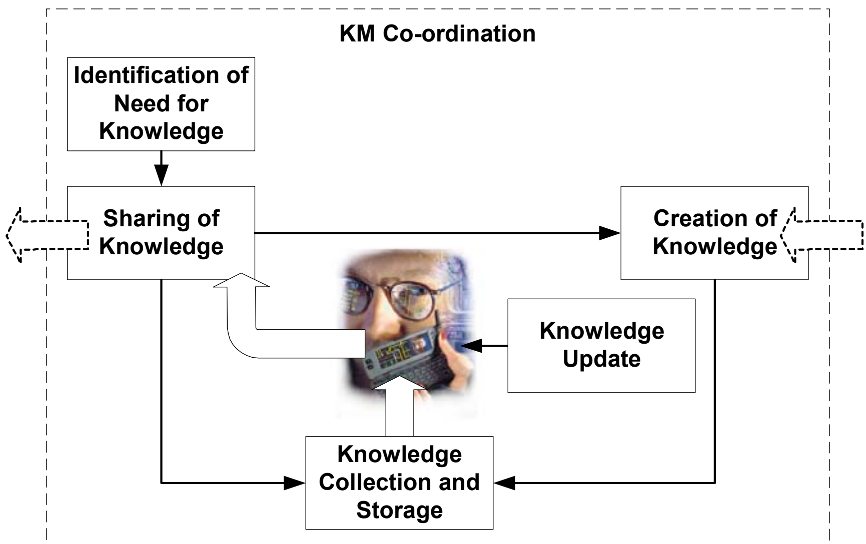
Timo Kucza

Knowledge Management Process Model



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Abstract

This report presents the results of research into knowledge management (KM) performed at VTT Electronics, the Technical Research Centre of Finland. Based on literature analysis and prior experiences with software process improvement (SPI) projects, a process model is proposed as an abstract and generic model to be used in KM projects. Its purpose is to enable one to understand knowledge management, perform analyses and plan processes in a structured way, as well as ensure that important aspects are taken into account in KM projects. A distinction into two separate parts of the model is used, which divide the processes into co-ordination processes and operational processes. Herein, co-ordination processes describe what needs to be performed to initiate and control knowledge management activities; operational processes describe what is done when performing knowledge management activities. The co-ordination processes are organised into a cycle of analysis, planning, defining and effecting to support continuous improvement. The operational processes consist of the main processes: identification of need for knowledge, knowledge sharing, knowledge creation, knowledge collection and storage, and knowledge update. The model is presented on a detailed level, meaning that the mentioned high-level processes are refined into 39 more detailed processes. Each of these is presented by describing its input-links, the activities the process covers, products, and output-links. Initial verifications made are presented. The model and its use is discussed, and finally, an outlook on further activities related to the development of the model is presented. The discussion covers both the explanation of expected benefits and anticipated pitfalls/shortcomings. Further development needs to address the identified shortcomings thus extending the model and thus allowing it to mature.

Preface

At VTT Electronics, knowledge management research has been part of software engineering research. Knowledge management is a new complex topic that requires new ways of thinking.

The research task, as given to me, was to determine the type of processes taking place within Knowledge Management to increase the understanding of KM. Having worked extensively with the V-Model, a generic reference model in software development, I had the idea of creating a similar, detailed process model for KM. This report presents the results of this approach.

Many people at VTT have directly or indirectly contributed to this work and influenced its outcome. I would like to express my sincere gratitude to my colleagues in the Embedded Software Engineering Group; especially to Seija Komi-Sirviö, Minna Pikkarainen, and Päivi Parviainen. They assisted me in getting into scientific work as well as, with patience, in endless discussions about KM. Also Dr. Tua Rahikkala, Cybelius Software Ltd., has taken part in the early discussions and helped to direct this work to the right direction. I'm also grateful to Professor Veikko Seppänen, who reviewed this report and provided constructive comments.

The work related to this report was mainly performed in the TOTEM projects, a series of strategic research projects funded by VTT Electronics. I would like to express my gratefulness for the opportunity to learn as much as I have learned throughout this work. Some of the later developments of this model were made within the Knots-Q project, funded by Suomen Akatemia (Academy of Finland). This funding is gratefully acknowledged.

Oulu, 2001-12-01

Timo Kucza

Contents

List of Symbols

BPR	Business Process Re-engineering
CKO	Chief Knowledge Officer
CSA	Current State Analysis
DMS	Document Management System
GQM	Goal/Question/Metric
HRM	Human Resource Management
IM	Information Management
IT	Information Technology
KM	Knowledge Management
KO	Knowledge Officer
PDM	Product Data Management
Pr^{2}imer	Practical Process Improvement for Embedded Real-time Software
QM	Quality Management
R&D	Research and Development
ROI	Return-on-Investment
SE	Software Engineering
SPI	Software Process Improvement

SPICE	Software Process Improvement and Capability Determination
SW	Software
UI	User Interface
VTT	Technical Research Centre of Finland

1. Introduction

"Knowledge management is really about recognizing
that regardless of what business you are in,
you are competing based on the knowledge
of your employees."

Cindy Johnson,
Director of Collaboration and Knowledge Sharing
at Texas Instruments[1]

Knowledge is essential in everyday work. Everyone knows how to carry out his work and this knowledge can be reused later in similar tasks by adopting this knowledge to new situations. The general purpose of Knowledge Management (KM) is to make knowledge usable for more than one individual, e.g. for an organisation as a whole; that is, to share it. New knowledge-based views on organisations suggest that it is knowledge that holds organisations together [Brown and Duguid 1998]. KM has existed and has been used for a long time, although it was neither called by this name nor necessarily recognised as what it is until a few years ago [Davenport and Prusak 1998]. The way of making knowledge available for others has evolved with time. It once started with family clans, where knowledge was passed on from father to son by a long process of learning. With the coming up of teamwork, people were supposed to work closer together to benefit from the synergy of their joint knowledge. Today's efforts aim at knowledge being shared among large organisations which may be geographically spread over the world and active in different kinds of areas. First cases perform this sharing even among different organisations, e.g. use defined interfaces to mediate knowledge not only inside one specific organisation but to also share parts of it among partners.

Another change influencing knowledge acquisition and sharing is the steadily increasing speed with which new technologies are evolving. These always

1 Cited in [O'Dell and Grayson 1998].

require new or updated knowledge and allow new working practices. As an example, there is a growing number of new versions of software systems/applications and new or revised standards. Successful organisations need to absorb and utilise an increasing amount of knowledge to keep up with this development. At the same time, knowledge becomes outdated faster. As Kevin Marler put it: "You no longer need to be managing a sophisticated research lab for your people to be on the brink of technological change" [Marler 1999]. This emphasises both the need for new knowledge in general and the need to manage the according processes to enable one to deal with large amounts of knowledge in a shorter time.

Today, knowledge is increasingly considered the most important asset of organisations [Carneiro 2000] and it is assumed that every experience is reusable [Basili and Rombach 1991]. This does not apply only to specific parts like programming code but also means that any knowledge can be reused by others. "Identifying, managing, and transferring knowledge and best practices has worked for some companies, sometimes saving or earning them literally billions" [O'Dell and Grayson 1998]. But "Knowledge management is an evolving practice. Even the most developed and mature knowledge management projects we studied were unfinished works in progress" [Davenport and Prusak 1998].

1.1 Research Problem and Approach

KM is nothing new and research into it can be traced back for decades [Davenport and Prusak 1998]. However, standardised KM methods and techniques are still not available, if not taking into account some publications on “best practices”. Different attempts to determine KM have been undertaken (e.g. [Nonaka and Takeuchi 1995, Davenport and Prusak 1998, Wiig 1999, Bhatt 2000]), but they have always dealt with high-level processes only, been too specialised on specific aspects, or dealt with KM too broadly. KM is difficult due to its nature and complexity. While knowledge itself is something intangible, KM has to cover various aspects such as

- the way people work together (sociology),

- the way specific people react to specific situations and changes in the environment (psychology),

- what are the technical tools that can be of assistance in the creation and mediation of knowledge (information technology), and so on.

Accordingly, there are many possible approaches to research on KM. The approach selected for this research was to look at the processes taking place within KM with the goal of developing a representation that is simultaneously both simple and comprehensive enough. A process-oriented view on activities has helped in understanding and managing other activities in the past. This applies to both individual activities such as business processes of one's own which are written down in quality handbooks according to ISO 9001, and to general process models like those for Software Engineering (SE), these including, for example, the V-Model ["The V-Model" 1996]. Standardisation is regarded a big competitive advantage in today’s complex environments [Rada and Craparo 2000]. Thus the goal was set to create a presentation of KM processes allowing a common understanding of KM, providing a possible framework for analysing KM, and enabling a structured approach to KM projects in which interfaces can be designed between different application areas. This was started by collecting the results of the studies on KM from various literatures such as [Nonaka and Takeuchi 1995, Davenport and Prusak 1998, O'Dell and Grayson 1998].

As there does not seem to be any detailed models on KM available, one had to be made up. The processes found have been generalised and should be applicable to various KM activities. Together they build a process model for KM, i.e. an abstract and generic reference model providing a description of necessary steps of KM. Thus, the processes presented in the following are templates which need to be adapted to the concrete needs of a KM initiative, i.e. have to be instantiated.

1.2 Document Roadmap

In Chapter 2, relevant terms used in this document are defined and a general introduction to issues related to KM is provided. These include the nature of knowledge, the nature of people with respect to KM and the impact of KM on organisations. There is also a description of further focuses and strategies for KM as proposed in literature.

In Chapter 3, the proposed process model for KM is described on a high level. An overview is provided by explaining the general structure and introducing the processes and their relation to each other. The processes are divided into two major categories: co-ordination processes and operating processes.

In Chapter 4 and 5, the two main categories of processes are presented in detail, and sub-processes are proposed for each process. Each sub-process contains relevant input-links, activities, expected products and relevant output-links.

In Chapter 6, the proposed process model is discussed by focusing on the way it can be used in its current form. The anticipated benefits and possible pitfalls are listed and explained, and the verifications performed together with industrial partners are described. Finally in Chapter 7, conclusions are drawn and an outlook is provided on the further development of the KM process model.

2. Knowledge Management

The "rate of change in technologies exceeds the time to develop subject matter experts, training courses, and human resource interventions" [Marler 1999]. However, not only technologies are changing faster, but also products and product-lines, laws etc. Therefore, the focus is on how to speed up knowledge creation and sharing. KM is supposed to be the answer to this question. Before getting to the core of this work, the KM processes, terms are defined and KM and some important factors influencing it are introduced. The purpose is to provide an overview of the topic and the most important related areas. Although every organisation has somehow dealt with knowledge since its beginning this does not mean that it is easy to control and steer KM processes. "Organizations cannot truly manage knowledge because it is tacit or internal to individuals; however, they can manage the environment necessary for the community of practice to flourish and share information that is a product of that knowledge" [Jarzombek 1999]. Knowledge can be managed - at least to a certain grade [Stecking 2000]; a proper management of the environment, however, is a necessary precondition [Davenport and Völpel 2001].

The following sections introduce the most important topics generally affecting KM. Definitions for the terms used throughout this work are provided and issues concerning KM are introduced. Finally, common strategies for conducting KM are listed.

2.1 Definitions

In the domain of KM, multiple different attempts to categorise, classify, and define knowledge and related terms have been undertaken in the past [Davenport and Prusak 1998] and are still questioned, widened or changed [Tuomi 1999]. [Spiegler 2000] presents an overview over this development. The following set of terms is used in this document:

- **Knowledge**: Knowledge is used as an overall term, without making a further difference between wisdom, intelligence, creativity etc. A common expression for knowledge is "information in action", i.e. information applied for a purpose. Thereby it is pointed out that knowledge is context-specific.

According to [Nonaka and Takeuchi 1995], there is a difference between tacit and explicit knowledge. Tacit knowledge is knowledge in the human mind and it is difficult to externalise or mediate. Explicit knowledge is formalised knowledge, i.e. knowledge recorded as video, in a document, etc. and usually covers part of the original tacit knowledge but is not a full representation of it. Implicit knowledge can be transferred throughout any direct face-to-face communication between people or by transmuting it into explicit knowledge and sharing the according artefact. The transformation back to tacit knowledge takes place during the reading and understanding of explicit knowledge. Knowledge can thus have various shapes. Knowledge transfers can take place by means of a technical system or can be performed by human interaction. Throughout this document the processes cover any appropriate way of transferring knowledge, and knowledge refers to the appropriate state of knowledge, either tacit or implicit. Or, like Albert Einstein expressed it: “Knowledge is experience. Everything else is just information.” [McDermott 1999].

- **Knowledge Management**: According to the above definition of knowledge, KM is the overall task of managing the processes of knowledge creation, storage and sharing, as well as the related activities. Generally speaking, this has to include the identification of the current state, the determination of needs, and the improvement of affected processes in order to address these needs. Consequently, KM projects are improvement projects. Three main aspects have to be taken into account in these projects. The first is the management of general conditions in an organisation (the cultural environment and the KM processes). The second is the provision of assistance for the direct, inter-human KM processes, i.e., communication. The third is the management of generation, distribution, access and use of knowledge coded into artefacts (documents, training, videos etc.), i.e., information management. Due to KM ranging under these different dimensions, it has to take into account or incorporate such activities as Business Process Re-engineering (BPR), Document Management Systems (DMS), Human Resource Management (HRM), Quality Management (QM), Product Data Management (PDM), and Information Management (IM), which all relate to KM.

