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KNOWLEDGE MANAGEMENT LIFE CYCLE: AN INDIVIDUAL'S PERSPECTIVE

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1. Introduction

Project managers in product development regularly use the conventional iron triangle, time, cost and quality, as a benchmark for developing their project strategy. The desirable outcome of a project is affordable high quality products developed fast. However, these desires usually stand in conflict to companies' capabilities. The fierce competition today drives companies to make fewer errors in order to succeed on the market, or even to stay in business [Locher, 2011].
A solution of making fewer errors is knowledge, knowledge that also fosters capability. Yet, typically little time is given for knowledge dissemination in product development projects, even though lessons often are individually learnt. Where might this paradox derive from? Project managers are expected to, from a predetermined project goal, deliver impeccable results [Dinsmore and Cooke-Davies, 2005]. The results delivered by a project are however not solely the project manager's responsibility; the outcome is rather a projection of the project members' knowledge possession. Since knowledge is claimed to be costly to re-create [Kogut and Zander, 1992] and has great impact on efficient decision-making, it is highly valued in organizations [Grover and Davenport, 2001]. However, at some point in time, employees leave companies. Either they retire, resign or are made redundant. And, as individuals leave, their knowledge seldom remains in the organization over time [DeLong, 2004]. The effects of lost knowledge first become apparent when something goes wrong, and knowledge is needed. Practitioners claim that knowledge is a key factor for successful product development. Yet, it is emphasized that getting an organization to learn from errors is extremely challenging [Wheelwright and Clark, 1992]. On an individual level, when a project's outcome differs from the intended project goal, failure occurs and is regularly learned from, since the individual then involuntarily reflects and rethinks – a process that is claimed to foster learning [Argyris, 1991].
Even though it is not always apparent, errors are frequently repeated within and between projects. The term "reinventing the wheel" is commonplace, yet it exhibits the essence of the disregard for knowledge management (KM). This paper is driven by the idea that errors can be learnt from once, contextualized and disseminated. Systematic management of knowledge, over time, leads to low probability of errors being repeated in and between projects, and highly prepared capabilities.
In this paper, organizational learning (OL) is defined by the process of the knowledge life cycle, while KM focuses on the content [Easterby-Smith and Lyles, 2003]. KM is the planning, organizing, motivating, and controlling of individuals, processes and systems in the organization, to ensure that its knowledge-related assets are improved and effectively employed [King, 2009]. KM requires a mix of business awareness, attitudes and practices, systems, tools, policies, and procedures [Lehaney, 2004].
In order to organize KM thoughts, several KM life cycle models have been developed. Davenport and Prusak [2000] suggests a 3-stage model ("generate, codify/coordinate, transfer"). Ward and Aurum

[2004] advocate a 7-stage model ("create, acquire, identify, adapt, organize, distribute, apply"). Also, the SECI framework for knowledge creation ("socialization, externalization, combination, internalization") [Nonaka, 1994] is well known.

1.1. Post-project reviews as a concept for organizational learning

Some practitioners suggest applying 'lessons learned meetings' in the end of every project [Mascitelli, 2007] in order to prepare dissemination of knowledge into the organization. The concept is used in product development and is also referred to as post-project reviews. However, it has been found that post-project reviews carry at least four malfunctions:

- Typically carried out in the end of a project [Kotnour, 2000], when much of the project learning has already been forgotten
- Typically conducted by one individual, often the project manager [Busby, 1999, Kotnour, 2000, Williams, 2008]
- There is a lack of useful input, and input is often stated in general terms [Bresnen et al., 2003]
- The outcome is regularly a large, inaccessible record [Von Zedtwitz, 2002, Schindler and Eppler, 2003, Parry and Turner, 2006]

The concept of post-project reviews might be a useable model since it considers constructing individual knowledge into organizational knowledge. However, it can clearly be further elaborated. The four bullet points above indicate that post-project reviews include risks of being ineffective. And since post-project reviews are widely used in product development, these projects are seldom as effective as they could be. Effectiveness in this case can be defined as a low chance of error. Fewer errors ideally indicate shorter lead times, lower development cost and better product quality.

