Proposition of a Tool to Build Virtual Teams : Virtual Team Building Support System : Considerations of Virtual Project Management, Competence Management and Virtual Team Interaction

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Proposition of a Tool to Build Virtual Teams: Virtual Team Building Support System. - Considerations of Virtual Project Management, Competence Management and Virtual Team Interaction.

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Pour Mika ...

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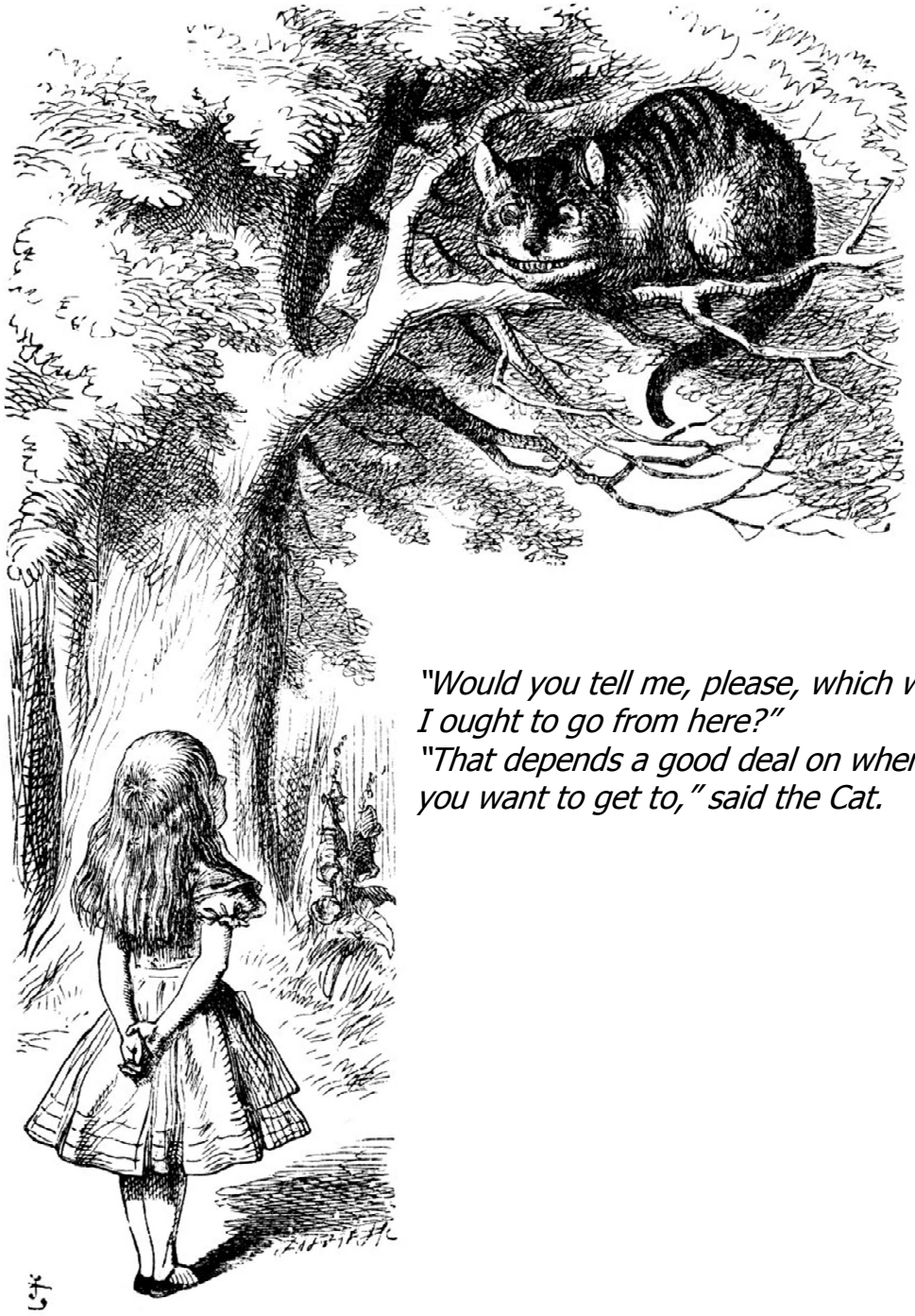

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.

aroll: Alice's Adventures in Wonderland, 1865
on: John Tenniel

Résumé

Les équipes virtuelles deviennent de plus en plus courantes dans les organisations actuelles pour la conception de produit, service, système ou processus organisationnel. Etant donné que des partenaires potentiels de ces projets de conception peuvent être répartis dans de nombreux pays, ces organisations doivent accéder à des modes de communication dynamiques qui permettent cette mondialisation. De nombreuses organisations ont répondu aux contraintes d'un tel environnement dynamique par l'introduction d'équipes virtuelles. Celles-ci ont des caractéristiques particulières incluant la distance géographique, temporelle et des différences organisationnelles et culturelles.

Dans notre travail, nous proposons une conception préliminaire d'un outil d'aide au montage d'équipes virtuelles dénommé Virtual Team Building Support System (VTB Support System). Le VTB Support System fonctionne comme un outil d'analyse, communication et planification du montage d'équipes virtuelles dans le domaine de développement de nouveaux produits. Cet outil est un support qui facilite la constitution d'une équipe virtuelle non seulement dans des organisations mais aussi dans des projets sans réelle structure organisationnelle.

Le VTB Support System identifie des besoins et apporte des recommandations et des solutions techniques adaptables permettant la constitution d'une équipe virtuelle. Dans un environnement virtuel, les membres d'une équipe projet peuvent changer fréquemment, ceci nécessite d'identifier les exigences d'un système de support d'aide au montage de telles équipes. Le processus de constitution d'une équipe virtuelle ne se limite pas uniquement au développement du groupe et aux aspects ressources humaines ou des interactions humaines, mais prend également en compte l'organisation des processus de travail. Les recommandations pour la constitution d'équipes virtuelles sont considérées sous trois domaines qui sont précisément présentés dans notre travail par management de projet virtuel (VPM), management de compétence (CM) et l'interaction d'équipe virtuelle (VTI).

Dans le but d'élaborer le VTB Support System, nous choisissons l'approche globale de l'analyse fonctionnelle. Cela nous permet d'identifier toutes les fonctions du VTB Support System qui décrivent les exigences d'un tel système. Ensuite, nous utilisons le Quality Function Deployment (QFD), en particulier la «maison de qualité», pour déduire des recommandations sur les fonctions les plus importantes détectées par l'analyse fonctionnelle. La maison de qualité permet de représenter dans une matrice les recommandations ou solutions techniques et les fonctions (issues d'une analyse fonctionnelle) et d'évaluer si une recommandation/ solution satisfait une ou plusieurs fonctions.

Le VTB Support System est appliqué dans trois cas différents qui soulignent l'aspect générique du modèle.

Mots clés: Virtual Team Building Support System, équipe virtuelle, développement des nouveaux produits, management de projet virtuel, management de compétence, l'interaction d'équipe virtuelle, analyse fonctionnelle, maison de qualité

Abstract

Virtual teams become more and more courant in today's organisations for New Product Development (NPD) of a new product, service, system or organisational process. As potential partners of those projects are spread out over countries, organisations need access to a dynamic communication to increase de-centralisation and globalisation of work processes.

Many organisations have responded to this dynamic environment by introducing virtual teams. These virtual teams have specific characteristics including distance of geography or time and cultural or organisational differences.

In this PhD thesis we provide a preliminary design of a tool of support to build virtual teams, named Virtual Team Building Support System (VTB Support System). The VTB Support System functions as tool of analysis, communication and planning for virtual team building in the domain of NPD. This tool is a support that facilitates the constitution of a virtual team not only in organisations but also in projects without a real organisational structure.

The VTB Support System identifies requirements and provides recommendations and adaptable technical solutions that permit to build a virtual team. In a virtual environment, project members can change frequently, which necessitates to identify the requirements of a VTB Support System to build those virtual teams. The process of virtual team building is not just limited to team development under the aspect of human resources or human interactions but takes also the organisation of working processes into account. The recommendations for virtual team building take into consideration three domains that are precisely presented in this work as Virtual Project Management (VPM), Competence Management (CM) and Virtual Team Interaction (VTI).