- **Knowledge Levels**: The following different levels of knowledge can be differentiated. Firstly, a distinction has to be made between ***internal and external*** knowledge. Internal knowledge is adapted to the specific needs of an organisation, while external knowledge is on a more general level and needs to be adapted before it can be utilised inside an organisation. This has to be taken into account when dealing with inter-organisational knowledge transfer, which requires the knowledge to be adapted to the circumstances of the receiving organisation. Secondly, knowledge levels in an organisation can be differentiated according to the ***holder****:* individual, group, and organisational levels. Contrary to individual knowledge, group knowledge is the combined knowledge of e.g. a team, being more than the sum of the knowledge of all team-members, because the variety of knowledge contributed by the different members results in new knowledge [Brown and Duguid 1998]. The organisational level denotes a special kind of group knowledge as it describes knowledge formed by all the members of an organisation, i.e. knowledge embedded into the overall business process. Organisational knowledge is the overall know-how of an organisation including all the different activities taking place in it. Knowledge levels can be differentiated further according to the ***knowledge scope***, which has vertical and horizontal differences. The vertical differences vary from less abstract to more abstract (factory workers need different knowledge from that required by managers). Depending on the topic, the horizontal differences include, for example, QM, Controlling, and HRM on the executive level and R&D, product design, and product development on the operative level. Finally, knowledge can be differentiated on the basis of the ***knowledge depth***. Thus, initial awareness of facts and the ability to apply data to certain situations and act appropriately is the basic level of knowledge, which equals an understanding of one's own role in an organisation. Knowledge then tends to specialise. This signifies a higher level of knowledge - an understanding of the detailed processes in complex machines like nuclear power sources serves as such an example. The requirements on the knowledge depth depend on the knowledge scope, i.e. on the level of senior management, only basic knowledge is needed about the concrete production processes while knowledge of higher level is required about the organisation as a whole. Whereas producing units need to have a detailed knowledge of the production processes and accordingly need only basic knowledge about the organisation as a whole.

- **Knowledge Domains**: During the development of the process model, there arose the question how to differentiate between different knowledge levels. Knowledge domains serve as the standard means for this purpose. An organisation starting its first KM activities should start with one knowledge domain as a pilot project; for example, with knowledge about testing in the SE process. New domains should not be addressed before the processes designed for the first domain have proven to work out. Domains can address different knowledge holders, knowledge scopes and knowledge depths. A proper determination of knowledge domains is important for the success of KM activities, as different knowledge depths will have different requirements on the knowledge processes.

- **KM Co-ordination/Operational Processes, Sub-Processes, Input-Links, Activities, Products, and Output-Links**: Throughout the description of KM process model a distinction is made between KM co-ordination processes and KM operational processes. The KM co-ordination processes cover the management of KM thereby including planning and tracking, and the KM operational processes cover the actual work with knowledge, such as creating, storing, and sharing knowledge. Each process is divided into sub-processes, which split each process into different stages. Each sub-process is in its description presented by input-links, activities, products, and output-links. Input-links provide information on what kind of input a sub-process requires or is able to handle: such examples include activation by another sub-process and the type of documentation or results from other sub-processes used in it. The activities provide an example of the steps taken in executing a sub-process, and products describe the results of a sub-process. The output-links provide information on the activation of other sub-processes, or help to define in which other sub-processes the products are needed or utilised.

- **KM System**: A KM system is the overall product produced when the KM process model is applied. It consists of a number of KM domains and according, defined KM processes that are linked with other organisational processes, and it incorporates tools and techniques to be used in these. This includes co-ordination processes for the tracking and possible modification of the operational processes. Thus, a KM system is a complex unit of different layers (co-ordination processes and operational processes for each

KM domain) dealing with the different aspects of KM: influencing culture, facilitating creation and sharing of knowledge, providing tools and methods, and monitoring KM processes.

2.2 General KM Issues

This section presents a summary of the important influencing factors related to managing knowledge, these including the nature of knowledge, the nature of people, and organisational environments. Each of these has a remarkable impact on KM, as explained in the following.

2.2.1 The Nature of Knowledge

The ongoing discussion about defining knowledge and related terms is a sign of both the complexity of this topic and the various different viewpoints which the issue can be approached from. This kind of analysis is not carried out here. It can be said that knowledge is something that evolves in people's minds by a combination of data, information and experiences. There are two general categories of knowledge, which have to be differentiated: tacit (implicit) knowledge and explicit knowledge [Nonaka and Takeuchi 1995][2]. Tacit knowledge is the internal knowledge which is hard to describe (like e.g. how to ride a bike - everyone can do it, but hardly describe it), while explicit knowledge is codified knowledge, that is, knowledge written down (like e.g. a handbook).

Knowledge is generated only in people's minds [Nonaka and Takeuchi 1995]; also, it is very complex. It has to be, because human actions depend on a large number of parameters. It is the complexity that enables the adoption to different kind of situations. Similarly to a procedure in a programming language, which can solve a certain number of problems by using parameters to define a concrete problem, knowledge provides different reactions depending on the situation. In contrast to code, the parameters of knowledge are unfortunately hardly countable

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[2] Nonaka and Takeuchi refer to: Polanyi, M.: The Tacit Dimension. Routledge & Kegan Paul, London, 1966.

and definable. This makes it difficult to record or document knowledge in such a way that others can benefit from it. It is difficult but possible, however, to turn tacit knowledge into explicit knowledge. This kind of knowledge can be stored and transferred and be later turned into implicit knowledge by the receivers. However, such explicit knowledge never describes the original tacit knowledge as a whole, but instead assumes a common basis of understanding on which the transmission back to implicit knowledge is based.

Because human minds can be assumed to have knowledge about many things, another problem is how to locate knowledge, i.e. find out who has knowledge about what. This is not always a problem when dealing with a small number of people. But crossing the border somewhere between 200 and 300 people [Davenport and Prusak 1998], it becomes impossible for everyone to know who knows what. Also organisational knowledge held by a group of individuals requires that a number of storage places be taken into account instead of only one specific one [Brown and Duguid 1998]. A distributed environment, as it becomes more and more common with organisations acting globally, makes this even more difficult. Therefore, besides storage, a major problem is how to make knowledge locatable, which is a precondition for an effective and efficient use.

But even if knowledge is stored and can be located, the problem of determining who needs what knowledge, and when, stays. At this point it becomes important to interface KM processes with other organisational processes. This has to be done in such a way that it allows the identification of needs for knowledge and accurate determination of these needs based on which the stored knowledge can be then accessed.

Modern technology offers new and extended possibilities, such as codification to videos/animations, transmissions across distances, and communications via videoconferences etc. The use of technology therefore plays an important role in KM. However, knowledge is mainly about humans and therefore the role of technology can only be of assisting nature [Davenport and Prusak 1998, McDermott 1999].

2.2.2 The Nature of People

Additionally to the nature of knowledge, KM is also difficult due to the nature of people [Davenport and Prusak 1998]. This is especially problematic, because the possibilities to influence people are limited and difficult, while on the other hand people's decisions heavily depend on their personal attitudes [Kreie and Cronan 2000]. Knowledge is part of what makes a person's personality. Passing one's knowledge to others also means enabling others to perform according tasks, thus making the originator more easily replaceable [Davenport and Prusak 1998]. Despite the fact that this is positive and desired from the organisations' point of view, people often tend to keep their knowledge for themselves because they fear that they would not be needed anymore after passing their knowledge to others [Stecking 2000]. Without motivation and a supporting environment, people therefore tend not to share their knowledge. And even if people know about the necessity to share their knowledge with colleagues, they need a certain amount of trust to do so [Davenport and Prusak 1998]. This especially becomes a problem when people do not know each other, which is often the case in today's large organisations. People tend to say then: "Why should I tell others what I know? Shall they go and find out for themselves, as I had to do!"[3] [Stecking 2000].

The usability of knowledge further depends on the way people express it. There are differences in the ability to transfer knowledge directly between people, depending on the will (as mentioned above), the communicational skills but also simply the language they are using [Davenport and Prusak 1998]. For example, a manager who talks to workers in a factory in financial terms may not get the message through. Another problem is that people have different viewpoints on things. Knowledge is not simple as an instruction and depends on values and beliefs [Davenport and Prusak 1998]. This leads to problems when transferring knowledge. So even if a best practice is announced, it might not be adopted because people believe that there is no need to change anything - "People do what seems rational for themselves based on their own agendas and goals, irrational as these might seem to outside observers" [Davenport and Prusak 1998]. Or as a Baldrige-award winner expressed it: "We can have two plants

[3] Translation of the author from the German original

right across the street from one another, and it's the damnedest thing to get them to transfer best practices" [O'Dell and Grayson 1998].

Another psychological factor becomes important in the assessment of knowledge, i.e. when asking people what they know. Assuming that knowledge is valued in an organisation, having knowledge is a synonym for power and influence. People might give wrong or inexact answers, because they either do not know how well they know things or because they try to present themselves as good as possible [Davenport and Prusak 1998]. At this point, the cultural environment given by the organisation becomes very important once again, because it drives people to certain attitudes, which can, in the context of KM, be good or bad.

2.2.3 Organisations

Organisations consist of a number of people connected to each other in different ways (departments, hierarchies, rules etc.). The willingness of individuals to share their knowledge in an organisation heavily depends on the organisational culture. "In addition to providing the infrastructure, organizations have to invest in hiring smart people and providing incentives for sharing information, then provide enough unstructured time to let people talk face to face" [Jarzombek 1999]. To motivate people towards knowledge sharing, the according activities must be encouraged and rewarded from the highest hierarchical level (upper management) to make it clear that sharing knowledge is seen as something important for the whole company, similarly to other improvement activities such as measurement or Business Process Re-engineering (BPR). Without this, the natural tendency mentioned before will prevent the flowing of knowledge.

Not only is there a need for mental support from the management, but also for monetary funding due to the long-term nature of KM projects. Experiences with SW reuse projects show that the benefits are initially difficult to express in financial terms (figures) because they are, at least partly, intangible [Lim 1998]. Convincing management can therefore be hard. This also holds true for KM projects. Further knowledge is something creative and thus continuously developing. Therefore, KM needs to be flexible and capable of steadily adapting to changing environments. As creativity cannot be predicted, there must be space for unexpected ways [Davenport and Prusak 1998]. This combination of being hardly predictable on one hand and having a long-term pay-off on the other hand makes KM a matter of believes.

With the organisations becoming larger and being distributed over cultural, organisational and geographical borders, there are additional problem areas coming up: lesser face-to-face meetings, different cultures and languages, different time-zones, etc. [Rahikkala et al. 1998]. Also, organisations tend to introduce more hierarchies when growing large, thus becoming inflexible. But knowledge might initiate changes, because "higher knowledge levels live near a frequent dissatisfaction and the capacity of questioning what seems to be already understood" [Carneiro 2000]. An organisation needs to be flexible to accept this kind of questioning. The management has to "understand that knowledge of everyday, complex, often messy reality of work is generally more valuable than theory about it" – this is especially important because denying initiatives blocks the development of knowledge and "when knowledge stops evolving, it turns into opinion or dogma" [Davenport and Prusak 1998].

Because knowledge is complex and difficult to handle, people who process knowledge need time. Therefore, it takes even more time before knowledge influences actions and thus may lead to improvements. This once more underlines the long-term nature of KM, so that an immediate return on investment (ROI) cannot be expected. Experiences from SW development projects adopting reuse technologies show a characteristic negative ROI before reuse will start to pay back – and this is hard to predict in advance, as it is usually easier to perform such analysis after the collection of data [Lim 1998]. This can be regarded holding true also for KM projects which additionally are more difficult to measure than reuse projects.

To address the issues mentioned before, it seems sensible to start with a tight focus that improves the everyday work of people in a measurable way. This will enable an understanding towards KM within both: a) management, addressing the willingness to finance and support further KM activities, and b) the staff, supporting the development of a supportive culture. The full synergy, meaning "the whole is greater than the sum of its parts" [Liebowitz 1999], can then be addressed in extensions to cover a growing number of areas.

A modern trend towards the so-called virtual organisations, consisting of several different distributed partners who are steadily changing and therefore only loosely bound, makes management issues principally more complicated while they at the same time become more important [Rahikkala, et al. 1998]. This can be regarded to hold true also and especially for KM. At the same time, it can be assumed that geographically distributed environments require to be especially addressed in KM activities.

2.3 Strategic Planning of KM

The overall goal and possible focuses and strategies for KM are introduced in the following.

2.3.1 Focus

Companies that have already undertaken efforts towards KM have chosen different strategies for KM [Grayson and O'Dell 1998]:

- *Knowledge as a product:* Knowledge is generated, packaged and sold.
- *Transfer of knowledge and best practices:* Identification of best practices and transfer to other parts of the company.
- *Customer-focused knowledge:* Capturing customer's needs, preferences and businesses to increase sales.
- *Personal responsibility for knowledge:* Support every single people in identifying, maintaining and expanding his or her knowledge.
- *Intellectual-asset management:* Enterprise-level management of specific intellectual assets like patents, technologies and operational and management practices.