An elaboration of post-project reviews suggests that many individuals' knowledge can feed a knowledge repository continuously between projects. This deduction is however not revolutionizing. The concept of continuous improvements is known and thoroughly deliberated in research, for example in the concept of the knowledge value stream [Kennedy, 2008], the approach of Kaizen or, more specifically about post-project reviews, by von Zedtwitz [2002].

1.2. Technology platform and known barriers in human interaction with KM systems

To categorize and capture organizational knowledge, a knowledge repository is typically applied. In this paper it is represented by a technology platform solely composed by knowledge records of explicit knowledge [Levandowski et al., 2013]. The knowledge is exclusively related to technologies describing product and manufacturing systems. It is designating the link between product systems and manufacturing systems, by the communication between man-computer, computer-computer and computer-man. The knowledge records are delimited to describe manufacturing systems capabilities, guidelines of "know how" [Levandowski et al., 2013] and ISO as well as corporate standards, in a product development context.

The objective of a KM system, including the technology platform, is to support the KM life cycle and in that sense support individual creation, transfer, and application of knowledge in organizations [Alavi and Leidner, 2001]. However, there are several barriers connected to human interaction with KM systems. Project members regularly have unrealistic expectations on KM systems, that the system alone will do the work of sharing knowledge. There might be an inappropriate technology integration, mismatching the project members' needs, adoption, support, IT project management, upgrades and costs [BenMoussa, 2009]. Any implemented method must support knowledge to be updated, accessible and available for the personnel within the organization [Davenport and Prusak, 2000]. It is further claimed that specific knowledge records need an owner to be completed. Several definitions on knowledge ownership exist. In this paper it is defined as the one responsible for the accuracy of the knowledge content and ensuring its validity over time [Jarvenpaa and Staples, 2001].

2. Research approach

In the field of KM we can distinguish the challenge of absorbing valuable knowledge, not exclusively short-term, relying solely on knowledge in project members' minds (whether it is compiled facts or "know-how"), but also long-term. The long-term perspective of caring for individuals, respecting their knowledge, while at the same time exploiting it, is a balancing act. However, we believe that an appropriate KM life cycle might be useful for visualizing how individuals can contribute to the company's aggregate knowledge capabilities.

This study is both descriptive and prescriptive. It is descriptive in the sense that industrial issues are analyzed and contextualized within the framework of the integration between product designers and manufacturing engineers, where the link between them is represented by the technology platform. The KM life cycle is described from an individual's perspective in order to understand the knowledge user and creator, which is why project managers may find the model appealing. The research is prescriptive since the approach is founded on systematic mapping of industrial KM issues, where incentives to find practical solutions are presented. The findings include discussions on how to overcome core barriers.

In incremental product development projects, the communication between product developers and manufacturing engineers is not as effective as it could be. Knowledge can be lost in translation, due to several reasons. We believe that by investigating the current state of practice in two case companies and by mapping empirical data and related theory, we will be able to distinguish possible solutions to exploit many individuals' (project members') created knowledge in and between projects. This paper is hence driven by the two following research questions:

1. What core barriers, that restrain an ideal-working KM life cycle, exist at the case companies?
   The empirical data is analyzed and an ideal KM life cycle from an individual's perspective is presented. Core barriers are identified. The barriers are then mapped into a proposed KM life cycle model, described from an individual's perspective.
2. How can core barriers be overcome?
   From the mapped core barriers, solutions to overcome some of the barriers are proposed.

The research is delimited from the process of individual knowledge creation, since this particular process is difficult to systemize. The KM life cycle in this paper is seen from an individual's perspective in order to understand the user. Organizational knowledge intends to denote the knowledge that is continuously fed into the technology platform. What we mainly want to deliberate upon is a technology platform as a link between product developers and manufacturing engineers. The processes of "acquiring", "refining", and "transfer/sharing" knowledge, in and between projects, are of particular interest.