In order to provide the VTB Support System, we choose the holistic approach of the functional analysis. This allows us to identify all the functions of the VTB Support System that describe the requirements of such a system. Then, we use the tool of Quality Function Deployment (QFD), especially the "house of quality", to deduce substantiated recommendations of the most important functions that are detected by the functional analysis. The house of quality allows representing the recommendations or technical solutions and the functions (issues of a functional analysis) in a matrix and to evaluate if a recommendation or a technical solution satisfies the demand of one or multiple functions.

The VTB Support System is applied in three different cases, which underlines the generic aspect of the model.

Keywords: Virtual Team Building Support System, Virtual Team, New Product Development, Virtual Project Management, Competence Management, Virtual Team Interaction, Functional Analysis, House of Quality

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List of Abbreviations

A	Adjourning
APM	Agile Project Management
C.P.R.	Commenting, Polling and Rating
CM	Competence Management
CSCW	Computer-Supported Cooperative Work
CSSQ	Cost-Scope-Schedule-Quality
CWE	Collaborative Working Environment
e.g.	exempli gratia ("for example")
et al.	et alia ("and others")
F	Forming
FC	Constraint Functions
FP6	6th Research Framework Programme
FP7	7th Research Framework Programme
FT	Transfer Functions
ICT	Information and Communication Technologies
i.e.	id est ("that is")
IFF	Fraunhofer Institute for Factory Operation and Automation
N	Norming
NPD	New Product Development
P	Performing
P.S.	Posting and Sharing
PM2.0	Project Management 2.0
QC	Quality Characteristics
QFD	Quality Function Deployment
R&D	Research & Development
RTD	Research and Technology Development
S	Storming
SIG	Special Interest Group
S.N.	Social Network
SME	Small and Medium-sized Enterprises
VPM	Virtual Project Management
VTB Support System	Virtual Team Building Support System
VTI	Virtual Team Interaction

Lecture Guide

In this part we give an overview of different styles used in the manuscript to facilitate the reading of this PhD thesis.

The body of the manuscript is written using the style Tahoma with police 10. This is an example of the style of the body.

Propositions or **proposed synthesis** by us are bold as shown in this example.

Definition 1. Example of Style: Definition – Our Proposition

> *This is an example for the style used for definitions proposed by us. All definitions are in Tahoma, italic, police 10 and encircled with a frame. They are numbered and preceded with the term "Definition" and its respective number. They can be found in the recapitulative list of definitions.*

Definition A 1. Example of Style: Definition – Proposition by other Authors

> This is an example for the style used for definitions proposed by other authors. All definitions are Tahoma, police 10 and encircled with a frame. They are numbered and preceded with the term "Definition A" and its respective number. They can be found in the recapitulative list of definitions.

1 Introduction

Global competition, reengineered short product life cycles, mass customisation and strong collaborations on the international market are some of the trends that influence currently organisational changes. The radical technological advances like the exponential development of the Internet and the web have changed the way that teams are collaborating together beyond temporal, geographical, cultural or organisational boundaries. Virtual instruments and digital tools are used nowadays in the daily working life in consequence of the growing complexity of global organisations, the increasing need of flexibility, reactivity and the advances in communication technologies. Today's economic prosperity depends on generating new knowledge, innovation and technological progress. Striving for worldwide competitiveness requires access to worldwide communication, as prospective partners and customers are separated over countries and continents. Efficiency increases tremendously according to the speed of interaction. Knowledge, competencies and expertise evolve fast. Work has become mobile and working power has to be available when it is needed to rapidly complete required tasks by having quick access to all necessary resources such as skills or knowledge, regardless of where they are situated.

In light of the increasing de-centralisation and globalisation of work processes, many organisations have responded to their dynamic environments by introducing virtual teams. Team members of virtual teams are temporally, geographically organisationally and/ or culturally dispersed. They coordinate their work mainly with electronic Information and Communication Technologies (ICT). New forms of teamwork have been made possible by ICT and projects are often described by a high degree of virtuality. The radical advances in technology do not only influence the domain of Virtual Project Management (VPM) but also Competence Management (CM) and Virtual Team Interaction (VTI).

Teams in organisations today are characterised by dimensions of virtuality, as this is the current way to collaborate. In a study of the German AfW - Bundesverband Finanzdienstleistung e.V. (2002) almost 400 business managers from different branches in Germany revealed that about 20% of the managers worked mainly as a member of a virtual team, and about 40% worked at least temporarily in virtual teams. Similar numbers have been reported for other countries (AfW, 2002 quoted in Hertel et al., 2005). Virtual teams can be found in various domains, such as Research & Development (R&D), New Product Development (NPD), customer services, problem-solving task forces etc. as well as in non-economic purposes, like scientific collaboration (Hertel et al., 2005). They are needed e.g. for idea creation, product design, establishment of competitive advantages, effective utilisation of human resources, to tackle the necessity of specialised and expensive high-tech equipment, software tools and simulators, to improve financial return and to speed up e.g. the NPD process. These are done in short-term projects as well as in the complexity of the open-world economy. Stevens et al., (2009) distinguish that virtual teams might be most evident in the domain of NPD. They also exist in non-economic organisations such as in scientific virtual collaborations. Large industrial organisations as well as Small and Medium-sized Enterprises (SMEs) have undertaken profound transformations to structure, coordinate and facilitate design activities along with CM. An integral part of fostering new com-

petencies, continued innovation and technological progress are improvements of the NPD and project management process (Ramesh and Tiwana, 1999). According to Schmidt et al. (2001) studies have shown that ca. 70% of organisations use cross-functional teams to perform NPD tasks (Schmidt et al., 2001 – referring to: Page, 1993; Griffin, 1997). Such cross-functional teams are indispensable because prospective team members of NPD projects are spread out over countries. As NPD requires increasingly deepening technical competencies as well as the combination of different kinds of expertise, organisations need access to worldwide communication to aspire worldwide competitiveness (Leenders et al., 2007).

In a professional world where competencies of team members are increasingly internationally distributed and virtual teams become more and more common, according to Edwards and Wilson (2005) there is definitely "[…] a demand for guidance to understand and tackle the specific requirements that this form of work poses for organisations, managers, team leaders and team members". In this work we aim to define these requirements in order to propose a coherent framework for virtual team building.

Collaborative NPD virtual teams need to be more intense, interactive and dynamic. In order to form virtual teams quickly a Virtual Team Building Support System (VTB Support System) is needed, a blueprint that organisations and projects can follow to design their own particular virtual team according to their respective needs. The VTB Support System functions as a tool of analysis, communication and planning for virtual team building. It can be used to obtain in short time, a low-cost and secure virtual team building process that considers multiple aspects of different domains. This helps to meet the claim of a holistic approach that respects the technological as well as the human dimension. The VTB Support System takes into account three domains:

- Virtual Project Management (VPM)
- Competence Management (CM) and
- Virtual Team Interaction (VTI).

The model is adaptable to different forms. It covers different demands and can be applied in many ways based on the multiple recommendations and technical solutions that are provided. The VTB Support System should not be applied uniformly within organisations or projects, but is to be adapted to the specific needs of each one. We introduce the problematic aspects in Computer-Supported Cooperative Work (CSCW) and its features to give recommendations for the integration of a VTB Support System in organisations. New paradigms are presented to integrate a VTB Support System as well as general directions for planning the implementation of collaboration within organisations and projects without organisational structure with the aim of obtaining the best performance. The integration of different cooperation functionalities may lead to innovation. The compositions enable the creation of new applications based on existing ones.

The chapter 1 is structured as follows. The motivation for this research is presented in § 1.1. It is sectioned in a technical (§ 1.1.1) and a human dimension (§ 1.1.2). Before introducing related works and our positioning in § 1.3 according to the three scientific disciplines of Industrial Engineering: Management Science, Human and Social Science and Engineering Science, we

present in § 1.2 the research problem and objectives of the PhD thesis. We close this chapter with a global plan to present the structure of the work in § 1.4.