This enumeration shows that there are several different options on what KM can focus. It principally seems desirable to share existing knowledge as extensively as possible in an organisation [Davenport and Prusak 1998] to benefit from synergies. For example, knowledge about a product might be helpful not only in product development but also in marketing. As stated already, especially in initialising KM a tight focus is reasonable - this can be achieved e.g. by conducting a pilot project. This work can later be expanded. To enable a development from pilot projects to overall KM, processes have to evolve according to the actual scope. First KM processes are made to match the pilot project. With the scope being widened to a whole unit or even multiple units, also the processes need to be adopted.

This leads to the idea behind KM, which is to turn an organisation into a learning organisation. This means [Liebowitz 1999][4]:

- Continuous learning of individuals and integration of knowledge to organisational routines and actions,
- Effective knowledge generation and sharing among the people in the organisation and eventually also outside the organisation (it may be embodied in products or services),
- Critical, systemic thinking allowing the questioning of established procedures,
- A culture of learning, where new ideas are honoured and rewarded,
- A spirit of flexibility and experimentation including the possibility to take risks in order to innovate, and
- A people-centred environment, that cares about the development and well-being of people.

As mentioned, knowledge is in a strict sense created only in human minds. Therefore a transition from individual knowledge to organisational knowledge

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4 Liebowitz refers to: Gephart, Marta et al: Learning Organizations Come Alive. In: Training and Development Journal, Issue December, 1996.

needs to be performed. This process can be described as a spiral according to [Nonaka and Takeuchi 1995]:

1. Socialisation (tacit - tacit): Tacit knowledge is shared among individuals allowing the creation of new knowledge.

2. Externalisation (tacit - explicit): Tacit knowledge is formed into explicit knowledge by the creation of concepts.

3. Combination (explicit - explicit): The created concept is justified through a combination with existing knowledge, e.g. against the criteria cost, profit margin, etc.

4. Internalisation (explicit - implicit): The new external knowledge is shared within the company. People create tacit knowledge from the explicit knowledge by internalisation, thus adding this knowledge to their knowledge pool, which can start the spiral up again.

KM should in accordance with the ideal cover all the sections and activities of an organisation, i.e. manage all the knowledge of a company. Today it looks like this kind of scope is likely to stay an ideal. KM can, however, efficiently connect such distinct areas as research, SE, QM, marketing, etc., which today are often seen as single entities. Due to the problems mentioned above, there is too much wishful thinking in the thought of turning an organisation into a knowledge creating and sharing company all at once. Therefore, the focussed start with pilot projects is sensible.

2.3.2 Strategies

There are several possible strategies to conduct KM. In general, these can be categorised as shown in Table 1 [Liebowitz 1999]. This schema differs between input (contribution) and output (dissemination), the general parts of KM. Passive contribution means that contributions to the knowledge system are made occasionally, depending on to what extent people recognise topics worth integration. Contrary to this, active contribution means that such topics are searched for all the time (e.g. code analysis for code reuse). Passive analysis and dissemination means that any input made is accepted to the knowledge base without any validation (e.g. general common storage place) and usage of the knowledge base is not promoted ("use it or leave it"). Whereas active analysis and dissemination means that any input to the knowledge base is validated (e.g. knowledge team controlling the content) and usage of knowledge is promoted (e.g. feeding knowledge to users).

Table 1. KM Models.

Name	**Contribution**	**Analysis & Dissemination**
Knowledge Attic	Passive	Passive
Knowledge Sponge	Active	Passive
Knowledge Publisher	Passive	Active
Knowledge Pump	Active	Active

The table shows how KM becomes more efficient - from top to bottom (the two in the middle are alternatives):

- Knowledge Attic: just provides a basis, the rest is left open,
- Knowledge Sponge: improves the collection of knowledge but does not influence the use, or Knowledge Publisher: does not influence the collection, but does facilitate the use of knowledge, and finally
- Knowledge Pump: powers both, the collection and the use of knowledge.

Knowledge pump is a desirable option when one wants to get the most out of KM. In accordance with this, a KM project needs to support simultaneously the active contribution and active dissemination of knowledge. To achieve this, it is predictable that a strong supportive culture is needed and that the KM activities have to be linked to other organisational processes.

3. Structure of the KM Process Model

This chapter introduces the KM process model by introducing its main processes, sub-processes and the way these are refined to tasks. The process model can be separated into two major parts: the co-ordination processes and the operational processes. The co-ordination processes represent the management tasks related to KM, these including analysing and planning KM, dealing with organisational issues, etc. They are structured into a cycle that supports continuous improvement and is based on the "Practical Process Improvement for Embedded Real-time Software" (Pr^2imer) model [Komi-Sirviö, et al. 1998]. This model proposes a cycle of four stages for process improvement projects: current state analysis (CSA), definition of a target state, plan for development measures, and pilot operation and commissioning (see Figure 1). After the cycle has been performed, it starts with the first phase again. This cycle has been adapted for the KM process model as the KM Pr^2imer consisting of the following phases: analyse, define, plan, and effect. These phases will be described in more detail in Chapter 4.

Figure 1. Pr^2imer Model.

The operational processes present the processes of actually carrying out KM, i.e. knowledge collection, sharing, update, etc. Before elaborating on the processes and their sub-processes in the following sections, an overview of the model is provided below: Figure 2 shows the main processes of the model and their basic dependencies.

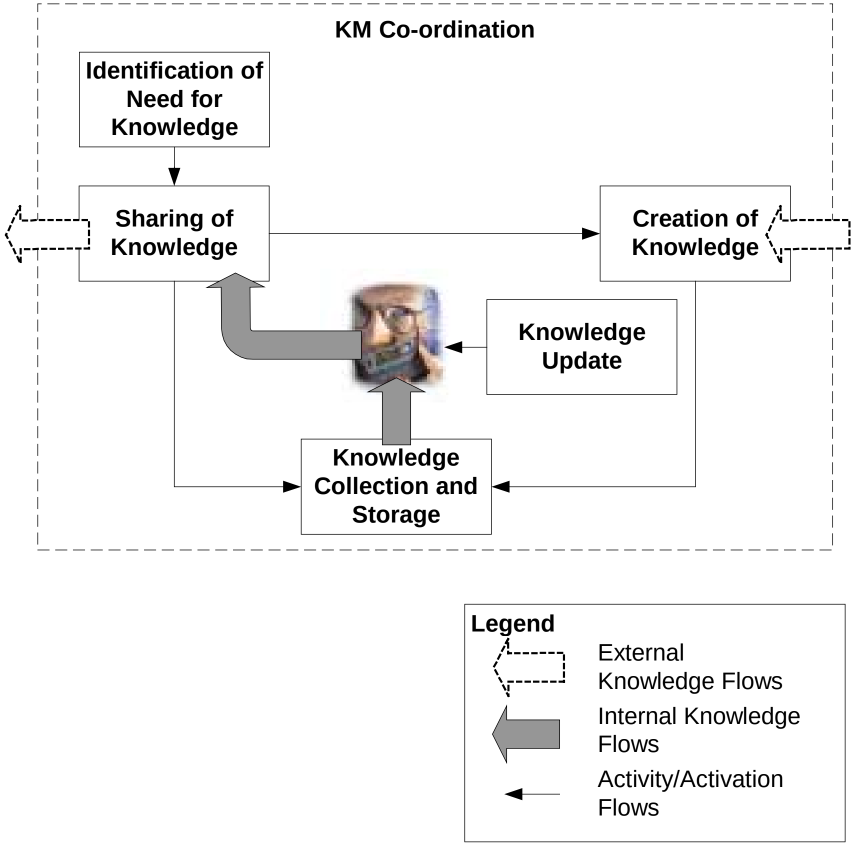

Figure 2. Overview of the Main Processes.

The co-ordination processes are underlying the operational processes. In Figure 2, this is shown by the rectangle lying behind all other processes. The operational processes are presented as the following main processes: “Identification of Need”, “Sharing”, “Creation”, “Collection and Storage”, and “Update”. Please note that there are two processes that represent the main process “Sharing” in the model: “Knowledge Pull” and “Knowledge Push”. The arrows connecting the processes provide an overview of the interaction and knowledge flows. The picture in the middle represents the place where the knowledge is stored. The purpose of this picture, showing a human and a machine, is to express the variety of possible ways of storing knowledge, including both technical (databases, documents, videos) and non-technical (human mind) repositories.

The general concept of the process model is that within the co-ordinating processes the operational processes are planned and initiated. Together these make up the KM system. The main processes are described in the following. "Identification of Need for Knowledge" identifies a need for knowledge and determines it. "Sharing" is initiated in order to find out whether knowledge that already exists in the system can be used. This covers both the searching for knowledge by a person who needs the knowledge ("Knowledge Pull") and the feeding of knowledge to recipients who are known to be in need of it ("Knowledge Push"). If the needed knowledge is not available yet, "Creation of Knowledge" is initiated. Consequently, the new knowledge (the result) has to be collected – this is done in "Knowledge Collection and Storage". Also when sharing knowledge, new knowledge is often created throughout the combination of the shared knowledge with the receiver's existing knowledge [Nonaka and Takeuchi 1995] - this is indicated in the graphic by the activation of "Knowledge Collection and Storage" by "Sharing". Both "Creation of Knowledge" and "Sharing" may have external links. In the graph, this is indicated by the dotted arrows. "Creation of Knowledge" may utilise knowledge from outside the organisation. This external input is connected to the main process creation, because knowledge has to be adapted to the needs and context of the organisation. The external link of "Sharing" on the opposite side enables knowledge brokering, such as selling of knowledge, to the outside world. In fact, this is what consultants are specialised in, but it can also be applied to organisations developing software components, which they sell to others.

The presentation in Figure 2 is simplified and does not reflect the fact that there might be several instances of the operational processes for different knowledge domains. Such different knowledge domains are likely to occur; for example, there can be those based on the knowledge for the management staff or those based on knowledge for the production staff. But even if there are several knowledge domains, it is sensible to have them managed centrally. This enables a proper identification of commonalities, e.g., the possibility to use tools, repositories or processes jointly. Figure 3 expresses this by showing different instances of the operational processes but the same underlying co-ordination as in Figure 2. The possible common use of repositories among different KM domains is expressed in Figure 3 by the two KM domains on the right side that utilise a common repository.

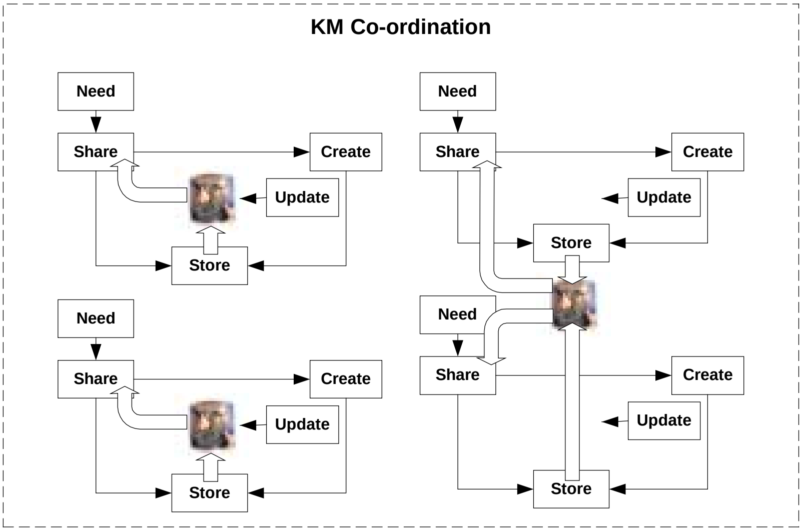

Figure 3. KM Domains.[5]

Each of the processes mentioned so far contains a number of sub-processes. These are going to be described in detail in the following sections of Chapters 4

5 Please note that due to the compressed presentation of KM domains in the figure, shorter descriptions for the operational processes are used, which, however, refer to the same processes as used elsewhere in this study.

and 5. An overview of the more detailed view on the processes is available with Figure 4 for the co-ordination processes and Figure 5 for the operational processes. Both graphs also include major activation dependencies. It should be noted that these might vary depending on how the processes are realised and therefore are neither complete, nor mandatory. Throughout the following determination, a description, probable input-links, suggested activities, expected products, and probable output-links shape the processes. These are presented in a tble for each sub-process to support readability.