2.1. Studying two case companies

In this paper we will elaborate on the current practice at two large technology driven companies, Toyota Material Handling Europe (TMHE) and Volvo Car Corporation (VCC), both dependent on their product development efforts. The two companies' product development departments are located in Sweden. The characteristics of the two are presented in Table 1.

The dissimilarities between the two companies were intentionally chosen. This choice was motivated by the need to see if and how, knowledge management requirements differ between industry sectors, market segments and customer relations. Three case studies were conducted in order to substantiate theory and collect data to answer the research questions. Eleven interviews at TMHE (2011-2012), ten interviews at VCC (2013), and then nine follow-up interviews at TMHE (2013) were conducted. The interviewees consisted of product developers, quality engineers and senior-level managers, all affected by how knowledge is managed in product development projects. The interviews were transcribed and verified by the interviewees. The results were thereafter analyzed and categorized, where core barriers were mapped within a proposed KM life cycle model. Further, as a second phase of the study, the interviewees were invited to a workshop in order to discuss the results for internal consistency. As a concluding stage, a final presentation was held at the case companies to validate the results. The internal and external acceptance of the findings indicates possible high impact of this study on the future of KM within product development.

Table 1. Characteristics of the two case companies.

Characteristics	TMHE	VCC
Market Segment	Premium/volume	Premium/customized
Customer Relation	B2B	Mainly B2C
Produced units	55 000	449 000
Market Share	Large	Small
Turnover	4 000 M SEK	107 000 M SEK
Products	Platform/Modular	Platform/Integrated (Modular implementation)
Industry Sector	Industrial equipment	Automotive
Drivetrain	Mechanical/Electric	Mechanical/Combustion
Process	Semi automated, Flow/Kanban	Highly automated, Flow/Kanban
Number of Employees	9000	21000

3. Empirical data and analysis

The conducted interviews at the two case companies have given insight into the current state of practice of KM in product development. Between projects within each of the two companies, there is a consistent approach on how to make knowledge reusable, namely by post-project reviews. However, organizational learning might be a dysfunctional process. Some of the most critical questions and corresponding answers from the interviews and workshops are given in Table 2.

Table 2. Representative questions and answers derived from interviews and workshops

Interview Question	TMHE Answer	VCC Answer
How is knowledge generally captured in projects?	Post-project reviews	Post-project reviews
How is the capturing of knowledge regulated?	Moderately regulated	Strictly regulated
How is OL affected by the choice of capturing knowledge?	“We end up with a bunch of different knowledge records that no one uses”	“Every project writes the same lessons learned, so we do not learn as an organization”
How well is ‘previously created lessons learned’ utilized?	“When I search for it I can’t find it, so I ask someone who might know”	”Post-project reviews are often forgotten”
What is the main reason for knowledge not being captured?	“When we perform post-project reviews, individuals tend to be drawn into new projects before their learnings are captured”	“Lack of time” “We do not see the future use of it”
Why is it difficult to gain access to knowledge?	“The system is slow”	”All the information is available, but the landscape of the systems is as scattered as the organization”

The data collected in this study has contributed to the idea that, since individuals create new knowledge, the aggregate lessons learned from a project is a projection of the project members’ knowledge. This reasoning resulted in a KM life cycle described from an individual’s perspective and the idea that barriers can be correlated to this model. Additionally, it was understood that there is a distinction between individual benefit and future user benefit of utilizing knowledge. This reasoning is further discussed below.

3.1. Presenting a KM life cycle model from an individual's perspective

KM life cycles are typically described from a broad perspective [Davenport and Prusak, 2000, Ward and Aurum, 2004]. Conversly, in this paper a strict connection between an individual and the knowledge life cycle is proposed and presented, see Figure 1. This proposed model is based on theory and empirical data. It has its base in organizational knowledge, represented by the technology platform, and follows the individual knowledge application involving four processes ("acquisition", "creation", "refinement", "transfer/sharing") and three decision points ("knowledge reused", "knowledge created", "knowledge captured"). In every decision point, the individual is encouraged to take action on what the past process has given and how to move on to the next. The process of "creation" is not focused upon in this paper.