1.1 Motivation

The reasons for conducting this research work are multiple. During the first years of the PhD thesis we have been actively involved in different European projects where virtuality was seen as a continuum, which implies that the daily work of these projects was characterised by a high virtuality as this was the current way to collaborate. The following three European projects appertain mainly to the reference source that has been used to find out about experiences, expert opinion and recommendations: smE-MPOWER (www.sme-mpower.net), Knowledge Board (www.knowledgeboard.com), IST-EC2 (www.ist-ec.org). Understanding NPD as development of new products, services, systems or organisational processes, all three named European projects has been considered as virtual NPD projects. Based on our experience of virtual teamwork we submitted, additionally, a project proposal in the framework of FP7 (7th Research Framework Programme). The proposal intended to create and develop customer-driven products and services by active decision support for the formation of virtual partnerships for dynamic sharing of engineering resources and competencies and fostering new, innovative and global product design and development.

To answer explicitly to the call of FP7 we aimed to achieve following main objectives within the project proposal:

- Building a user and market driven platform that facilitates NPD process through access to distributed resources on demand.
- Building sustainable and globally competitive networked NPD virtual teams with heterogonous dynamic resources, competencies and knowledge.
- Providing enhanced competitiveness through virtual team building and collaboration.
- Enabling more creative approaches to NPD and new knowledge production to improve the quality and extent the organisation's portfolios.

The list of the objectives that copes with the call of FP7 shows that there is a real demand of research in the domain of CSCW and virtual team building. Virtuality is regarded as solution for organisations to increase their competitiveness by sharing their resources like competencies and knowledge for NPD. The recommendations of the domains VPM, CM and VTI are highly important to achieve the objectives of the European commission's call. Motivated by this demand we started the research for this PhD thesis.

The subject of the PhD thesis deals with a support system for virtual team building, the VTB Support System. It is embedded perfectly in our laboratory's theme of Design Management that focuses on design activities in industrial contexts, not in terms of elementary design acts, but for modelling, analysing (simulating and assessing) and designing the design systems (tools, processes, organisations). The thesis covers exactly following items: the management of innovative design processes, steering design projects by values and collaborative design.

This research is motivated by two major factors, a technical and a human. Our understanding of "virtual team building" is not only embossed by the traditional understanding of "building" that concentrates on "constitution". In this work virtual team building considers three aspects of building a virtual team: its organisation, its staffing and its development. Further explications to these aspects are made in table 1-1.

Table 1-1. Our Understanding of Virtual Team Building

Our Understanding of Virtual Team Building			
Dimension	**"Virtual Team Building"**	**Focus**	**Represented in this work by**
Technical	Virtual Team Organisation	Working processes and project management aspects	Virtual Project Management (VPM)
Human	Virtual Team Staffing	Competencies of team members and human resource management aspects	Competence Management (CM)
	Virtual Team Development	Human behaviour and interactions	Virtual Team Interaction (VTI)

We derive following definition 1-1 of virtual team building in this work.

Definition 1-1. Virtual Team Building

> *Virtual Team Building deals with the organisation of working processes, the staffing of competencies of team members and the development of human behaviour and interactions. It considers the domain of Virtual Project Management (VPM) as technical dimension and the domain of Competence Management (CM) and Virtual Team Interaction (VTI) as human dimension.*

The first major factor motivating our research is the domain of VPM and in an example of application (§ 5.3) web 2.0 tools. It is understood as technical dimension in this PhD thesis as it deals with working processes and technical aspects of project management. A second focus of the technical dimension is the product itself, as this work is situated in the domain of NPD. NPD is incorporated as context. This is the reason why it is not explicitly listed in table 1-1.

The second major influence comes from a human point of view and is represented by the domains CM and VTI. Both domains are determined as human dimension in this research and are heavily influenced by human and social considerations. There is an increasing recognition of the importance of collaboration and virtual team building, especially with regard to aspects of CM in the Human and Social Science literature. In this understanding "virtual team building" focuses on competencies of potential team members to staff virtual teams by the means of human resource management. As the style of interaction in a virtual team can impede or enhance team members' ability to share their unique knowledge and competencies, VTI is strongly affected by virtual team building. Its focus is set on the human aspect of virtual team development.

Both dimensions, the technical and the human, are interwoven with each other. Stevens et al. (2009) underline this interdependency by stating that the right selection of technologies is required to support social interactions, knowledge creation processes and innovation.

The technical dimension of the PhD thesis is presented in § 1.1.1 while the human one is handled in § 1.1.2.

1.1.1 Technical Dimension

With the aim of building a VTB Support System we have to consider the variety of existing recommendations and technical solutions and their purposes in the domain of VPM. Hereby, we focus on the technical dimension of virtual team building: the framework of the team organisation. This incorporates environmental factors, standards of organisational team and working processes, project management and the use of ICT (Cohen and Bailey, 1997; Duarte and Snyder, 2006).

The exponential development of the Internet, Intranet and the World Wide Web has changed the way teams are working together. Recently, ICT have rapidly advanced. They are enabling modes of interaction, communication and collaboration not formerly possible. The advantages of computer-based environments are indisputable. But at the same time, the literature discusses challenges, problems and unsatisfied promises of this technology-based reality. Even well designed information systems are often not successfully adapted to the organisational context (Nikas and Poulymenakou, 2008). Apparently, there is a gap between the promises and the often disappointing reality concerning working processes and project management that virtual teams are faced with, e.g. in the domain of NPD (§ 2.2). The technical dimension of this research is handled in detail in §§ 2.3.1 and 2.3.2.

Even if Lurey and Raisinghani (2001) postulate that virtual teams could be more effective if more advanced technologies were available, the authors also highlight that the technologies are only a partial factor. The introduction of collaborative technology does not coercively enhance intensive collaboration among team members of a project (Nikas and Poulymenakou, 2008). Being equipped with the best technologies is not enough to ensure virtual team building. According to Lipnack and Stamps (2000) the success of virtual teams and their virtual team building should be attributed "[…] 90 percent to people and 10 percent to technology". Internal group dynamics and external support mechanisms must also be present to succeed virtual team building (Lurey and Raisinghani, 2001). These aspects are taken in following § 1.1.2 into consideration.

1.1.2 Human Dimension

The human dimension of this work determines two domains that are implemented in the VTB Support System: Competence Management (CM) and Virtual Team Interaction (VTI).

Other authors delineate the human dimension by group processes and team working (Cohen and Bailey, 1997; Vakola and Wilson, 2004), organisational culture and training (Vakola and Wilson, 2004; Duarte and Snyder, 2006) or human resource policies (Duarte and Snyder, 2006) (table 3-1).

One of the advantages of a virtual team in the domain of NPD is that it enables to design a new and innovative product, service, system or organisational process by sharing and combining previously isolated and distributed knowledge and competencies from different locations (Harzallah and Vernadat, 1999) (§ 2.2). NPD comprises numerous knowledge intensive tasks and thus, the need for highly skilled experts. According to costs, such experts are rare resources which are necessary in order to achieve innovative products and thereby to accomplish competitive advantages. Whenever a product opportunity arises, the right competencies (technical, contextual and behavioural) must be selected to form the virtual team to take advantages of market opportunities. This "new" way of beholding human resource requires a more precise formalisation of concepts like competencies in order to be able to give recommendations in the domain of CM. Competencies need to be identified, for instance, to work effectively in a virtual team environment and to assign team members efficiently to NPD process activities. Challenges in the human resource management, particularly in terms of staffing and managing of competencies should be respected. As important aspect of the human dimension of this research, competence management is presented in § 2.3.3.1.

Even if all required competencies are available there is a risk that they might not be used in a way that the project can benefit. As the communication of a virtual team may be more limited as in a traditional face-to-face team in consequence of the distance, the capacity of turning tacit knowledge in explicit knowledge and finally in innovative products may be also limited. The issues of knowledge management remain an uncharted area within the virtual NPD research. According to Stevens et al. (2009) research is missing on how to provide virtual team members with the required knowledge particularly from external sources. Kogut and Zander (1992) affirm that the knowledge base of an organisation is embedded in social processes, which means in interaction of individuals. In our research this aspect is incorporated as VTI (§ 2.3.3.2). Organisations and virtual teams consist of individuals with their own personal knowledge, competencies and expertise. The organisational cognition emerges from the interaction of these individuals who exchange and combine their unconnected pieces of knowledge to create new knowledge. Virtual teams that learn and are able to improve continuously their processes to provide products, services, systems or organisational processes that reflect these changes in the external context are also able to survive in an ever changing marketplace. According to Senge (1990), Schein (1993) and Nonaka and Takeuchi (1997) teams are a fundamental source of learning and organisational effectiveness. Stevens et al. (2009) conclude that if the architecture of the organisation designates the possibility of knowledge creation, virtual teams as one possible architectural option have great impact on the knowledge creation process.