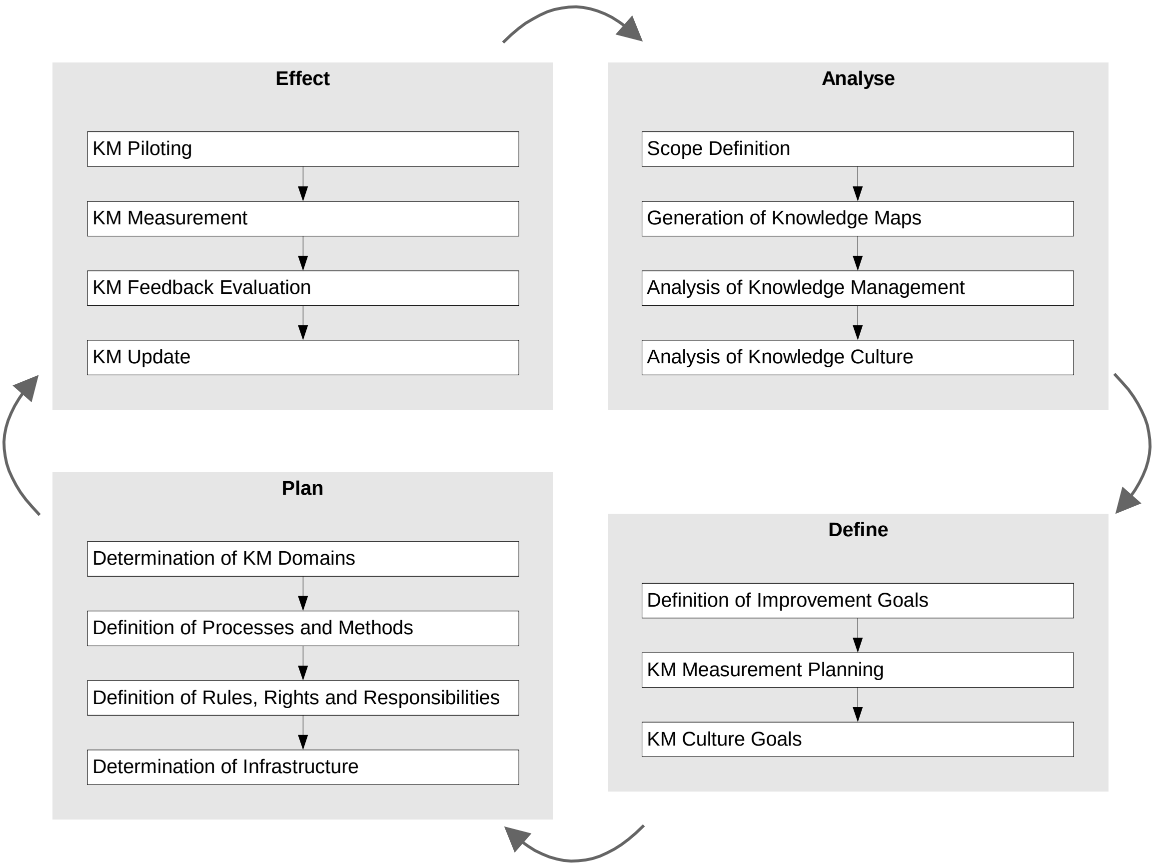

Figure 4. KM Co-ordination Processes or KM Pr²imer.

Figure 5. KM Operational Processes.

4. KM Co-ordination Processes (KM Pr²imer)

The co-ordination of KM activities is the very centre of all other activities as everything is initiated and controlled from here. Knowledge is always already dealt with (created and also shared), although the necessity to manage these processes might not have been realised yet. This clearly indicates that it is a question of improving current practices instead of replacing them with some entirely new ones.

First, the existing knowledge stacks, the channels used to transfer knowledge, and the general surroundings have to be analysed to enable their management. Then a target state needs to be defined. To enable both an effective tracking of the success and an identification of any shortcomings of the processes set up, it is necessary to define metrics. This at the same time provides a possibility to make the usefulness of KM visible.

4.1 Analyse

KM aims at improving the knowledge creation and sharing processes in an organisation. The first step has to be the definition of scope to determine what has to be taken into account. As KM is an improvement activity, a current state analysis (CSA) is needed in order to find out what the current state is, upon which improvement steps can then be developed. The CSA has to take into account different aspects: what knowledge is already available, how is knowledge handled at the moment, and what kind of culture exists in the organisation. These different steps are explained in the following sections.

4.1.1 Scope Definition

One major influence on KM activities is the scope in which they are performed. Generally it seems desirable to take into account as much knowledge and parts of the organisation as possible. But KM should always start small, i.e. with pilot projects, and then be widened after operation in a small scope has shown successful [Davenport and Prusak 1998]. This serves a number of purposes. Firstly, it ensures that if something goes wrong the impact is not very big. Thus, this approach gives space for mistakes – and such have to be expected. It secondly allows one to think about the larger scale while planning the pilot operation. This makes it possible to e.g. start influencing cultural issues identified in the analysis. This can have effects also outside the defined scope and can be seen as a preparation for further KM activities. As cultural influence is a matter of long-term activities, this seems desirable.

Table 2. Sub-Process: Scope Definition.

Input Links	General knowledge about the organisation and KM, i.e. internal and external knowledge flows and known problems that might be addressed by KM activities.
Activities	Determine possible scopes for KM activities. Compare the determined possibilities according to costs, expected benefit and impact on business. Select and define a scope.
Product	A defined scope for the KM activity.
Output Links	The scope definition affects all other activities.

Scopes can be very different depending on the organisation conducting KM. Examples include: a group of people (e.g. senior management, all sales representatives or all project managers), one or a number of projects, a specific business unit, one of the sites of the organisation, etc.

4.1.2 Generation of Knowledge Maps

To identify the current knowledge generators, holders and storage places, a knowledge map needs to be generated that shows these in a structured way. Depending on the scale of the defined scope (see section 4.1.2), it might be necessary to create several knowledge maps. There is no defined form for such a map. An organisational diagram might be a good starting point to identify knowledge holders and creation places, but is insufficient for reflecting who has what knowledge, as this is not predictable only upon titles and positions. So there is a need to interview people about what they know and what they do if they have a problem in a specific area, e.g. whom they ask for advice, whereupon additional knowledge holders will be identified. Further documents and related matters such as a DMS need to be considered in this.

Table 3. Sub-Process: Generation of Knowledge Maps.

Input Links	The scope definition (section 4.1.1). Already existing and relevant documentation about the organisation, such as organisational diagrams, process descriptions, job descriptions, records from the human resource department, existing knowledge maps, specifications of databases and KM related tools etc.
Activities	Analyse existing profiles for potential knowledge holders, e.g. upon titles (study fields) and working areas (working fields). Identify where knowledge is primarily created, e.g. R&D units. Find out where knowledge is stored, e.g. DMS, intranet, quality handbook, etc. Create a knowledge map to show knowledge holders, creation and storage places.
Product	A knowledge map showing the creation and storage places and main holders of knowledge.
Output Links	A knowledge map containing implicit information about the knowledge processes. It is used in the KM analysis (section 4.1.3) as a starting point. A knowledge map might reflect e.g. knowledge gaps, in which case it can be used in culture analysis (section 4.1.4) as input. As knowledge changes over time, the knowledge map needs to be updated whenever knowledge changes and/or people gain additional knowledge. This is done within the process of updating the knowledge map (section 5.5.6) and initiated by the knowledge update process (section 5.6.3) in case of changes.

4.1.3 Analysis of KM

To be able to manage knowledge inside a company it is important to understand the processes and methods currently used for communicating the existing knowledge. This leads to the need of an intensive investigation on how knowledge is generated and spread by the people and by the organisation. This means to internally analyse both the vertical up-down communication from the management to the employees and the horizontal communication between the employees, and additionally take into account such external knowledge-relations as consulting or research partners. Also communication not usually defined that takes place for example during coffee breaks, festivities and leisure-time activities needs to be taken into account because such occasions are important in the context of knowledge transfer. The results from this analysis have an high impact on the definition of the processes later on. The value of analysing and modelling these processes lies not in reaching an exact understanding of them but in identifying possibilities to influence them [Davenport and Prusak 1998].

Table 4. Sub-Process: Analysis of KM.

Input Links	The scope (section 4.1.1) determines the analysis range. The knowledge map (section 4.1.2) is used as a starting point. If process descriptions are available (e.g. through the documentation of quality certification), they can be used to start investigations on what knowledge is used in the processes.
Activities	With respect to the planned focus of the KM system (section 4.1.1), analyse business and internal management processes for knowledge used/needed in them. Analyse when, how and by whom this knowledge is created and exchanged. Ask the people belonging to the focus group about problems (with missing knowledge, sharing, etc.) in the past. Analyse the knowledge map for gaps that result from shortcomings in the organisational structure.
Product	A descriptive evaluation of knowledge processes and methods.
Output Links	The knowledge process description can be used in the analysis of knowledge culture (section 4.1.4) to identify where cultural enablers or barriers exist. The description can also be utilised to derive goals for improvements (section 4.2.1). There may arise a need to extend or further limit the focus that has been initially set.

4.1.4 Analysis of Knowledge Culture

The analysis of the current cultural situation in an organisation needs to be determined to assess if the surroundings are suitable for knowledge to develop and flow, because otherwise any attempt to KM is likely to fail [Davenport and Prusak 1998]. This means one should consider questions such as whether hoarding is seen as something good, whether admitting to have a problem is considered as weakness/incompetence, and whether the presentation of individual performance (bragging) is accepted. If a 'yes' is provided as an answer to any of these, there is obviously a need for changes in the environment, as it is not enough just to provide technology to share knowledge. Environmental changes for their part need careful planning and can be introduced only over time. Therefore, to ensure that the environment develops in such a way that KM is possible needs to be the first step when starting to manage knowledge.

Table 5. Sub-Process: Analysis of Knowledge Culture.

Input Links	Existing documentation, e.g. guidelines from the upper management, may be used to determine the position of the organisation towards KM. The knowledge map (section 4.1.1) can be used to identify possible anomalies in the map that might be due to cultural problems. The description of processes (section 4.1.3) can help to identify where cultural enablers / barriers exist.
Activities	Analyse if, when, and to what extend knowledge is shared or not shared in the organisation. Determine what factors might hinder knowledge sharing/creation. Determine how knowledge sharing is encouraged. Determine how senior management relates to knowledge sharing.
Product	A descriptive evaluation of the knowledge culture.
Output Links	The evaluation is utilised within the definition of goals (section 4.2.1) to address any identified shortcomings by according goal-settings.

This process must be considered both important and difficult. The influence of the cultural surroundings heavily influence communication [De Long 1997]. Furthermore, where culture does not guide an employee, his or her attitudes do [Kreie and Cronan 2000]. Equally, there is no standardised procedure to evaluate or determine this culture. An initial descriptive evaluation can be achieved through interviewing, and watching the behaviour of, relevant persons such as group leaders as well as project and division managers. By fostering sensibility for this topic, feedback (see section 4.4.3) can provide further details to this analysis.

4.2 Define

After the current state of the overall KM process or KM in the specific focus area (e.g. SW engineering) is known, it is time to define the desired state. The desired state can be represented through goals, which refine the focus that has been initially set. The goals should guide the coming activities, which are the definition of processes and methods, rules and responsibilities and the determination of the technology to be applied.

4.2.1 Definition of Improvement Goals

Goals have to be defined to ensure that the development of all other activities is goal-oriented. Feedback-loops from the processes are very important to control whether and to what extend the goals are reached.

Table 6. Sub-Process: Definition of Improvement Goals.

Input Links	Facts visible in the knowledge map (section 4.1.2) may lead to improvement goals (e.g. unfilled gaps in a knowledge map). Problems identified in the description of the processes and methods (section 4.1.3) may lead to improvement goals. Shortcomings identified in the description of the cultural environment (section 4.1.4) may lead to improvement goals.
Activities	Analyse the results of the analyses undertaken so far and determine possible improvements. Define improvement goals regarding KM in the organisation.
Product	Goal definitions.
Output Links	The goals guide the planning (sub-processes presented in section 4.3).

The type of goals set in this process will depend on the type of organisation and on the defined focus (see section 4.1.1). Examples for KM related goals are: Increase the communication between project managers, foster the knowledge creation in a R&D unit, improve the hiring procedures to better match the organisational needs or enable to safe the knowledge of retiring employees for the company. Goals can though also be defined directly related to the other organisational processes, e.g. minimise the need for adaptation for reusable assets like code or minimise the defects in production.

4.2.2 KM Measurement Planning

It is important to determine how to control the processes and their capability of reaching the goals set for them. In addition to verbal feedback, measurement is a valuable approach to this. There are various approaches to measurement - from measuring all that is possible to measure and later picking the data which seems to be important (data warehouse and data mining), to starting measurement only when there is a specific measurement question that needs to be answered. Experiences have shown that the definition of useful metrics is often a difficult task in improvement projects [Carneiro 2000]. The difficulty is that the object of the measurement is something new and therefore unknown. For example, the Goal/Question/Metric (GQM) approach [Basili, et al. 1994, Solingen and Berghout 1999] - a method developed at the University of Maryland, proven to be effective in industrial projects [Komi-Sirviö, et al. 1998, Parviainen, et al. 1999] - can be applied here. The GQM approach contains a template for defining understandable and structured goals including purpose, perspective and context characteristics [Solingen and Berghout 1999]. This approach ensures a development towards success by guiding the planning and effecting phases. The following figure illustrates the approach (Figure 6). It requires that the goals be refined by questions, which allow a verification of success. These questions are then again refined through suitable metrics that make it possible to answer the corresponding question, thus providing the possibility to control the success of the process. The resulting combination of refinements from goals to metrics with details on how and where to collect these metrics is called a GQM Plan.

Table 7. Sub-Process: KM Measurement Planning.

Input Links	The goals (section 4.2.1).
Activities	Refine the overall goals to measurement goals. Refine the measurement goals to questions. Refine the questions to metrics that answer the questions. Determine the occasions for verbal feedback (interviews). Define who collects what metrics and when.
Product	A GQM plan with an adequate definition of metrics for controlling each goal. A measurement plan with definitions of what metrics are collected, when, and by whom. A plan for verbal feedback occasions.
Output Links	The metrics are taken and analysed in the corresponding sub-process (section 4.4.2).

A simple example of this process is illustrated by means of the theoretical goal to improve communication between project managers. Assuming this goal is derived from the analysis of KM (section 4.1.3) and the identified fact that project managers in an organisation often have the same problems and are solving these completely independent from each other, thus searching for solutions for the one similar problem multiple times, then KM measurement goals and KM measurement questions and metrics could be those shown in Table 8.