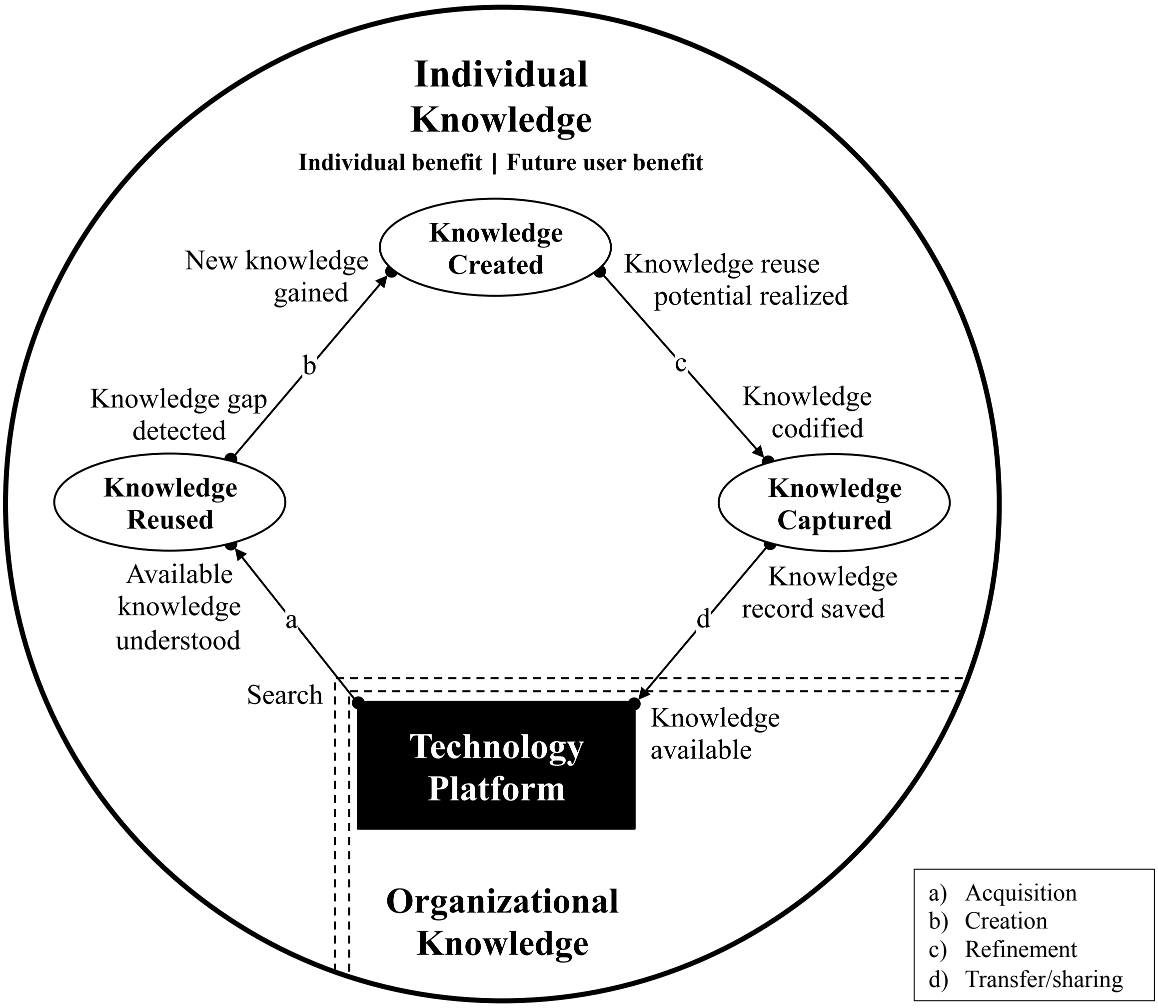

Figure 1. The proposed KM life cycle, presented from an individual's perspective.