1.2 Research Problem and Objectives

As presented in table 1-1 and definition 1-1 virtual team building stresses in this work three foci: VPM, CM and VTI. As a virtual team is set into operation to achieve a common goal (e.g. Griffith et al., 2003) working processes and project management aspects should be taken into account to establish a support system of virtual team building. This is done by the implication of VPM in the domain of NPD that typifies the technical dimension of this PhD thesis. The specific human dimension of this work is the challenge to integrate recommendations of the domain of

CM and VTI in the VTB Support System. Even if methodologies handle not only technical but also soft competencies they do not consider the human dimension of virtual team building that is in this work respected by the domains CM and VTI. The VTB Support System helps to integrate virtual team members with complementary competencies into a virtual team. It provides recommendations that focus on the organisational role of virtual teams and the associated challenges for human resource management and interaction.

Therefore, in order to be as exhaustive as possible we propose a framework taking into account three different life cycles in our proposal of a VTB Support System. To summarise, the research problem of this work concerns those three life cycles: product, project and team, which are in interrelation. They are visualised in figure 1-1.

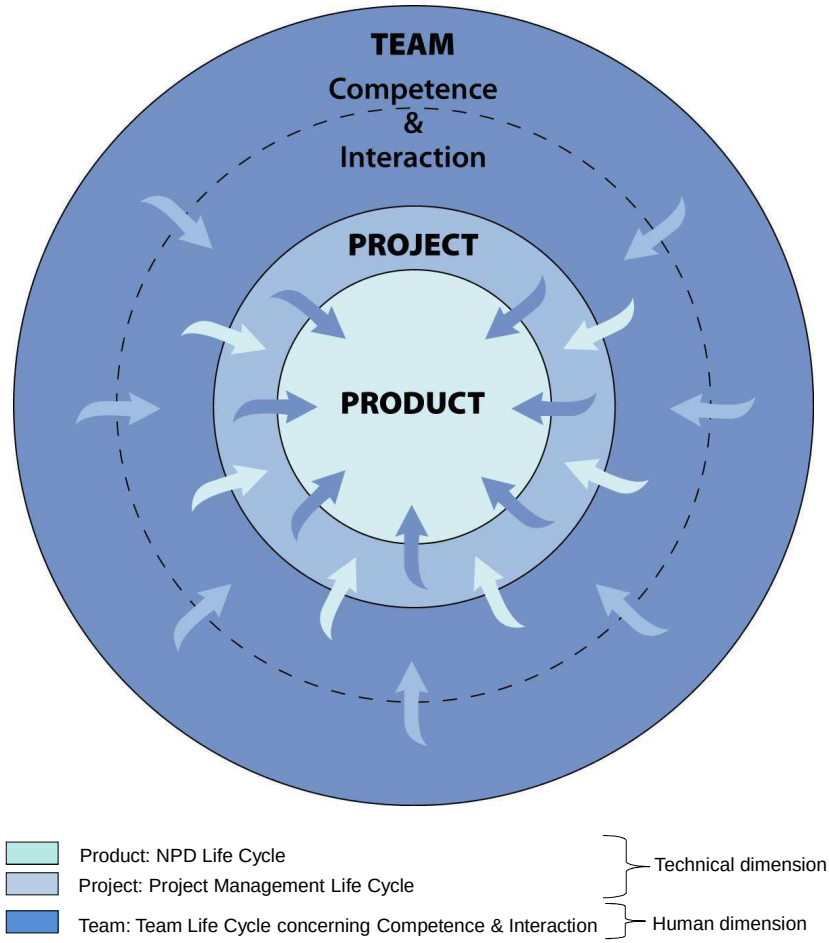


Figure 1-1. Interrelation of Life Cycles: Product, Project and Team

As this work is situated in the domain of NPD, the product is the core of our research. To ensure the conduction of the processes of the NPD, that are organised in the manner of VPM, acquired competencies must be provided. These competencies are realised at the moment of activity. This happens at the moment of interaction within the virtual team.

Our research approach is set in the conceptual design. The objective of this PhD thesis is designing needs and generating concepts to provide a preliminary design of a VTB Support System. Those concepts should be evaluated by different applications.

The main objective of this work is to answer the research question:

How to support the building of a virtual team in the domain of VPM, CM and VTI?

Sub-objectives are presented in the following list:

(1) Understanding the manner in which virtual teams collaborate,

(2) Providing a holistic view of virtual team building,

(3) Defining the requirements of the VTB Support System,

(4) Analysing and developing recommendations and technical solutions to improve virtual team building,

(5) Translating the requirements into recommendations and technical solutions that are adaptable to industrial reality,

(6) Developing a preliminary design of the VTB Support System as tool of analysis, communication and planning,

(7) Introducing and using of a VTB Support System that facilitates virtual team building.

1.3 Related Works in Industrial Engineering

Industrial Engineering considers mainly three scientific disciplines: Management Science, Human and Social Science as well as Engineering Science (Tissot, 2005).

In this PhD thesis we aim to respect these different points of view. The Management Science makes its contribution by providing knowledge about the management of a system and the strategic and organisational point of view of management. The Human and Social Science permits to take the human dimension of the system into account. The Engineering Science provides tools that help us to develop the system.

Related works to this research are allocated to these three disciplines: Management Science, Human and Social Science and Engineering Science. They are presented in the following §§ 1.3.1 - 1.3.3.

1.3.1 Management Science

We cope with the demand of Management Science of providing knowledge about the management of a system and the strategic and organisational point of view of management by leaning on the work of Tølle and Bernus (2003), Rice et al. (2007), Stoeckert et al. (2010) and Hlaoittinun et al. (2008).

- Tølle and Bernus (2003) analyse different types of reference models with the help of mapping onto a Virtual Enterprise Reference Architecture, called VERA. The analysed reference models are applicable to support the set up and the configuration of virtual

enterprises with the aim of reducing the time needed for its creation. They consider reference models as models that capture characteristics and concepts common to several entities in the domain of business process, information exchange, human resource and organisation/ management. They serve as sketch that companies may follow to design their own particular model of virtual enterprise (re)creation and operation. This makes the modelling process more efficient. Tølle and Bernus (2003) refer to the Generalised Enterprise Reference Architecture and Methodology (GERAM, 2000) to explain the purpose of reference models that is to "[…] capitalise on previous knowledge by allowing model libraries to be developed and reused in a 'plug-and-play' manner rather than developing the models from scratch." In this line of reasoning the authors highlight that the availability of reference models enhances the success of enterprise architecture framework.

- Rice et al. (2007) refer to the "Advanced Interactive Discovery Environment (AIDE) for Engineering Education" project that has been initiated by Syracuse and Cornell Universities in 2001. One of its main purposes is to develop a virtual environment that integrates and advances the best features and "best practices" of virtual, collaborative engineering environments. Herby they set priorities on technical aspects that are reflective of the technology being used and project processes. Human aspects are not taken into account.
- The work of Stoeckert et al. (2010) describes investigations in the field of collaborative engineering as well as German's automotive, aviation and plant engineering industries. It regards challenges according to the application of distributed NPD and collaborative engineering processes to prove that methods to support collaborative engineering can be used cross-industry for automotive, aviation and plant engineering.
- The research of Hlaoittinun et al. (2008) provides a framework for multidisciplinary team building in projects that help to characterise team members' competencies and assign them to tasks by local or global task assignment with clustering algorithms. It can easily be adapted to "soft factors" like leadership, relationships etc. It helps project managers to manage human resources to attain their strategic competencies objectives.