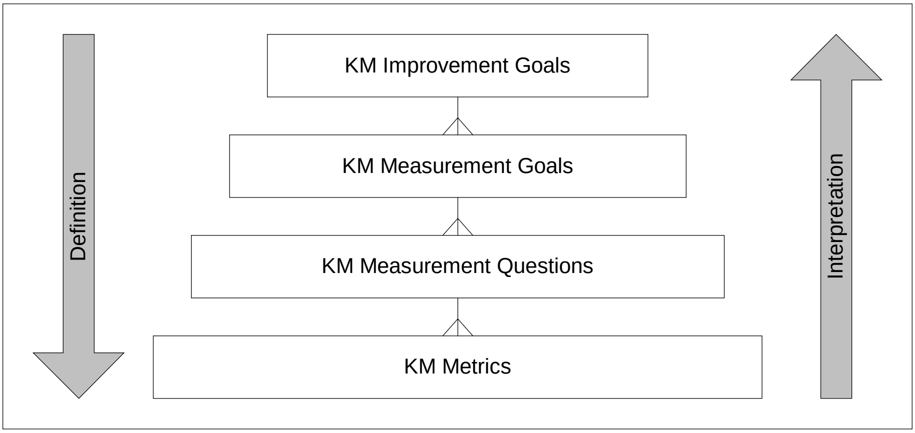

Figure 6. KM Measurement Approach.

The example provided in Table 8 is simple and could be extended by questions aiming to clarify what tools are used in inter-project problem solving and according metrics. The metrics have to be properly taken into account in the ensuing steps to ensure they are measured. This can be achieved by integration to processes, this denoting e.g. short reports to be written after inter-project meetings, identifiers in discussion bases for closed discussions, or questionnaires with suitable fields at the end of each project. According approaches are part of the resulting GQM Plan.

Table 8. Example of the GQM Approach.

KM Measurement Goal	**KM Measurement Questions**	**KM Metrics**
G1: Analyse inter-project communication in order to improve it with respect to its effectiveness for problem solving from the viewpoint of project managers in the context of all projects within the scope of the KM project.	Q1.1: How often were project managers able to solve a problem by advice from other project managers?	M1.1.1: Number of cases where the advice helped to solve the problem.
	Q1.2: How often were project managers not able to solve a problem by advice from other project managers (although they tried to)?	M1.2.1: Number of cases where the advice did not help to solve the problem.
	Q1.3: What is the success rate of inter-project problem solving?	M1.3.1: Percentage of advice that has been helpful. $x=\left(\frac{M1.1.1}{M1.1.1+M1.2.1}\right)*100$

4.2.3 KM Culture Goals

The political and cultural surroundings are known from the analysis of knowledge culture (section 4.1.4). Because "[…] effective knowledge management cannot take place without extensive behavioral, cultural, and organizational change" [Davenport and Prusak 1998], there is a need to initiate according changes. This especially aims at creating an environment where knowledge sharing is encouraged. This can be supported in various ways, like e.g. honouring sharing while at the same time dishonouring hoarding, providing employees with unscheduled time to talk, etc. In 3M, for example, a company that has been successfully innovating for years, all employees can use 15% of their working time for pursuing their own dreams [Nonaka and Takeuchi 1995]. This arrangement clearly points out the interest of the management in knowledge creation, especially regarding innovation, and the company has been successful with this.

Table 9. Sub-Process: KM Culture Goals.

Input Links	The results from the analysis of knowledge culture (section 4.1.4) might show cultural barriers that need to be addressed.
Activities	Plan how the management can show its serious interest in knowledge creation and sharing. Plan how to address identified barriers. Determine what could be done to encourage knowledge creation and sharing, e.g. give people time to think and time to talk.
Product	An (probably long-term) action list to build a KM supportive environment.
Output Links	While the success of the whole KM can be regarded to be dependent on environmental circumstances, this influence is rather indirect.

A supportive environment is the most critical factor for the success of KM projects [Davenport and Prusak 1998]; therefore this task should be paid highest attention to. Since according changes have long-term effects, they should be initialised as soon as possible. The need for this type of changes constitutes one more reason to start KM with pilots, thus approaching the goal step by step.

4.3 Plan

The planning phase of KM Pr^{2}imer serves the purpose of determining how the defined goals are going to be reached. It contains the determination of different KM domains upon the defined scope, definition of processes according to the descriptions in Chapter 5, putting these processes into human context by the definition of roles, rights and responsibilities and the setting up of a supporting infrastructure to be used throughout the processes.

4.3.1 Determination of KM Domains

It is likely that several storage techniques and locations are used due to the different knowledge levels (see section 2.1). Especially the transformation of implicit to explicit knowledge might require techniques like story-telling videos, business television or presentations on internal congresses, which might allow absorption of knowledge also in difficult cases [Davenport and Prusak 1998]. This kind of transfer might require domains of its own due to the media and the used communication channels. But also security requirements on knowledge might require separated KM domains, e.g. for knowledge on the senior executive level. Therefore KM domains can have different responsibilities, rules and techniques. However, KM domains might include linkages.

Table 10. Sub-Process: Determination of KM Domains.

Input Links	The scope (section 4.1.1) itself might be a domain, or also, may spawn multiple knowledge domains. The knowledge map (section 4.1.2) offers an overview of the knowledge holders in the organisation and thus may provide principal separation needs. The goals (section 4.2.1) may include some information on the need for separated KM domains.
Activities	Analyse the differences between knowledge needs in different parts of the organisation for the need of separated domains. Analyse the existing KM and the scope (goals) for the need of KM domains.
Product	Definition of KM domains.
Output Links	Links between KM domains are defined within the definition of processes (section 4.3.2). The roles and responsibilities for each KM domain are determined within the according process (section 4.3.3).

Also, with the growing content of repositories, there might come up a technical necessity to split existing KM domains into different ones. This can be a solution to address performance issues, e.g. in geographically distributed environments.

4.3.2 Definition of Processes and Methods

After the KM domains have been determined, they are realised as operational processes as they are presented in Chapter 5. This means that existing processes are redefined or new processes are put in place with respect to the goals. In this, the shape of each process and the links between KM domains are defined.

Table 11. Sub-Process: Definition of Processes and Methods.

Input Links	The identified knowledge creators/holders from the knowledge map (section 4.1.2) and the determined KM domains (section 4.3.1) provide information on what needs to be linked together. The goals (section 4.2.1) guide the design of all processes. The KM processes are defined according to the templates that the process model provides in Chapter 5 with connections to other organisational processes.
Activities	Define processes for knowledge capturing. Define processes for knowledge transportation. Define processes for knowledge sharing (feeding and retrieving). Determine triggers for activating processes. Determine what techniques should be used in the processes and what tools are suitable to assist the processes in an optimal way. Determine metrics to measure processes if necessary.
Product	Definition of KM processes; clarifies when a process is performed and what is done. Definition of techniques to be used in the processes
Output Links	All operational KM processes (see Chapter 5) are specified here. Additional metrics to be taken on process level are specified (evaluation in section 4.4.2).

The identified parts of knowledge flows inside the organisation are modelled on the basis of the knowledge map and the defined hierarchy in order to clarify how knowledge is collected and shared. An important part is the design of feedback processes and metrics according to the measurement plan (see section 4.2.2).

4.3.3 Definition of Roles, Rights and Responsibilities

This primarily signifies that the roles and responsibilities for the different areas of KM need to be defined, e.g. positions like that of a Chief Knowledge Officer (CKO) with its corresponding overall responsibility and Knowledge Officers (KO) with their responsibility for specific areas such as knowledge domains or assistance with searching or codifying knowledge. The establishment of KM positions also shows that KM is given priority at the management level and thus it supports cultural change by underlining the importance of KM. By this operation it is also possible to avoid adding tasks to people's current work - such a situation could cause people to neglect KM.

Table 12. Sub-Process: Definition of Roles, Rights and Responsibilities.

Input Links	The definition of processes (section 4.3.2) provides input for role definitions.
Activities	Analyse the KM domains (section 4.3.1) and the defined processes (section 4.3.2) against what roles are needed to successfully establish KM. After the determination of roles, decide which of the roles need to be realised as full time jobs and which are to become part of existing jobs. Define responsibilities and rights for each role.
Product	Definition of roles. Definition of responsibilities. Definition of rights.
Output Links	The definition of roles, responsibilities and rights is something of a refinement of the KM domains (section 4.3.1) and processes (section 4.3.2). The roles define who performs what processes and thus influence all other processes.

4.3.4 Determination of Infrastructure

After the organisational structure has been defined as domains and underlying processes, the important issue of utilising technology must be clarified. This means that one has to define what kind of technology is going to be used, and how, for storage, access and management. This includes tools to be used in locating a specific content, transferring it and actually viewing it. For example, a locator-tool could automatically search through web pages. A transfer of found content could utilise the UDP/IP protocol (utilising the existing network infrastructure), and a viewer could be a video-player-application.

Table 13. Sub-Process: Determination of Infrastructure.

Input Links	The use of technology in KM depends on the overall goals (section 4.2.1). The role of technology is to assist or perform the KM processes (section 4.3.2).
Activities	Analyse how technology can be utilised to achieve the goals. Analyse how technology can assist or automate the KM processes. Define what technologies and tools should be used.
Product	Definition of technology and tools for supporting KM.
Output Links	The defined infrastructure and provided technology is used throughout the operational processes as described throughout Chapter 5.

It is important to notice that technical solutions can support KM, but will not solely be the cause of it. Davenport and Prusak express the situation as follows:

"If more than a third of the total time and money resources of a project is spent on technology, the project becomes an IT project, not a knowledge project" [Davenport and Prusak 1998].

4.4 Effect

Piloting, monitoring and updating are ongoing KM co-ordination activities. The KM system as defined throughout section 4.2 is put in place and the processes are piloted by using them. This should first be done in a small pilot project. This use is monitored and evaluated. The results of this review are the basis for updating the KM system by improvements to any shortcomings that have been identified. These improvements are implemented by updating KM, which leads to the next piloting. Theoretically this is an endless process; thus, each instance of the KM system is a pilot in a strict sense. In practice, with the improvement of the processes, the update intervals should become less frequent in number. A specific pilot might remain valid for several years, before further changes are required. Also these updates will be due to changes in the environment.

4.4.1 KM Piloting

The first time the KM system is taken into use, it should be a pilot project with a defined focus to carefully check its usefulness throughout everyday use. This provides room for trials and allows improvements to be made without the danger of large investments that prove to be non-suitable. From this the focus area should be widened step by step to take into account a larger area of knowledge and serve an increasing number of people.

Table 14. Sub-Process: KM Piloting.

Input Links	The KM system as defined throughout section 4.2.
Activities	Introduce the KM processes to the target group. Initiate KM by taking the processes into use.
Product	A working KM system.
Output Links	The KM system is monitored by measurement as defined in section 4.4.2 and feedback evaluation as defined in section 4.4.3.

As people are not willing to radically change their working practices in one day, changes are to be realised step-by-step. This means that the introduction should be performed in phases and supported by according training, e.g. on KM in general.

4.4.2 KM Measurement

The main monitoring activity is measurement, i.e. gathering metrics from the running processes. The goal-metrics defined in section 4.2.2 allow to track how well the KM system reaches the goals set. The process-metrics defined in section 4.3.2 allow to monitor the processes in detail. Identified shortcomings will be addressed by the process described in section 4.4.4.

Table 15. Sub-Process: KM Measurement.

Input Links	The goal-metrics defined in section 4.2.2 need to be collected. The process-metrics defined in section 4.3.2 need to be collected.
Activities	Collect the goal-metrics. Collect the process-metrics. Evaluate whether the goals are reached. Analyse the process metrics to identify weaknesses or shortcomings.
Product	Management reports on KM. KM reports on KM processes.
Output Links	May initiate updates on KM processes via the KM update process (see section 4.4.4). May initiate updates on knowledge via identification of change (see section 5.6.1).

4.4.3 KM Feedback Evaluation

Although measurement provides an effective tool for tracking the processes, there is a need to additionally collect and evaluate feedback. This allows the detection of those problems / shortcomings / improvements that the defined metrics are not able to identify. Ongoing feedback possibilities as integrated into the processes should be supported by regular feedback occasions. These allow asking for feedback on specific topics.

Table 16. Sub-Process: KM Feedback Evaluation.

Input Links	Results from measurement analysis (section 4.4.2). Feedback from the processes, e.g. a feedback form to be filled in after every successful access to the knowledge base. Results from feedback occasions (e.g. questionnaires, feedback meetings, etc.).
Activities	Hold additional feedback occasions if needed. Keep the originator informed about what is happening with his / her comment. Evaluate the feedback with respect to possible improvements.
Product	Results from feedback analysis.
Output Links	If improvements have been identified, these are initiating an update as described in section 4.4.4. If shortcomings or failures on the knowledge stored in the system have been identified, an update of the knowledge is initiated via the process of identifying changes (see section 5.6.1).

4.4.4 KM Update

KM Updates aim to improve the KM process itself, which may be initiated either by shortcomings identified during measurement or by feedback. KM needs to be evolving and flexible and therefore updates need to be performed whenever improvements are identified.

Table 17. Sub-Process: KM Update.