The processes are described from an individual's (project member's) point of view. It describes how the individual travels in the model domain – searching for knowledge in the technology platform, understanding knowledge records, detecting a knowledge gap, closing the gap by creating new knowledge, codifying the knowledge into a record and finally making new knowledge available by feeding it back into the technology platform. In an ideal process, certain barriers are overcome along the way, or no barriers exist. However, an ideal process is seldom genuinely representative. What is possible though, is to move towards the ideal process.

The identified core barriers in this paper have been derived through analysis of the empirical data collected from the two companies and the three case studies. The core barriers are mapped into the processes of the presented KM life cycle model, see Figure 1.
There is also a mind-set change included in the model in order to distinguish the individual's contribution to the company's aggregate knowledge capabilities. The first half ("search" to "new knowledge gained") describes the processes ("acquisition" and "creation") from an individual benefit (short-term) perspective ("what knowledge do I need?", "what is the benefit for my work?", etc.). The knowledge that is missing, to complete a task, has to be created for own benefit (see process "creation" in Figure 1). However, the second half of the model (from "knowledge reuse potential realized" to "knowledge codified") describes the processes ("refinement" and "transfer/sharing") from a future user benefit (long-term) perspective ("what knowledge do future users need?", "what is the benefit for future user's work?", etc.). This mind-set is summarized in Table 3 below.

Table 3. The first half of the proposed KM life cycle describes a mind-set from an individual benefit (short-term) perspective. The second half describes a mind-set from a future user benefit (long-term) perspective. This is illustrated by presenting questions related to each tangent point ("search" or "knowledge available") of the technology platform.

	Which knowledge do…	Where do…	What keywords do…	How do…
Short-term	…I need?	…I search?	…I search for?	…I apply located knowledge?
Long-term	…future users need?	…future users search?	…future users search for?	…future users apply located knowledge?

The preparation work done by an individual during the "refinement" and "transfer/sharing" processes will be the basis for the "acquisition" process for another individual. Therefore these processes are of great interest.

3.2. Identifying and mapping core barriers

The present practice at the case companies for measuring effectiveness of a product developer or a product development project does not involve working with KM such as post-project reviews or lessons learned. Without dedicating time or receiving encouragement from managers for these efforts, other tasks become more important to deal with. The interviewees state that there is (1) lack of time and they point out that they are already overloaded. The tasks concerning KM are often given low prioritization.
Incremental development implies designing and improving products. A preconceived opinion is that reusing knowledge will constrain the possibility to develop better products that represent the developer.

a) Process: acquisition

Knowledge acquisition involves the search, recognition, and the assimilation of potentially valuable knowledge until it is understood. In this context it aims at describing knowledge acquired from the technology platform that has been embraced and understood. The KM life cycle is seen from the perspective of individual interaction in relation to the technology platform. Acquisition thereby includes internal search of knowledge that is seized in the organization's memory – the technology platform. Grafting (adding desired knowledge from outside in the form of an individual) and searching from external sources, that are not included or linked to the technology platform, are parts of the creation process which is different from Huber's definition of acquisition [Huber, 1991].

Several core barriers have been identified within the process "acquisition". (2) It is unclear to know when to look for knowledge in the technology platform and, due to that, valuable knowledge can be missed unconsciously. Even if an individual tries to acquire knowledge, it must be (3) accessible and (4) available, concerning search-and-find functionality and configured restrictions. In the companies

the user is required to know the part number related to the knowledge sought. Also, in some cases the knowledge is restricted to only a dedicated set of users.
Knowledge can be expressed in many ways. (5) An unstructured record, bad language and poor grammar may prevent the receiver to assimilate knowledge. There is also lack of possibilities to express knowledge by clarifying meanings with help of, for example, illustrations, short describing text, tables and links. (6) A non-updated record may contribute to individuals ignoring knowledge content, due to uncertainty of its validity.