Different aspects of the beforehand presented related works in the area of Management Science inspirited us, as e.g. the reference models of Tølle and Bernus (2003). Their reference models capture characteristics and techniques for four different fields. While the authors concentrate on the four domains: business processes, information exchange, human resource and organisation/ management, the main fields of this work are: VPM, CM and VTI. Instead of proposing reference models this work gives guidelines in form of generic recommendations and technical solutions. Like Rice et al. (2007) we intend to give best features that enhance collaborative engineering environments, in our case especially the virtual team building. While Rice et al. (2007) consider only technical aspects this PhD thesis deals also with human aspects like CM and VTI. Stoeckert et al. (2010) prove the generic aspect of engineering processes in distributed NPD which is important for our model. The work of Hlaoittinun et al. (2008) highlights the importance of soft factors like leadership, cohesion, relationship that should be included in our

model as influencing aspects. Different authors have dealt with task sequencing and grouping with algorithms to assign them to competencies or roles of actors (e.g. Hlaoittinun et al., 2008; Petersen, 2007). Even if they consider not only technical but also soft competencies like communication skills, decision making ability etc., they do not take the dimensions of VPM, CM and VTI into account.

1.3.2 Human and Social Science

In the domain of Human and Social Science, we refer to the works of Schleidt and Eigner (2010) and Uflacker and Zeier (2011) that are briefly presented in the following list. Furthermore we treat the research of other authors who devote their focus on factors influencing or facilitating virtual team building (e.g.: Rezgui, 2007; Connaughton et al., 2010; Connaughton and Daly, 2003; Rasters et al., 2002).

- Schleidt and Eigner (2010) present an approach that sets value on Cross Enterprise Product Design and the competencies needed on the individual level to work successfully under the respective working conditions. Cross Enterprise Product Design is part of their definition of Cross Enterprise Engineering that highlights Engineer's tasks and their associated processes and information technologies. They respect the whole product life cycle. The aim of their work is to develop criteria for the description of working conditions in Cross Enterprise Product Design on the one hand and on the other hand to identify relevant personal and social competencies.
- Uflacker and Zeier (2011) take the early stages of engineering projects in the domain NPD into account to point out the increasing role of distributed online interactions. They present a generic approach for collaboration structures captured from heterogeneous groupware and communication resources to describe the temporal relationships between different actors and information resources over the course of collaboration.
- There are several studies that examine virtual team building related to the team development models to examine several factors like leadership or communication media that may influence it (Rezgui, 2007; e.g. Connaughton et al., 2010; Connaughton and Daly, 2003; Rasters et al., 2002). Connaughton et al. (2010) study how virtual team members experience team development. Rezgui (2007) explores the effectiveness of virtual teams in the construction sector. The author analyses factors that facilitate successful adaptation of virtual teams.

The work of Schleidt and Eigner (2010) instigates us to provide a model taking technical solutions into account that consider CM as well as working conditions in virtual projects. In this PhD thesis this domain is named VPM. In contrast to Schleidt and Eigner (2010), Uflacker and Zeier (2011) concentrate on distributed online interactions that are incorporated in this work as VTIs. The approches of Rezgui (2007), Connaughton et al. (2010), Connaughton and Daly (2003) and Rasters et al. (2002) deal with factors that influence virtual team building. Their patterns are accommodated in this work in the functional analysis as environments (§ 4.1) and in the house of quality (§ 4.2). They are incorporated in form of customer requirements (§ 4.2.1). Although virtual collaborative environments and platforms are gaining more importance in various domains like NPD, R&D, problem-solving task forces, customer services etc. Horvarth and Tobin

(2001) point out that until now only little research has been done on the network of influencing factors on virtual team building.

1.3.3 Engineering Science

Concentrating on the domain of Engineering Science we take consideration to the work of Schleidt and Eigner (2010), Stal-Le Cardinal and Marle (2006), Mekhilef and Stal-Le Cardinal (2005) and Ouni (2009). We set the Phd thesis in relation with previous research of our laboratory by referring to the approaches of Martin (2001), Schindler (2009), Patay (2008) and Mansilla Pellen (2006).

- Martin (2001) presents in her PhD thesis different tools that help to develop new models, systems and functions in industrial engineering processes. Especially the Functional Analysis and the Quality Function Deployment (QFD) are of high interest for this work.
- Based on a tool of the QFD, called the house of quality, Schleidt and Eigner (2010) analyse how working conditions and competencies can be assigned to increase the efficiency of cooperation with the help of the house of quality.
- The Functional Analysis has been used in the works of Ouini (2009), Schindler (2009), Patay (2008), Mansilla Pellen (2006) to provide a systemic approach.
- Stal-Le Cardinal and Marle (2006) propose a definition process with inputs, tools, methods and outputs of the project structure which should be constructed in order to reach the project's objectives. They focus on the scope, activity definition and resource assignment. Other work of Marle et al. (2010) is set on complexity and risks of projects. The authors propose an interactions-based clustering methodology with associated tools and algorithms to facilitate the coordination of complex projects by reducing interfaces when dealing with risks. They model project risk interactions through binary matrix and numerical matrix representation. While the research of Marle takes risks into account, further work of Stal-Le Cardinal deals with decision tasks. Mekhilef and Stal-Le Cardinal (2005) aim to determine the dysfunction profile of a company to propound a generic plan of the decision-making process. They recapitulate work connected with CM, to offer a representation frame of dysfunction sources.
- Research concerning CSCW has already been done before in our laboratory LGI in collaboration with Renault in form of the PhD thesis of Ouni (2009). The issue of Ouni's work is on designing and performing a way to use collaboration tools within complex organisational environments (Ouni, 2009). The author provides methods for the analysis and the improvement of the collaborative usages environment in heterogeneous collaborative work contexts. A meta-model for collaborative working tools' usage analysis is developed; generic units of analysis are identified that allow the description of the collaboration contexts, their specificities and the usages models in these contexts. Ouni (2009) proposes afterward a set of "fit actions" between technologies and contexts while combining activities of collaboration modelling, technologies' customising and appropriation support.

The Engineering Science provides approaches and tools that facilitate to develop the VTB Support System. The research of Martin (2001) permits us to choose the apposite tools of the functional analysis and the QFD. The functional analysis has been used in previous works of our laboratory like the PhD thesis of Ouni (2009), Schindler (2009), Patay (2008) and Mansilla Pellen (2006) and is a proven tool to be as objective, generic and exhaustive as possible. The functional analysis helps connecting the customer needs to the functional domain. One objective of this work is to describe the functions of the VTB Support System reflecting the requirements. The approach of Stal-Le Cardinal and Marle (2006) support us in our understanding of projects and their interrelated decisions and risks. Like in this PhD thesis, they determine CM as important factor in the functioning of projects. The PhD thesis of Ouni (2009) is of high importance for us as it is situated in the domain of CSCW. While Ouni (2009) focuses mainly on collaboration tools and stresses therefore the technical dimension of this work, we also stress the human dimension in form of competencies and interactions of virtual team members. Even if CSCW research made great progress towards the support of cooperative work, an integrated environment that supports all forms of cooperation in a seamless and integrated way is, according to Prinz et al. (2010), still missing.

1.3.4 Positioning

The presented related works in § 1.3 highlight the importance of this PhD thesis to consider the three different disciplines of Industrial Engineering: Management Science, Human and Social Science and Engineering Science. Related works of Management Science provide knowledge about the management of the VTB Support System. We have been inspired to classify the virtual team building process in different fields, in our case in: VPM, CM and VTI. A need of reference models, best practices and recommendations in the domain of CSCW has been identified. This work focuses on virtual team building and is based on the three different life cycles: the NPD life cycle, the project management life cycle and the team life cycle (figure 1-1). They are incorporated in the management structure of the VTB Support System. The VTB Support System copes with the demand of Management Science of providing knowledge about the management of a support system for virtual team building. It covers the strategic and organisational point of view of management.

The related works in the field of Human and Social Science instigate us to take the human dimension of a VTB Support System into account. We identified the importance of CM and VTI for virtual team building. As shown before (figure 1-1) the project life cycle is in strong interrelation with the team life cycle, concerning in this work CM and VTI. To assure the conduction of the processes of VPM, competencies must be provided that are realised in the moment of interaction within the virtual team.

Referring to related works in the field of Engineering Science allows us to base on approaches and tools that help to provide the VTB Support System. At the same time we refer to works of our laboratory LGI that handle the complexity of projects and project management as well as the technical dimension of CSCW. Both are taken into account in this PhD thesis.