Input Links	Results from measurement (section 4.4.2). Results from feedback (section 4.4.3).
Activities	Analyse the shortcomings or the improvement idea. Determine and plan the needed changes. Initiate the according process for change.
Product	An update on the KM system or activation of the knowledge update process.
Output Links	If the product is an update on the KM system, a further cycle of the KM Pr^{2}imer is initiated starting again with the procedure described in section 4.1.1. If the product is an update on knowledge, the process identifying changes (see section 5.6.1) is initiated.

In practice, this process produces a reaction to the measurement and feedback activities. It is therefore of importance, because otherwise the purpose of the measurement and feedback activities has to be questioned. Consequently, appropriate reactions are necessary and important – if no changes can be realised, at least the reason for this needs to be announced to show that the issue has been dealt with.

5. KM Operational Processes

The operational processes of the KM process model will be presented in this chapter. This presentation follows the structure presented in Figure 2 with the exception that there are two different processes of sharing knowledge: Knowledge Push and Knowledge Pull.

The operational processes are instantiated for the concrete circumstances they are going to serve during the planning phase (section 4.3.2). As this environment cannot be predicted here, the processes are held in more general and are less concrete than the processes of the KM Pr^{2}imer.

5.1 Identification of Need for Knowledge

Before knowledge can be shared or created, the need for knowledge has to be identified. Further requirements on it have to be determined to allow finding the right knowledge in the case of sharing and to enable the creation of the right knowledge in the case of creation.

Needs for knowledge arise when starting work in a new field - for example, when starting to use a new tool, technique or technology. These needs are brought out when improving current work practices by implementing a new component and when changing the area of work. Identifying the need for knowledge, however, does not provide information on what kind of knowledge is needed. Subsequently, there arises a need to specify the requirements on the needed knowledge. Defined requirements allow an accurate search for the knowledge or a need-driven creation of new knowledge.

5.1.1 Identification of Need

Before knowledge can be searched for or created, the need for it has to be identified. This is not always a conscious process in practice, due to the nature of knowledge. However, for the management of knowledge to become possible, this need has to be consciously identified.

Table 18. Sub-Process: Identification of Need.

Input Links	Depending on the area of application and various types and origins.
Activities	Identify the need for knowledge.
Product	The identification itself determining that somewhere there is a need (expressed by someone) for knowledge for a specific purpose.
Output Links	The identification of the need for new knowledge initiates the determination of the requirements on the needed knowledge (section 5.1.2).

There are various possibilities that may lead to the identification of a need for knowledge, such as:

- An analysis of the working processes can identify shortcomings that lead to a need for additional knowledge.

- When starting a new task, the question whether (existing) knowledge can help in performing it must be answered. For example, when starting a development task on user interface (UI) design, knowledge of UI in general and specifically from the project viewpoint is needed; consequently, it is possible to utilise knowledge embedded into already existing UI modules.

- Starting work in new working areas implies a need for new knowledge - for example, when starting work with a new programming language generation such as the change from 3rd to 4th generation languages.

- Changes in the environment, like e.g. new versions of programming languages, new development methods, etc. are likely to act as triggers for needs of new or at least changed knowledge.

- An analysis of projects (measurement analysis, lessons learned) can help to identify a need for knowledge to solve specific problems that have occurred.

Two types of need identification can be differentiated: identification in advance during planning (e.g. planning the change to another programming language) and identification during performance, e.g. when starting development on a module.

The process of identifying the need for knowledge could be automated in specific cases, therefore it has been described as a process of its own. If not, identification and determination of a need for knowledge can be presented as a combined process.

5.1.2 Determination of Requirements

Before knowledge can be searched for, one needs to determine what exactly is needed. Depending on the desired type of knowledge, the approach to the definition of requirements may vary. Modules, processes, methods etc. have different specifications that describe them. The determination of the need has to meet these specifications to allow an accurate search or creation.

Table 19. Sub-Process: Determination of Requirements.

Input Links	The identified need for knowledge (section 5.1.1).
Activities	Determine what kind of knowledge is needed, e.g. process, method, module, etc. Define the requirements on the knowledge needed, e.g. what input and/or output a process should have, what scope a method should deal with, what operation a module needs to provide, etc. Estimate the cost for not reusing any knowledge but creating the needed knowledge instead.
Product	Requirements on the knowledge. Cost estimation for knowledge creation.
Output Links	The determination is used for searching according knowledge (section 5.2) or for creating it (section 5.4).

The determination optimally includes a cost estimation for the creation of new knowledge. This is for such a case in which no existing knowledge matches the requirements. This provides a basis for the decision whether to reuse or to create the needed knowledge.

5.2 Knowledge Pull

The purpose of KM is to provide a means of sharing knowledge, and all other processes are more or less enablers for this. Sharing knowledge is a complex and difficult process. The right knowledge has to be found, must be transferred and needs to be absorbed, i.e. brought into proper use. Searching is a problem if there is a large amount of knowledge available and the right knowledge becomes difficult to find. The technology used must suit the KM process. Still the success furthermore depends on factors like environment, type of organisation, psychological issues, etc.

There are two ways of how knowledge sharing is performed: the active pull of knowledge needed and the passive push. The latter is described in section 5.3. The first way includes all cases where the project members identify a need for knowledge. The knowledge is searched for, retrieved if available, and then adopted. Knowledge can be pulled by either direct communication between people or by utilising IT systems. The first possibility might be assisted by utilising the knowledge map (section 4.1.2), allowing identifying people inside the organisation that have related knowledge. The transfer of the knowledge then takes place using direct communication between both sides. IT systems can provide great assistance in finding and retrieving knowledge; the knowledge map can also be kept in such a system allowing its computer assisted use. The second possibility is search for relevant knowledge in an electronically realised knowledge repository.

In all cases, defined search criteria allow exact searches for knowledge. The results of searches are knowledge candidates. These need to be analysed to determine whether they are applicable for the current case. A candidate might then be selected based on such criteria as how well the candidate fits the needs and what estimated costs will arise from adopting it in relation to the estimated costs of creating that knowledge. If the needed knowledge does not exist, this process initiates the creation of new knowledge (section 5.4).

5.2.1 Establishment of Search Criteria

Requirements on the needed knowledge have been established within the process described in section 5.1.2. These need to be converted into search criteria according to the standards used in the KM system, e.g. categories, keywords etc. These standards may be dependent on a technically realised system and in that case have to match the syntax required by that system. If knowledge is inquired from people the search criteria may need to be verbally expressed without any formally existing standard.

Table 20. Sub-Process: Establishment of Search Criteria.

Input Links	The defined requirements (section 5.1.2).
Activities	Convert the requirements to search criteria.
Product	Search criteria for each repository to be searched.
Output Links	The search criteria are used within the search (section 5.2.2).

5.2.2 Search for Candidates

The defined search criteria are applied to search for knowledge candidates. Candidates can be one matching candidate or several knowledge sources that, combined, build up a candidate. The search can be performed via a technically realised system or by direct communication with people. Depending on the results, there might be a need to refine the requirements. In the case of a large number of results this can be done by specifying the requirements more exactly or in case of too few results by making the requirements more common. In these cases the search criteria need to be defined again (section 5.2.1). Otherwise the evaluation of candidates (section 5.2.3) is initiated.

Table 21. Sub-Process: Search for Candidates.

Input Links	The defined search criteria (section 5.2.1).
Activities	Apply the search criteria to search for candidates.
Product	A set of candidates.
Output Links	If there are no or too many candidates found, search criteria are established again (section 5.2.1). If no candidates are identified even with re-defining the search criteria, knowledge creation (section 5.4) is initialised. If a suitable number of candidates have been found, the evaluation of candidates (section 5.2.3) is initialised.

5.2.3 Evaluation of Candidates

After the set of candidates has been identified, there is a need to evaluate the candidates in order to enable a decision upon them. Such an evaluation has to include a prediction of the cost of adoption to the current situation. If the search result contains a number of suitable packages, it is possible to select the best and cheapest one for use from among the suitable ones. If the cost prediction for the cheapest knowledge package is remarkably higher than the predicted cost for developing the needed knowledge anew, than the decision is not to use a package from the repository. Results of the evaluation serve as potentially new knowledge, which might also lead to an update of knowledge (section 5.6).

Table 22. Sub-Process: Evaluation of Candidates.

Input Links	The defined requirements (section 5.1.2). The set of candidates (section 5.2.2).
Activities	Analyse each candidate and determine to what extent each one fits the requirements and what changes would be needed per each. Predict the cost for adopting the candidate to the current situation.
Product	Descriptive qualitative and quantitative information about each candidate.
Output Links	The information is used to select a candidate (section 5.2.4).

5.2.4 Selection of Candidate(s)

As input from the prior process for each candidate there is information available expressing to what extent it matches the requirements and how much adoption will cost. Based upon this information, it is now possible to select a candidate or to decide not to use any of them.

Table 23. Sub-Process: Selection of Candidate(s).

Input Links	The defined requirements (section 5.1.2). The set of candidates (section 5.2.2). The evaluation results for each candidate (section 5.2.3).
Activities	Determine the best candidate. Verify the predicted adoption cost against the estimated costs of creating new knowledge. Decide whether to use candidate or to create knowledge anew.
Product	A candidate for adoption or decision to create new knowledge.
Output Links	Either one or more candidate(s) is/are adapted (section 5.2.5) or new knowledge is created (section 5.4).

5.2.5 Adaptation of Candidate(s)

Modifications are performed on the basis of the extent to which the candidate matches the requirements. This adoption leads to new knowledge that has to be considered for storage.

Table 24. Sub-Process: Adaptation of Candidate(s).

Input Links	The selected candidates (section 5.2.4).
Activities	Perform needed modifications on the candidate.
Product	A modified candidate.
Output Links	The modified candidate is used. The modified candidate is considered as new knowledge (section 5.5.2).

5.3 Knowledge Push

Beside the knowledge retrieval presented throughout section 5.2 there is the important variant of transfer of knowledge to people known to need it. These processes are presented in the following.

5.3.1 Announcement of Knowledge

It might be sensible to inform certain persons about new knowledge. This is important, for example, because people will not search for specific topics concerning their everyday work over and over again.

Table 25. Sub-Process: Announcement of Knowledge.

Input Links	Availability of new or changed knowledge (section 5.5.6). Other cases like new colleagues joining the team might also initiate this process as designed throughout the process definition (section 4.3.2).
Activities	Analyse the knowledge towards a known need of persons. Announce the new knowledge to the identified person(s).
Product	Information about new knowledge.
Output Links	Informed people are aware of changed or new knowledge and able to retrieve it utilising the knowledge pull processes (section 5.2).

5.3.2 Knowledge Sharing Occasions

Knowledge sharing can often be done effectively by regular or event-triggered knowledge sharing occasions. 'Regular' means repeated at specific intervals while 'event-triggered' means at specific events like e.g. a project's end, coming up of a new technology etc.

Table 26. Sub-Process: Knowledge Sharing Occasions.

Input Links	Defined events or scheduled occasions as planned throughout the process definition (section 4.3.2). Identification of new knowledge (section 5.5.1/5.5.2).
Activities	Analyse available knowledge towards who is known to need it. Get people together and enable them to share this knowledge.
Product	Knowledge has been shared among the participants.
Output Links	Potential new knowledge that has come up throughout discussions is considered for storage (section 5.5.2).

5.4 Creation of Knowledge

In a strict sense knowledge is generated in the minds of people only [Nonaka and Takeuchi 1995][6]. It is hard but possible to steer this process by making people deal with specific topics. Additionally, knowledge creation can and should also take place in an uncontrolled manner. The process is similar,

6 There are different opinions on this, e.g. [McDermott 1999] states that only groups, not individuals, create knowledge.

whether it is initiated in a controlled way or takes place unconsciously. After the need for knowledge has been identified, available options (candidates) are determined. These represent the possibilities to acquire the desired knowledge, e.g. through sending people to training, have them read books, assigning a consultant that provides knowledge, etc. An evaluation of the identified candidates then leads to a decision on which approach should be taken to get the knowledge. The candidates need to be evaluated and the selected candidate needs to be modified to fit the surroundings. New knowledge is the product produced as a consequence of all this.

5.4.1 Identification of New Ideas

This main process aims at identifying arising new ideas, and collecting as well as evaluating candidates for identified knowledge needs. Each of these functions will be described by processes in the following. New ideas - innovations - often arise from everyday work. They need to be identified to possibly develop them further.

Table 27. Sub-Process: Identification of New Ideas.

Input Links	Various depending on the area of application.
Activities	Identify a new idea.
Product	A record of the idea.
Output Links	The idea is evaluated (section 5.4.2).

5.4.2 Evaluation of New Ideas

Any new idea needs to be carefully evaluated, as its potential may not be obvious. Denying ideas without such an evaluation could lead to great opportunities being missed. If a decision is made to drop someone's idea, reasoning also provides the creator of the innovation with a justification for such a decision, which is important as it backs up the principle of innovations being always valued as such.

Table 28. Sub-Process: Evaluation of New Ideas.

Input Links	A recorded new idea (section 5.4.1).
Activities	Evaluate the idea for its potential. Detail the impact of the idea. Determine the requirements on the knowledge needed to realise the idea.
Product	A detailed description of the possible impact of the idea, or reasoning for denying the idea.
Output Links	Candidates for the realisation of the new idea are collected (section 5.4.3).

5.4.3 Collection of Candidates

On the basis of the detailed description of an idea or the requirements on needed knowledge, sources inside and outside the organisation are searched for candidate knowledge that can be utilised. It is useful to consider as many candidates as possible. Although this might lead to a large number of candidates, it is nevertheless sensible because otherwise easily available knowledge will be seen as good enough, what it in fact usually is not [Davenport and Prusak 1998].