Decision point: knowledge reused

Corresponding concepts for this group of KM-activity are for example; used and applied [Heisig, 2009]. Knowledge from various sources needs to be understood in order to efficiently discover a knowledge gap. "Knowledge reused" refers to the knowledge acquired from the technology platform. Knowledge that might be reused for solving a current task and be the basis for the next process must be selected. In this point the knowledge gap between what we know and what we need to know must be defined to move on to the process of "creation".

b) Process: creation

Knowledge creation involves learning to extend or replace existing knowledge [Nonaka, 1994]. This can be with help from other individuals, both inside and outside the organization (socialization), adding knowledge from different explicit knowledge sources to create new knowledge (combination) or for example learning by doing which is using knowledge from different explicit sources to gain new tacit knowledge (internalization). Knowledge creation however, is not the focus of this study.

Decision point: knowledge created

New knowledge is gained, and this is the vital decision point where one needs to consider if the knowledge is valuable for future users or not, and if so, the knowledge must be codified. In order for the knowledge to become available for the organization, as in the technology platform, it has to go through the process of "refinement", where the new knowledge is codified into a new record or an existing record. The main function of this decision point is to carefully select which knowledge that can be of value for future users. How this selection process is done is not included in this study, however it is considered a very interesting question for further studies.

c) Process: refinement

Refinement is the process where the created and filtered knowledge becomes codified. Tacit, or implicit, knowledge must be explicated, codified, organized into an appropriate format and evaluated according to a set of criteria before it is ready to be disseminated within the organization. Explicit knowledge needs to be formatted and evaluated. The refinement process includes two opposing actions, either an existing knowledge record can be updated or replaced, or a completely new knowledge record is composed with new knowledge.
If the benefits of utilizing knowledge are not apparent, an individual might discover (7) lack of motivation. This may result in prioritizing other tasks, or ill result on the codifying of knowledge. At the case companies there are (8) lack of routines for what, when and how to create knowledge records. Without routines, knowledge records are rarely generated before individuals are drawn into other projects. And, over time, (9) individuals forget what they have learned. No matter how hard an individual tries to remember something, there are always things that will be unspoken. This is coupled to Snowdens principle number seven of KM: "we always know more than we say, and we always say more than we can write down" [Snowden, 2008]. The efforts for refinement is seldom given enough time, especially if an individual do not have a major impact on the project or product and do not have the opportunity to instantly add knowledge into a record. Sometimes short interruption is enough to forget necessary details.
Currently, a series of complex operations makes it (10) difficult to update a record. Records uploaded into the product data management (PDM) system need to be checked out, edited, sent to record owner,

accepted and then checked in to the PDM system. The steps in which the operations are performed are complicated and difficult to understand, even if the user has repeated the task several times.

Decision point: knowledge captured

When knowledge is captured in a knowledge record a decision needs to be taken with consideration to who the knowledge receiver is, and how the knowledge will be best made available for future use. Transfer refers to when sender and receiver are defined. Sharing refers to when the knowledge is spread throughout the organization to individuals that are usually unknown to the contributor [King, 2009].

d) Process: transfer/sharing

When performing the important step of mixing transfer and sharing, a high pressure is put on the system to work the way that is expected. (11) Difficult to transfer, which involves preparing for availability and accessability for a specified receiver. (12) Difficult to share, which involves preparing for availability and accessability for an arbitrary receiver.

4. Discussion

This paper is deliberated from the perspective of exploiting many individuals' knowledge for organizational use and value previous insights. This presumes that an organization will learn continuously in order for companies to meet the ever-changing demands from customers and users.

4.1. Batchwise vs. continuous knowledge feeding

In this paper it is shown that a long time between individual "knowledge gained" to a post-project review might slow down potential positive impact on organizational learning. This is partly because knowledge is forgotten and individuals are drawn into other projects before individual learnings are shared. Continuous knowledge work is proposed to nourish the ability to capture valuable knowledge into a technology platform before it is filed away somewhere in the individual memory, where it is difficult to access. Continuous knowledge work is an improvement of the batchwise knowledge work process, which is defined as lessons learned submitted when the project is completed, i.e. post-project reviews.