1.4 Global Plan

This PhD thesis is composed of six chapters that are organised as following:

- Chapter 1: Introduction,
- Chapter 2: State of the Art,
- Chapter 3: Setting and Main Keywords,
- Chapter 4: Modelling of the VTB Support System,
- Chapter 5: Examples of the VTB Support System's Application,
- Chapter 6: Conclusion and Perspectives.

Chapter 1 gives an introduction to the topic. It delineates the motivation of the research, research problems and objectives as well as related works.

Chapter 2 presents the context of the PhD thesis and the state of the art. We describe three different life cycles (product, project and team) that are strongly related with our research questions. We explore the domains VPM, CM and VTI as important dimensions of this work.

Chapter 3 focuses on the setting and the main keywords of this research. Main recurrent themes of virtual team building are introduced and structured regarding the setting and its main dimensions: NPD, VPM, CM and VTI. A survey of these themes is presented that identifies opportunities and risks for virtual team building.

Chapter 4 demonstrates the modelling of the VTB Support System that is based on two tools, the functional analysis and the house of quality. The functional analysis is used to get an exhaustible vision of the requirements of the VTB Support System. The house of quality facilitates in a second step to translate these requirements to technical solutions that are applicable in the industrial practice. The chapter closes with a synthesis of the construction of the VTB Support System.

Chapter 5 gives three examples of the VTB Support System's application. Firstly, we focus on a theoretical evaluation referring to Tuckman's Team Development Model (Tuckman, 1965). It is used to evaluate a part of the model and to provide a second supporting structure. This helps organisations and projects during the constitution of the virtual team to identify important key functions depending on their specific needs. The second application is conducted with a European funded project. Customer requirements are defined and analysed to give recommendations to the specific needs of the project and recommendations are proposed. The third application is based on an enquiry on web 2.0 tools that were organised in form of interviews with 34 marketing managers. We compare the results of the presented application with specific needs of the project from the second application.

Chapter 6 finishes with the conclusion of the PhD thesis where perspectives and limits are presented.

The structure of these chapters is illustrated in figure 1-2. They are organised in three parts.

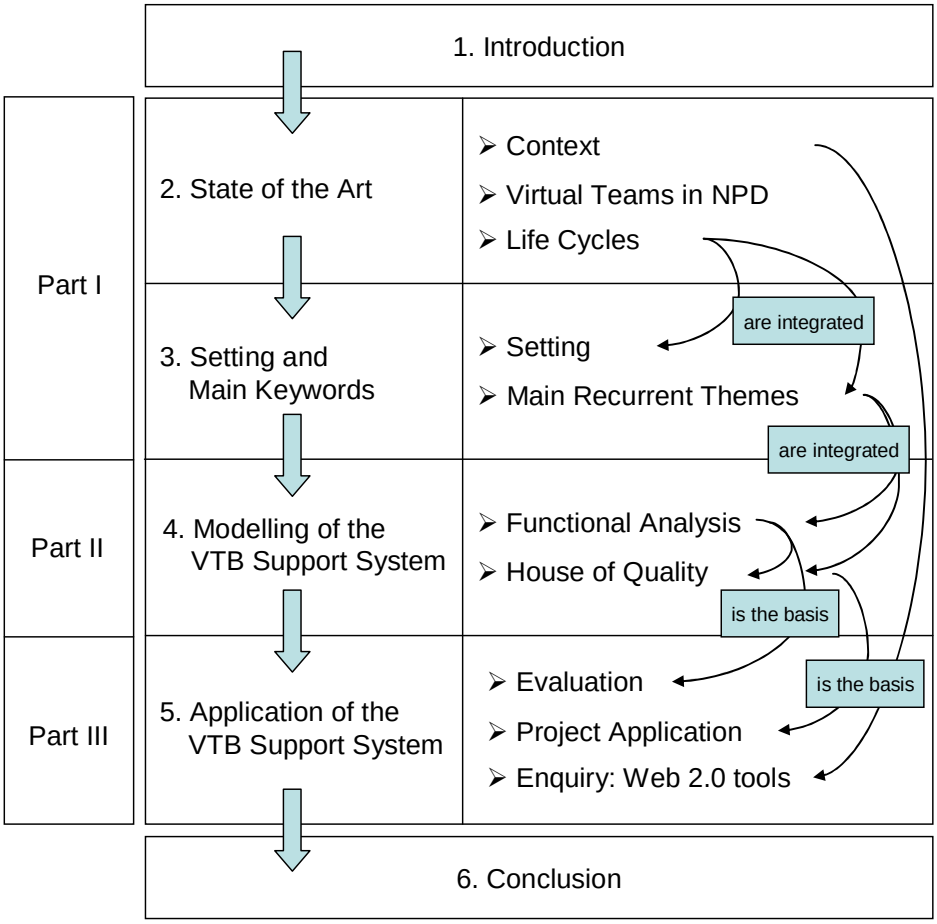


Figure 1-2. Structure of the PhD Thesis

Part I: State of the Art, Setting and Main Keywords

2 State of the Art

In this chapter 2 the context of the PhD thesis is described in the first place (§ 2.1). Dealing with the research objective to contribute to a support system of virtual team building in the domains of VPM, CM and VTI, the context is set in the research field of CSCW. We give definitions of CSCW (definition 2-1), groupware (definition 2-2) and web 2.0 (definition 2-3) as they are needed later in one of the examples of the application of the model (§ 5.3). Furthermore, in § 2.2 we determine a virtual team (definition 2-4) and explain the differences between diverse kinds of communication: from interaction to collaboration and cooperation as optimum of collaboration (figure 2-4). Afterwards, in § 2.2 virtual teams in the domain of NPD are illustrated. We specify the virtual teams that we handle as Virtual Project/ Product Development Team (§ 2.2) and present the respective life cycles of the project, the product and the team (§ 2.3). Herby, we take into consideration the domains NPD, VPM, CM and VTI and give a detailed state of the art for each in §§ 2.3.1 - 2.3.3. We finish this chapter 2 with a synthesis about a summary of patterns where we highlight concepts that are excerpted from this state of the art (§ 2.4). They are reused to construct the VTB Support System.

2.1 Context of the PhD Thesis

This research is situated in the field of CSCW. CSCW finds its early beginnings in the 1980s focussing on networked computers that promised new possibilities of cooperation processes (Prinz et al., 2010). CSCW is a generic term that concentrates on how individuals work together in teams with the support of ICT (May and Carter, 2001; Wilson, 1991; Teufel, 1995). Primarily, the Internet was used to distribute information between individuals. In the last years the Internet advanced to enable individuals to work together even if they are dispersed in space and time.

Tackling issues like coordination, collaboration and cooperation CSCW has played a key role in facilitating human interaction in virtual teams.

By taking advantage of CSCW, virtual teams provide higher innovation capabilities, as well as opportunities of savings on transaction costs which can even be applied to competencies transfers. To explain CSCW in a simple way the focus should be set on the group-oriented tasks that CSCW technologies support. May and Carter (2001) suggest that these can be divided into following four main categories:

- Communication,
- Shared workspace and mutual awareness,
- Shared information and information management,
- Group activity support.

To summarise we give definition 2-1 of CSCW:

Definition 2-1. Computer-Supported Cooperative Work (CSCW)

> *Computer-Supported Cooperative Work (CSCW) is a generic term, which combines the understanding of the way individuals work together with technologies and how collaborative activities and their coordination can be supported by means of computer systems.*

CSCW applications enable users to work synchronously or asynchronously on shared multimedia objects. The concepts of synchronous and asynchronous communication as well as direct and indirect communication are explained more in detail.

- Synchronous communication occurs if team members communicate with each other in real-time.
- Asynchronous communication does not enable team members to communicate in real-time.
- Direct communication means that a sender transfers information especially to a receiver.
- Indirect communication occurs if the sender performs "actions", like a manipulation of documents, by which the receiver obtains indirectly knowledge. The sender does not take care if the information is well transferred to the receiver.

In this line of reasoning asynchronous communication can be indirect, e.g. by e-mail, or indirect, e.g. by shared documents. Differently to this, synchronous communication is mostly direct.