Table 29. Sub-Process: Collection of Candidates.

Input Links	Requirements on knowledge (section 5.1.2), or description of a new idea (section 5.4.2).
Activities	Search internal and external sources for possible approaches to the needed knowledge or the new idea.
Product	A set of candidates for the desired knowledge.
Output Links	The set of candidates is evaluated (section 5.4.4).

5.4.4 Evaluation of Candidates

After candidates for realising a new idea have been identified, they need to be evaluated. It will often be the case that one or all candidates do not exactly match the requirements. Such candidates have to be modified to become appliable. This raises the cost of the knowledge package. These costs should be estimated for each candidate.

Table 30. Sub-Process: Evaluation of Candidates.

Input Links	Requirements on the needed knowledge (section 5.1.2), or requirements on the knowledge needed to realise a new idea (section 5.4.2). A set of candidates (section 5.4.3).
Activities	Analyse the capability of each candidate against the requirements. Regarding each candidate, estimate the cost of realising the related idea and the potential it has.
Product	Descriptive qualitative and quantitative information about each candidate.
Output Links	A selection of one of the candidates is performed (section 5.4.5).

5.4.5 Selection of Candidate(s)

The requirements concerning the determination of a need (section 5.1.2) or the evaluation of a new idea (section 5.4.2) are compared against the information concerning the evaluation of candidates for realising the idea (section 5.4.4). A selection of one of the candidates from the set of candidates (section 5.4.3) is performed.

Table 31. Sub-Process: Selection of Candidate(s).

Input Links	The requirements on knowledge (section 5.1.2 or section 5.4.2). The set of candidates (section 5.4.3) and information from the evaluation of these candidates (section 5.4.4).
Activities	Select a candidate from the set of candidates.
Product	Decision on candidate for knowledge generation.
Output Links	The knowledge generation is initiated (section 5.4.6) based on the decision.

5.4.6 Creation of Knowledge

The chosen candidate needs to be adapted to the environment of the organisation. This denotes the creation of knowledge in which something new is created by combining existing knowledge with the actual environment.

Table 32. Sub-Process: Creation of Knowledge.

Input Links	The selected candidates (section 5.4.5).
Activities	Process the selected candidate thus creating new knowledge.
Product	New knowledge.
Output Links	The new knowledge is considered for collection (section 5.5.2).

5.5 Knowledge Collection and Storage

The processes presented in this chapter identify, evaluate, codify and store knowledge. Depending on the way the processes have been planned this might simply mean an update of a knowledge map or the storage of packaged knowledge into an electronically realised knowledge management system. Whenever new knowledge is generated this needs to be recognised first to be able to collect and store it. As knowledge may arise unconsciously from everyday work, it is not principally identified, except in the case of consciously driven knowledge generation. After new knowledge has been identified, an evaluation is needed to determine whether the knowledge is worth an integration to the repository. If the knowledge has been decided to be worth making it available using a knowledge repository, then a knowledge package needs to be designed, the knowledge needs to be codified to it and the package needs to be integrated to the repository. Any further changes in the knowledge environment require the knowledge map of the organisation to be updated. The according processes are described in the following.

5.5.1 Identification of Knowledge

This process identifies knowledge that has been created. Also knowledge that already exists but is not yet identified can be identified. Mechanisms for the purpose include e.g. according interviews and questionnaires aimed at finding knowledge.

Table 33. Sub-Process: Identification of Knowledge.

Input Links	The knowledge map (section 4.1.2) might be uncompleted, thus hinting at unconsidered knowledge. Within the definition of KM processes (section 4.3.2), connections to other organisational processes may have been defined that initiate this process.
Activities	Search for knowledge.
Product	Identified knowledge.
Output Links	The identified knowledge is analysed to determine whether it is worthy of an implementation (section 5.5.2).

5.5.2 Evaluation of Knowledge

After knowledge has been identified, an evaluation is needed to determine whether this knowledge is worthy of an implementation to the organisation's knowledge repository.

Table 34. Sub-Process: Evaluation of Knowledge.

Input Links	Knowledge either from knowledge creation (section 5.4.6) or otherwise identified (section 5.5.1).
Activities	Analyse the knowledge towards the potential of later use in the organisation (variety of reuse-situations and frequency of appearance). Decide whether to integrate the package to a repository or not.
Product	Decision upon integration of knowledge to a repository.
Output Links	If it is decided that the knowledge will be integrated into a repository, then package design, codification and integration, and update of knowledge map will be carried out (section 5.5.6).

5.5.3 Package Design

Depending on the type of knowledge that is to be integrated, a medium for its storage has to be decided upon. While explicit knowledge can well be kept in documents, implicit knowledge might require that it be packaged in a more indirect form like a story telling video etc. Depending on the defined infrastructure, one medium out of the possible ones has to be decided upon. The number of available media depends on the storage system and might therefore be limited.

Table 35. Sub-Process: Package Design.

Input Links	Knowledge for storage (section 5.5.2).
Activities	Analyse the type of knowledge and determine a suitable medium for it. Create an according package.
Product	An empty package for knowledge codification.
Output Links	The knowledge is codified into a package (section 5.5.4).

5.5.4 Package Codification

Knowledge codification describes the task of turning knowledge into a code that can be processed in the KM system. It does not deal with the media-type used for storage as this might differ between different types of knowledge and the capability to store the required types of media is an underlying requirement on the KM system. Instead, it concerns the meta-information stored with the knowledge that is used for finding it, which needs to be fitted to the systems needs to enable an effective search and retrieval.

Table 36. Sub-Process: Package Codification.

Input Links	Knowledge for storage (section 5.5.2) and the decision upon the design for this knowledge (section 5.5.3).
Activities	Codify the knowledge into a package.
Product	Meta-information on the knowledge. A knowledge package containing the codified knowledge.
Output Links	The knowledge package is integrated into a repository (section 5.5.5).

The search for knowledge is complicated because there are a large number of possibilities to approach the search for a specific knowledge package, like e.g. the functions that should be performed, the input a process should deal with, or the output a code fragment should provide etc. Combinations of this kind of criteria provide an even better possibility to limit the search results, which is especially important when the knowledge repository has grown big. An example is the search for (1) a process for (2) the requirements definition in (3) a SW development project utilising (4) the waterfall model; thus, four specifications are combined, ensuring that the search results are close to the knowledge package that is searched for.

To enable this kind of search, the codification of a package has to produce an extensive characterisation of each package. The following gives an example structure for characterisation [Basili and Rombach 1991]:

- **Name**: The name of the package according to the naming standard of the system, e.g. Code-C-StringToCharacter, Code-Java-CharactersToString, Process-SD/Waterfall-RequirementsDefinition, etc.

- **Function**: A short description of the package according to the description standard of the system, e.g. "Parameterised code (Java) that turns the given characters into a string", or "Description of process for requirements definition in a SW development project using the waterfall model", etc.

- **Use**: A description of the way the package can be used according to the systems standards, e.g. product, process, management, other knowledge, etc.

- **Type**: The type of the knowledge package according to the systems standards, e.g. document (specification, code), method (inspection, testing), etc.

- **Granularity**: The granularity of the package according to the systems standards describing its scope, e.g. level (function, product, project), process stage (specification, design, testing), etc.

- **Representation**: The representation of the package according to the systems standards, e.g. code fragment, set of guidelines, format mathematical description, etc.

- **Relations (Input / Output)**: The relations of the package describing the needed input and the provided output, e.g. input parameters needed for code execution, input specifications needed for testing, output format, etc.

- **Dependencies**: Dependencies describing what the possible use of the package is depending on, e.g. knowledge about a specific programming language to understand the code, or knowledge about the environment underlying the project management to understand a cost prediction model, etc.

- **Application Domain**: The domain in which the package has its origin, e.g. embedded SW for mobiles, ground-lying SW for satellite base-stations, etc.

- **Solution Domain**: The environment in which the package was developed, e.g. waterfall model, V-model, Pr^{2}imer, Software Process Improvement and Capability Determination (SPICE), GQM method, etc.

- **Object quality**: A description of the object's quality, e.g. response time of code, average correctness of the cost prediction model, etc.

The presented model needs to be adapted to the needs of the organisation; nevertheless, it provides an orientation to the ways characterisation of knowledge packages can be performed. The information and standards used at the stage of codifying knowledge packages is first defined during the preparation tasks. As the other areas of KM, also this one has to be flexible so that new categories can be added when appropriate.

5.5.5 Package Integration

After a package has been designed and codified, it needs to be integrated to the repository. It may be necessary to announce the new package and thus inform relevant people about its existence.

Table 37. Sub-Process: Package Integration.

Input Links	A knowledge package (section 5.5.4).
Activities	The package is integrated into the repository. Any related inventory, directory, etc. is updated to show the newly added package.
Product	An updated repository and according meta-directories.
Output Links	This task initiates the update of the knowledge map (section 5.5.6), if necessary. The announcement of new packages (section 5.3.1) is initiated, if applicable. The knowledge package might be introduced on specific knowledge sharing occasions (section 5.3.2).

5.5.6 Update of the Knowledge Map

The existing knowledge map (section 4.1.2) needs to be updated whenever knowledge is added, discarded or changed. If the knowledge map contains people, also the leaving or coming of members of the organisation has to be reflected accordingly.

Table 38. Sub-Process: Update of Knowledge Map.

Input Links	New or changed knowledge (section 5.5 or section 5.6).
Activities	Analyse the change towards the need to update the knowledge map. Update the knowledge map if needed.
Product	An updated knowledge map.
Output Links	Possible information about changes to the knowledge map via knowledge push (section 5.3.1 or section 5.3.2).

5.6 Knowledge Update

Today environments are rapidly changing and the same applies to knowledge. This covers technologies and products, but also politics (e.g. legislation). Consequently, there arises a need to verify if knowledge is still up-to-date in order to exclude expired knowledge. The validity of knowledge has to be checked and outdated knowledge needs to be updated or removed. To perform these activities, one needs to identify the need for such actions first.

To know and accept that knowledge and its use change over time is an essential principal that needs to be addressed in KM. Even small changes in the environment and/or the working processes may require the knowledge to be modified. While this kind of change might sometimes be predictable, so that the according knowledge packages can be updated beforehand, it is likely that especially smaller changes happen without (all) the knowledge being updated accordingly. Needed changes to knowledge need to be identified, because the acceptance of the whole system might be endangered as outdated knowledge calls the system in question as a whole. Updates on knowledge can take various forms, therefore an evaluation of the needed changes is necessary.

5.6.1 Identification of Change

To identify the changes needed to knowledge, the changes that happen to the environment on which the knowledge depends have to be identified first. This can be done by audits on the knowledge which can be performed regularly at specific intervals, or when specific indicators point out the possibility of outdated knowledge, like e.g. feedback.

Table 39. Sub-Process: Identification of Change.

Input Links	Metrics taken (section 4.4.2) or evaluated feedback (section 4.4.3) can be utilised to identify changes with impact on knowledge.
Activities	Identify a change having impact on knowledge.
Product	Identified changes requiring knowledge to change.
Output Links	The impact of the change is evaluated (section 5.6.2).

5.6.2 Evaluation of Change Impact

An evaluation of the impact of the change is undertaken to determine what kind of update is needed on what knowledge. This means identifying all affected knowledge packages as well as defining the type of change each of them requires.

Table 40. Sub-Process: Evaluation of Change Impact.

Input Links	Identified changes (section 5.6.1).
Activities	Evaluate the identified change towards its impact on the knowledge. Determine the needed changes on knowledge. Determine whether the update is sensible to perform.
Product	Determination of the update needed. Decision on whether to perform the update.
Output Links	Any update is performed (section 5.6.3) and might mean changing or discarding knowledge.

Knowledge updates can consist of discarding, joining, splitting or changing knowledge packages. Discarding denotes the deletion of a knowledge package from the active repository. Within deletion, the topic of archiving has to be taken into account. Splitting means that two different packages are made out of one that has been shown to be too large. Joining denotes reversed splitting, i.e. putting two packages that have been defined to be too small together into one. Changing means changing the content without splitting or joining packages.

5.6.3 Knowledge Update

The needed update on knowledge is performed. Accordingly, the knowledge map might also need an update; also, a notification of the update might be sent. Within discarding knowledge, it seems sensible not to finally delete knowledge, but to mark it as outdated and/or to archive it.

Table 41. Sub-Process: Knowledge Update.

Input Links	The determination of an update (section 5.6.2).
Activities	Update the knowledge as determined. Discard the knowledge, i.e. mark it outdated, archive it, remove it from the running system.
Product	An updated repository with updated or removed knowledge.
Output Links	The knowledge map needs to be updated (section 5.5.6). A notification about the change might be needed (section 5.3.1 and/or section 5.3.2).

6. Discussion of the Model

The intended benefits of the model are described and possible pitfalls are determined in this chapter. Performed and ongoing verifications are equally presented.

6.1 Benefits

The model has been created with the intention of understanding KM and providing help in the proper planning and performance of KM activities. Therefore, it is supposed to provide a number of benefits:

- **Understanding**: By investigating the model, the reader gets a picture of KM. This picture includes the two important viewpoints on KM: the management view and the operational view. This means that he on the one hand will understand that KM is a management issue with subsequent impacts. On the other hand, the reader develops a possible scenario of what KM can mean related to operational work by setting the operational processes into the context of his environment. It especially can be used for training towards KM and enables a common understanding among the addressees, when the process model is explained by using examples from the current context, i.e. the processes are presented as an instance and related to the organisation.