Continuous knowledge work refers to new valuable knowledge being fed into the technology platform continuously for future use during every project. Knowledge ownership is taken as an important aspect for refining, maintaining and updating knowledge. The empirical data and literature states that a knowledge owner is necessary to keep the knowledge records updated in the technology platform. The knowledge owner should be responsible for different tasks such as being a mentor or contact person for a specific knowledge area and be responsible for keeping the knowledge updated, available and relevant. For continuous knowledge work it is recommended that the knowledge creator hold the knowledge ownership instead of one single defined individual, e.g. the project manager trying to capture all project members' learnings. To increase the benefits of KM efforts a proposal is to move the feeling from obligation to long-term benefit to feed the technology platform, which in turn will build organization knowledge.

Working with continuous knowledge work provides the potential to speed up the knowledge sharing between projects since knowledge then can be transmitted faster into the technology platform.

4.2. How to overcome certain core barriers

The path towards overcoming certain barriers is not one-dimensional. One way to meet the challenge is by giving the individual the opportunity to feed the technology platform instantly. This concept also includes feeding knowledge continuously, keeping knowledge updated and valid. Updating knowledge records can be initiated for different reasons: knowledge has been enhanced, is missing, is incorrect or contains other errors. Instant knowledge work can be made possible with a supporting software that has a low user threshold, is easy to use and supports the knowledge holder in the process of making the knowledge explicit. In such a concept, changes can be instantly updated – small changes or corrections. However, for large updates, a proposal should be sent to a knowledge owner for acceptance, and during the time before it is accepted it is marked, to visualize the proposal.

The following aspects need to be considered in order to develop a software that supports instant knowledge work, which may be used to overcome core barriers:

- User friendliness
- Focus on visualization for increased utilization of knowledge
- Acquiring knowledge records
- Creating new records and specifying standards for different types of records
- Updating records, making update proposals
- Accepting or declining update proposals
- Accessability
- Availability

5. Conclusions

Core barriers at the case companies are categorized into the four different processes ("acquisition", "creation", "refinement" and "transfer/sharing") in the proposed KM life cycle described from an individual's perspective, illustrated in Figure 1. The identified core barriers are for example; (1) lack of time to perform KM activities, (3) low accessibility and (4) availability of knowledge, (6) non-updated knowledge repository, (7) motivation to utilize knowledge, (8) knowing what, when and how to store knowledge, (9) the fact that individuals forget and (10) non-user friendly software. The two companies have a short-term perspective. There is a need to move from the definite perspective of reusing knowledge for instant problem solving to focus on continuously and instantly feed knowledge to support future problem solving. This long-term resilient perspective of letting many individuals feed valuable knowledge into the technology platform may increase the awareness of each individual's perceived benefit of reusing knowledge, which may have positive impact on aspects such as motivation. This should however be further studied along with how to determine what knowledge to capture for future users' benefit.

Continuous and instant knowledge work has the potential to support and help the organization to benefit from all the positive aspects that reusing knowledge involves. It allows the user to affect the actual content of their knowledge. Continuous and instant knowledge work is a mind-set, a software and a methodology, that together support the organization to deal with some core barriers derived from working with post-project reviews.

At the moment, a software is under development, and an implementation at Toyota Material Handling Europe is planned for. From this study further issues have been identified and need to be taken into consideration. For example, how knowledge can be presented and visualized to improve the precision and understanding, instant update functionality and possibility for multiple users to interact with the same knowledge record simultaneously.

For future research several possibilities have emerged: test how continuous and instant knowledge work may be implemented to overcome core barriers, and how to further develop the KM life cycle from an individual's perspective. We want to be able to integrate valuable knowledge in the organization and make it seamlessly available and accessible. Future studies may be employed to figure out how to select valuable knowledge for future users.

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