May and Carter (2001) highlight that the term "groupware" is often used in conjunction with CSCW. As a matter of fact there is often a mix-up concerning the meaning of these two terms. Nevertheless we understand groupware as a result of CSCW. May and Carter (2001) defined groupware "[…] as a generic term for software products that 1.) support the co-ordination of office activities, 2.) are open and interoperable with other types of software and 3.) run on PCs that are on local area networks." Based on this explication we derive definition 2-2.

Definition 2-2. Groupware

> *Groupware comprehends software products that are designed for multiple users to support CSCW. They enable team members of a network to share and safe information and data in a coordinated way. Groupware is open and interoperable with other types of software and hardware.*

Another term, the "web 2.0", is highly important for CSCW. It is reused in one of our application cases in § 5.3. The term web 2.0 has mainly been influenced by Tim O'Reilly and Dale Dougherty. It describes the second generation of World Wide Web (WWW). Since the first web 2.0 conference in 2004, organised by O'Reilly, the term has received an enormous amount of attention. Web 2.0 offers important concepts of web applications that make the web a more dynamic, intuitive and social place. The key elements in web 2.0 are the users, their opinions and the collaboration between them. They interact with content rather than just consume the in-

formation to enhance the learning process. As it fosters to create collaborative systems it is also well-known as "social web" and the applications are named "social technologies". Social networking capabilities can enhance to capture unstructured tacit knowledge and make it reusable. But even if the literature on the topic of web 2.0 is voluminous, the concept of web 2.0 stays ambiguous as it is defined in many different ways. We define web 2.0 in this work as follows.

Definition 2-3. Web 2.0

> *Web 2.0 describes the second generation of the WWW that is focused on interactions of users, their inter-operational collaboration and their open information sharing. Web 2.0 makes the WWW more dynamic, intuitive and social.*

O'Reilly (2005) himself does not give a precise definition but characterises web 2.0 with the help of principles, called design patterns. Normally understood as standard solutions in the domain of software engineering, O'Reilly (2005) uses them as guidelines to characterise web 2.0. Any application that obeys the eight proposed design patterns is considered as web 2.0 application. Hence, the web 2.0 is the set and network of these applications.

The eight web 2.0 design patterns according to O'Reilly are presented in the following list:

- The Long Tail: Not the most popular topics make up the main part of the Internet's content, but a huge number of specialised topics and small communities. Web 2.0 applications should integrate also edges and not just the centre, to take advantage of the long tail.
- Data is the Next Intel Inside: As web 2.0 applications are data-driven, a unique, hard-to-recreate base of data must be established for competitive advantage.
- Users Add Value: Users are involved to participate actively by adding data to enhance the creation process of content.
- Network Effects by Default: As most users only consume instead of contribute and add value to data, inclusive defaults for aggregating user data as a side-effect should be set.
- Some Rights Reserved: As intellectual property protection limits re-use and prevents experimentation, an adaptable and flexible set of rights should be created that make sure that barriers to adoption are low when benefits come from collective adoption.
- The Perpetual Beta: Web 2.0 applications should be ongoing services that are continuously developed and constantly evolving.
- Cooperate, Do not Control: Web 2.0 applications are built of a network of cooperating data services that implies that users trust application providers. Provided data should be treated with respect and web services interfaces and content syndication should be offered to be open to the outside and to be able to re-use the data services of others.

- Software Above the Level of a Single Device: Web 2.0 applications should not be limited to a single device as the computer is no longer the only access device for internet applications.

Hermann et al. (2009) propose a differentiation based on three major characteristics of CSCW, groupware and web 2.0. These characteristics are: goal and work orientation, communication and coordination, and playfulness and user experience. The driving factor for CSCW is the goal and work orientation, while groupware focuses on communication and coordination. Web 2.0 concentrates on the aspect of playfulness and user experience. For each intersection figure 2-1 gives examples of web 2.0. tools.

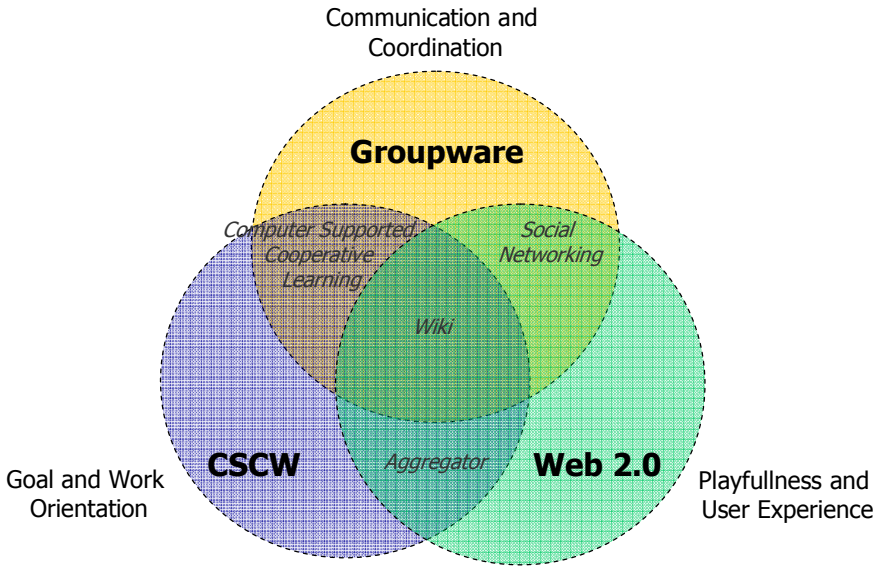


Figure 2-1. Conceptual Distinction based of CSCW, Groupware and Web 2.0 (based on Hermann et al., 2009)

According to definition 2-2, groupware mainly sets value on the technology while CSCW also tries to understand human behaviour within cooperative work. To be as precise as possible we have to define the term of cooperative work that is supported by CSCW as well as the term of collaborative work. The scientific literature argues that CSCW systems support both of them. The term collaboration and cooperation are often confused as both are defined as human interactions where different actors have common objectives that are attained by interdependent tasks.

Nevertheless, there are differences between those two concepts. Some authors regard collaboration as more complex and more orientated in cross-functional linkages than cooperation (e.g. Jassawalla and Sashittal, 1998). Other authors distinguish that cooperation is a more elaborated form than collaboration. The premise for this work, which is aimed to provide a VTB Support System, is first of all the understanding of cooperative and collaborative working environments. In this research we understand CSCW as the core foundation of Collaborative Working Environments (CWE), also named Collaborative Environments or Collaborative Networks.

To distinguish between collaborating and cooperating, a look on the concepts informing, coordinating, cooperating and collaborating is needed as there are often no clear boundaries. We postulate definition A 2-1 that is based on the state of the art:

Definition A 2-1. Informing, Coordinating, Collaborating, Cooperating (based on the State of the Art)

Informing: involves the exchange of information about events and activities. It is necessary, though not a sufficient condition to meaningful collaboration.

Coordinating: involves control of the workflow and communication process, allowing efficient control mechanisms to coordinate efforts of the virtual team. It involves managing the various interdependencies between activities and events. It is not necessary for participants to pursue a common objective. Common interest and organisational affiliations are sufficient.

Collaborating: is derived from the Latin "collaborare" that means "to work together". The term refers to mutual engagement of team members who are engaged in the same work process. Nevertheless, interaction between team members is weak as each individual is evaluated independently. Although there is a common output, all partial results serve as the result in the end of the collaboration. Collaboration describes the process of sustainable value creation that creates a shared understanding.

Cooperating: claims that team members are involved in a common work process, decisions are made by group consensus for collective actions and the team is evaluated as a whole.

The relationship between informing, coordinating, collaborating and cooperating is presented in figure 2-2 according to the different forms of collaborative works, a **proposition of scheme**.

