)	1.1.2interview	
1.2 What are other tools, methods and mechanisms that can/should be used?	1.2interview	1.2literature
2. What organizational structure can support knowledge flow		
2.1. How is the structure of the organization, from knowledge perspective? Why?	2.1interview	2.1company info.
2.1.1. Who is responsible for knowledge in line organization? What are their responsibilities? Why?	2.1.1 interview	
2.1.2. Who is responsible for knowledge in projects? What are their responsibilities? Why?	2.1.2interview	
2.1.3. How is knowledge transferred between projects and line organization? –	2.1.3interview	
2.2. How the structure of the organization should be? Why?	2.2interview	2.2literature
2.2.1 Who should be responsible for knowledge? What would they be responsible for? Why?		
2.3 What are the pros and cons for different organizational KM structure for managing knowledge and learning?	2.3Interview	2.3Literature

3. What cultural factors can facilitate knowledge flow		
3.1. What are the factors critical for knowledge flow?	3.1interview	3.1literature
3.2. What kind of culture is it in PD in the organization, which is related to knowledge flow?	3.2interview	
3.2.1. How trust influence people's attitude and behavior in knowledge capture and reuse?		3.2.1literature
3.2.2. How personal performance evaluation influence people's attitude and behavior in knowledge capture and reuse- Is there any item in personal (team) performance evaluation related to knowledge and learning behavior (such as behavior in capturing knowledge, sharing knowledge, reusing knowledge) –	3.2.2Interview	3.2.2company info.
3.2.3. How is the performance of a project (team) measured?		3.2.3company info.
3.2.4. How perception of value influence people's attitude and behavior in knowledge capture and reuse - Which behavior is more valued in problem solving: fire-fighting or search for previous knowledge and reuse them? - What is perceived more important: only the result (for example: problem solved) or how the result is achieved?	3.2.4Interview	
3.2.5. How do people perceive benefits of capturing knowledge in projects?	3.2.5Interview	
3.2.6. How do people in projects perceive their contribution to the line organization (functional areas)?	3.2.6Interview	
3.2.7. How people perceive time pressure and prioritize their work accordingly	3.2.7Interview	

Appendix III – Grouping of theory and framework from literature review