- **Integration with organisational processes**: The process-oriented view on KM with fine granularity supports the integration with other organisational processes. Links can be defined, e.g. initiation of collection of knowledge within project review meetings or of knowledge sharing occasions within the introduction of new tools. Such integration ensures that KM processes are performed and that they support the other organisational processes. Additionally, the process-oriented view provides a means for analysis and planning of tool support for KM. By analysing which processes could be automated, tools that support these processes can be identified and taken into use.

- **Assistance**: The model provides assistance for the performance of KM activities in multiple ways. By providing a step-by-step approach within the KM Pr^{2}imer, it tells one what to do in which order. At the same time, the KM Pr^{2}imer is designed towards continuing improvement, i.e. it includes this concept so that the KM activities will improve with time. And by providing templates for the operational processes the model also gives assistance in planning the actual KM by showing what activities need to be done and suggesting processes for these, which can be adopted according to the needs of the organisation.

- **Comparability**: By mapping any KM activities to the process model, the model might also be of use in comparing different KM projects by providing a common schema for such comparisons. This could be helpful especially in designing interfaces between different KM systems, like proposed in [Kucza and Komi-Sirviö 2001]. Therefore, when knowledge needs to be exchanged across organisational boarders, e.g. within so called virtual organisations, the model provides a means to compare the processes of partners and also assists in the design of interfaces for this inter-organisational knowledge transfer.

- **Continuous improvement**: The KM Pr^{2}imer is designed for continuos improvement, i.e. to detect shortcomings and address them by another cycle of its phases. This leaves room for failures, if KM activities are started by pilot projects, as suggested. The impact of failures will not be too large and the processes can be improved before leveraging the processes to further parts of an organisation. So the KM process model aims at an evolving KM system that should also be able to adapt to changing requirements.

6.2 Pitfalls

Although there are no long-term experiences in applying the model available yet, it can be assumed that there are some pitfalls one can run into. Anticipated pitfalls are going to be determined in this chapter.

A potential danger is the possibility of making KM include too much formalism. This is a similar problem to the one with quality handbooks. Without questioning the use of formal descriptions, it has to be clear that the formal description alone will not change anything. KM is about people and therefore the people issues need to be emphasised. Just by developing processes it will not be possible to make people use these processes properly. This issue should, however, be addressed within the model. In the KM Pr²imer, there is a suggestion for an analysis of the existing cultural environment (see section 4.1.4). This issue is furthered in section 4.2.3, where goals for influencing this culture are to be set which are to be taken into account in the planning of processes (see section 4.3.2).

Another issue that has to be dealt with is complexity. Although a general issue of conducting KM, the process-oriented view is nevertheless anticipated to be confusing when dealing with several knowledge domains. While knowledge domains are a means of splitting this complexity, the linking between them is important. KM can only be fully effective when knowledge flows are also enabled across organisational divisions or units, which are likely to be designed as separate knowledge domains. This can, however, be addressed by a KM role like a CKO, which has the responsibility for this issue.

Other pitfalls are currently not anticipated. However, it is possible that such will come up within the use of the KM process model. They need to be dealt with by appropriate actions. The continuous improvement integrated into the processes should be able to deal with the practical impacts of such pitfalls. Whenever such are identified, however, there might also be a need for modifications of the model to address them more specifically or to avoid running into them.

6.3 Verification

An initial verification of the model against industrial practices has been performed using interviews. The company subject to this verification is the developer of software that integrates KM functionality into it. By using the model to identify how these functions related to KM work, it became clear how KM processes can be automated in software. The tool is used for automation and control at mills and plants. The software is able to detect malfunctions or unusual functioning with sensors connected to the system. This equals the identification of need for knowledge (section 5.1.1) providing help in solving this condition. In such cases the tool determines the type of malfunction based on the available data. This equals the determination of requirements on needed knowledge (section 5.1.2). The tool automatically searches for records of similar situations that have taken place in the past. The search criteria is derived from the current sensor data (section 5.2.1), and a search is performed for available records dealing with similar situations (section 5.2.2). The operator in charge is thus provided with a list of links to related help-files, records of prior actions and technical manuals and descriptions at the same moment as the unusual condition is detected. He can look up appropriate documents and initiate actions to solve the problem. This verification is described in [Kucza and Komi-Sirviö 2001].

A further verification is currently going on in a project conducted together with an industrial partner. It deals with the utilisation of KM to support software code reuse. While this reuse itself can be seen as a KM activity, the focus set for the project is to analyse and improve the mediation of knowledge between the two major organisational parts of reuse: for-reuse producing the reusable assets and with-reuse utilising these. The plan on how analysis is going to be performed is presented in [Kucza, et al. 2001]. Currently, actions to foster a supportive culture and processes of communication and information exchange between these two parts of the reuse-organisation are planned. The final results of this verification are not yet available, as the project runs for multiple years. However, the current state seems to support the assumed benefits mentioned earlier in this report. When there are more results available, they will be analysed and published and possible changes or addenda to the model will be suggested.

A third validation of the usability of the model is currently underway and performed independently by a partner of VTT Electronics. This partner utilises the model in a project aiming to improve the management of existing knowledge and its development. This project is basically dealing with the view HRM has on KM, i.e. the creation of knowledge maps to show the current state of knowledge the employees have, management of interests to determine the direction each employee wants to develop in the future, and management of related activities. The latter includes the planning of training and assignment to projects/activities according to the interests of an employee. This project is at its very beginning and no results are available yet. As soon as the results are available, they will be published and possible changes or addenda to the model will be suggested.

7. Conclusions and Outlook

In this chapter, conclusions are drawn from this report by pointing out what can be said about its current usability. Finally, an outlook is provided on further activities. This includes the description of anticipated activities and possible, although not yet known, directions for the development of the model.

7.1 Conclusions

The processes are presented on a general level to allow the model to match as many situations as possible. At this level, the model therefore is supposed to be applicable in various types and parts of organisations. For example, it is assumed that the processes could be adopted for HRM as well as for SE. This, as a consequence, does not allow the processes to be used without adaptation. In this context, a distinction has to be made between the co-ordination processes (Chapter 4) and the operating processes (Chapter 5). The co-ordination processes are designed to assist in the adoption of the operating processes. Accordingly, the processes of the KM Pr^{2}imer are more close to the real world than the KM operating processes. An organisation starting KM activities is supposed to perform the processes of the KM Pr^{2}imer as described. The KM operating processes, on the contrary, are more generic and therefore general and need to be adopted according to scope. This is performed within the KM Pr^{2}imer (see section 4.3.2).

The initial verification and validation activities as presented above are not enough to finally determine the usability of this model for different cases. However, they do prove that the model in its current state can already be used with different scopes. Therefore, there is a need for further validation and verification activities to specify the cases in which the KM process model can be used and in which it probably cannot. The model, however, is to be considered an evolving means. That means that with the identification of situations that the model is not suitable for, modifications might become necessary. The resulting extended version of the model can then cope with such situations.

In its current state the model is quite abstract and, although pointing out what has to be done, does not in all cases provide enough help for the way things need to be done. In applying the KM process model, therefore, external knowledge is needed. This affects a number of processes, such as:

- the **analysis of knowledge culture** (section 4.1.4) and the according planning of **culture goals** (section 4.2.3), which, in order to be performed correctly, require that social and psychological sciences be taken into account.

- the **KM measurement planning** (section 4.2.2), which is difficult as knowledge is hard to measure. Although the suggested approach by the GQM method provides assistance in this, metrics on knowledge and KM need further investigation and according assistance by proposals for suitable metrics and ways to measure them.

- the **determination of infrastructure** (section 4.3.4), which is very important in today's often distributed environments or inter-organisational knowledge transfers when working close with external partners. At the same time it is difficult to support KM by technology, as there is a danger of placing too much emphasis on the technological issues and too little on the human factors. Consequently, there is a need for an analysis of applications that support KM properly and knowledge how to implement them into a KM strategy.

- the processes of **knowledge creation**, which often take place unconsciously and therefore are hard to model. By using the fine granularity presented in this report it is possible to assist them by providing additional input to the candidates (see section 5.4.3), e.g. by brainstorming meetings or discussions in virtual discussion places. However, good practices for identification of knowledge creation have to be determined to enable such support.

This list is not necessarily complete. KM is a difficult and complex topic and further needs for more explanation, addenda or corrections might come up. The suggested process model here differs from other attempts to determine KM [Nonaka and Takeuchi 1995, Davenport and Prusak 1998, Wiig 1999, Bhatt 2000]. Most of these other attempts deal with KM in a different way, e.g.:

- [Nonaka and Takeuchi 1995] focus on knowledge creation,

- [Davenport and Prusak 1998, Bhatt 2000] look at KM as a whole, but regarding granularity stay on the level named as main processes in this study (see Figure 2. Overview of the Main Process), and

- [Wiig 1999] emphasises the co-ordinating processes presented in chapter 4.

A closer focus allows dealing with issues more detailed. As explained above, this process model lacks such details. Such can, however, be incorporated in future revisions. Still the model provides assistance in the planning and performance of KM activities covering both the co-ordinating and operating processes related to KM.

Summing it up, the model in its current state provides help in understanding KM and provides assistance in conducting KM but requires additional knowledge about various aspects to result in proper KM. It is a starting point and needs to be further developed to mature, including the provision of detailed knowledge on specific aspects as it is contained in the related works referenced above.

7.2 Outlook

The long-term interest of VTT Electronics is to improve the software development processes for embedded systems. To reach this goal the connections between KM and SPI actions are going to be investigated. The process model as presented in this document has been initially verified in industrial cases. As more experiences and long-term impacts become available, changes are likely to come up in the future. Some of the anticipated changes and addenda are:

- **Growing experience base**: The use of the KM process model in other surroundings and long-term projects will provide input to possible improvements of the model. These can be minor changes like other names for the processes or more detailed descriptions, or more complex changes like additional processes or dropping of processes. With this report, the model becomes available to anybody interested in it and therefore it is possible that a large amount of feedback will contribute to the further development. This is desirable and needed for the model to mature.

- **Including good practices / KM Framework**: as mentioned above, a number of processes are named but not enough guidance for conducting them is presented. With a growing experience base on how these processes have been performed, means for the practical use will become available and might be included in the model. This would allow the extension of the model towards a KM framework, providing not only the information about the operations to be carried out but also guidance on how to perform the processes by including examples, reports on good practices, questionnaires, metrics, etc.

Beside these likely changes, some possible directions of the further development can be determined. These are:

- **Assessment**: Beside the above mentioned ways to utilise the model, it might be possible to extend the model towards an assessment framework. At the current state the model does not provide any scales for assessing KM processes, but it might be a good basis to start developing such.

- **Specialisation**: With the utilisation of the model in different environments the need to create separate versions of extensions are possible, if different application areas have different requirements on the processes. Experience can provide possibilities to identify such differing requirements and might result in different versions of the KM process model for application in specific areas. This would allow one to provide more concrete guidance on the performance of the processes, as known parameters of specific environments can be taken into account.

- **Standard**: There are currently projects underway investigating the creation of standards for KM. A process model could be such a standard. As a reference model as we know them from other areas, as the V-Model, or as the skeleton upon which to build a framework and further standards, like assessments. At the current state the model is far away from the maturity needed to propose a standard. However, if enough interest on the model comes up among researchers and practitioners of KM it might get an experience base broad enough to mature towards a standard.

The KM process model will be used in the future. The different scopes in which it will be applied and the amount of feedback becoming available from such applications will determine what the future development will be like. VTT Electronics is going to research into KM actively and will develop this model further. The model will be brought into international research networks to get the opportunity to mature. As is usually the case with research, one cannot say beforehand what is going to be the result, but some possible directions for this have been shown in this study.

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Appendix A: Table of Figures and Tables

Table of Figures

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Abstract

This report presents the results of research into knowledge management (KM) performed at VTT Electronics, the Technical Research Centre of Finland. Based on literature analysis and prior experiences with software process improvement (SPI) projects, a process model is proposed as an abstract and generic model to be used in KM projects. Its purpose is to enable one to understand knowledge management, perform analyses and plan processes in a structured way, as well as ensure that important aspects are taken into account in KM projects. A distinction into two separate parts of the model is used, which divide the processes into co-ordination processes and operational processes. Herein, co-ordination processes describe what needs to be performed to initiate and control knowledge management activities; operational processes describe what is done when performing knowledge management activities. The co-ordination processes are organised into a cycle of analysis, planning, defining and effecting to support continuous improvement. The operational processes consist of the main processes: identification of need for knowledge, knowledge sharing, knowledge creation, knowledge collection and storage, and knowledge update. The model is presented on a detailed level, meaning that the mentioned high-level processes are refined into 39 more detailed processes. Each of these is presented by describing its input-links, the activities the process covers, products, and output-links. Initial verifications made are presented. The model and its use is discussed, and finally, an outlook on further activities related to the development of the model is presented. The discussion covers both the explanation of expected benefits and anticipated pitfalls/shortcomings. Further development needs to address the identified shortcomings thus extending the model and thus allowing it to mature.

Keywords
knowledge management, process models, strategic planning, co-ordination, operation, knowledge, collection, storage, update, verification, communication

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