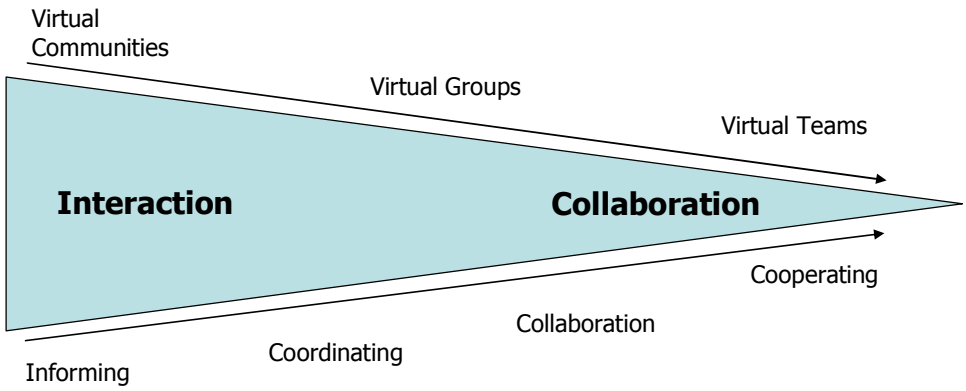


Figure 2-2. Proposition of Scheme: Relationship between Collaborative Entities and Interaction

The scheme's interior shows the level of communication from interaction to collaboration. Interaction is considered as a low level of human communication while collaboration describes a high level of communication. Informing and coordinating as a consequence settled in the field of interaction while collaborating and cooperating as a more mature form of interaction describe the high level of communication: collaboration. Cooperating is the most evolved form of collaboration. The scheme indicates that the level of communication is higher and more evolved in teams than in groups or communities. The different forms of virtual work – virtual communities, virtual groups and virtual teams – are explained in following section. They are set in the framework of collaborative networks.

Collaborative Networks as setting of CSCW has been defined by many authors as new organisational framework (Camarinha-Matos et al., 2009; Rasjsiri et al., 2008). It is seen as a set of participants who aim to work together in asset of relationship to respond to a common goal (Rasjsiri et al., 2008). Camarinha-Matos et al. (2009) define Collaborative Networks in a closer sense as "[…] variety of entities (e.g. organisations and people) that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture and goal" (Camarinha-Matos et al., 2005). A special type of a Collaborative Network is the virtual team. It constitutes the focus of this work.

Broadly speaking, there are various different forms of virtual work in relation to the number of persons involved and the degree of interaction between them (Hertel et al., 2005). Mainly, we make a difference between virtual communities, virtual groups and virtual teams. Additionally, we present briefly the entities teleworkes and virtual organisation.

- Virtual communities: are large entities in which members participate via Internet, guided by shared characteristics and interests, common purposes, roles and norms (Wellman, 1997 quoted in Hertel et al., 2005). They are defined as social systems of networks of individuals who use computer technologies as social interaction to mediate actively their relationship and for knowledge sharing (Picard, 2009; Walker, 2006). In contrast to virtual teams, virtual communities are normally initiated by some of their members and not implemented in an organisational structure like open source projects or scientific collaborations (Sproull and Kiesler, 1991). Even if community members do not necessarily know each other or maintain personal contacts, the virtual community is characterised as social relationship (Walker, 2006).
- A virtual group: is defined by several teleworkers that are combined and each of them reports to the same manager (Hertel et al., 2005). Telework, also often called telecommuting, is done partially or completely outside of the main organisation's workplace with the aid of information and telecommunication services (Hertel et al., 2005).
- Teleworkers: work mainly autonomous at a single location. It is seen as an alternative way for employees to organise their work and family responsibilities. Benefits for the organisation are cost savings in matters of time-consuming and expensive rents of offices.
- A virtual team: is, contrary to teleworkers, determined when the members of a virtual group do not only interact with a manager but also with each other in order to accom-

plish common goals (Lipnack and Stamps, 2000; Hertel et al., 2005). Virtual teams are precisely defined in definition 2-4.

- Virtual organisations: represent task specific, temporary networks of alliance and partnerships between independent entities to share skills, knowledge and access to others' expertise on the basis of a common business understanding (Eschenbächer et al., 2009; Walker, 2006; Chamakiotis et al., 2010). In the perspective of Walker (2006) the virtual organisation is an extension of the existing organisation and not as a radical organisational change. Nevertheless, collaborative networked organisations are according to Camarinha-Matos and Afsarmanesh (2007b) complex entities that require the integration of different modelling perspectives.

Regarding figure 2-2 illustrating the relationship between collaborative entities and interaction, the virtual team is the most advanced form of a Collaborative Network. It discloses a high level of communication and the most evolved form of collaboration.

The next § 2.2 introduces virtual teams in NPD. It gives a precise definition of a virtual team and describes its differences to traditional face-to-face teams before illustrating a new approach of cross-functional collaboration in the domain of NPD. We are finishing § 2.1 with the presentation of different types of virtual teams and a positioning on Virtual Project/ Product Development Teams in this work.

2.2 Virtual Teams in New Product Development

The terms virtual, distributed and dispersed are according to Chamakiotis et al. (2010) and Maznevski and Chudoba (2000) often used interchangeably in the scientific literature. Walker (2006) suggests that the term "virtual" describes something intangible and amorphous. In this PhD thesis we use the term "virtual" to describe distributed or dispersed work that is primarily supported by electronic information and communication tools.

Earlier research on virtual teams gravitated around comparing virtual teams to traditional face-to-face teams (Archer, 1990; Hollingshead et al., 1993; Warkentin et al., 1997 - stated in Gaudes et al., 2007). As a minimal consensus virtual teams have, according to Griffith et al. (2003), the virtual aspect and the same characteristics as other teams, but this narrow difference interferes with a significant diversity of innovation processes in organisations. However, recent arguments have stressed that the line between traditional teams and teams that are called virtual is becoming increasingly blurred. Fewer teams are remaining collocated, without any reliance upon technology for support of communication; and virtual teams may periodically meet face-to-face while undertaking tasks. Researchers instead have turned discussion on the extent that teams engage in virtual methods of collaboration, or the extent of virtuality that any team employs (Griffith et al., 2003; Stevens et al., 2009).

A clear picture of general similarities and differences between traditional and virtual teams based on the state of the art is given in figure 2-3, a **proposition of scheme**.

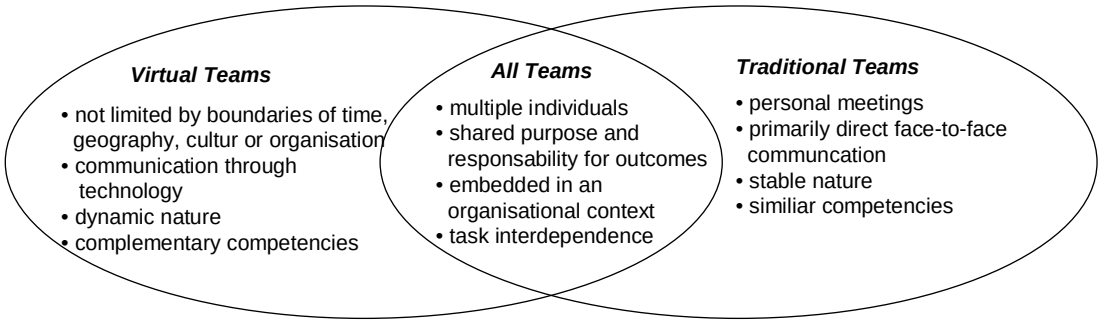


Figure 2-3. Proposition of Scheme: Similarities and Differences of Virtual Teams and Traditional Teams

The most important difference between virtual teams and traditional face-to-face teams is the lack of the physical proximity which permits virtual teams in contrast to traditional teams not to be delimitated by boundaries. This signifies that team members do not only work in different locations but often also at different times.

The dynamic nature of virtual teams obliges the team to accept new team members who float in and out of the project without the benefits of an evolving socialisation process while a traditional team is often stable throughout the life of the project (Harvey et al., 2004).

Traditional team members often share similar competencies, while virtual team members are reunited because of their individual expertise and specific competencies to accomplish highly task interdependent projects (Harvey et al., 2004).

Many definitions of virtual teams overlap at the core and diversify in the specifics. Griffith et al. (2003) define virtual teams as groups of individuals who work together in different locations at interdependent tasks. They share responsibility for outcomes and have a significant reliance upon technology to support their communication to counteract their geographic dispersion (Griffith et al., 2003). Leenders et al. (2003) add the temporal aspect and place a virtual team in an organisational setting. They point out that a virtual team is a group of individuals who collaborate while geographically and temporally distributed within and beyond their parent organisation (Leenders et al., 2003). Many authors distinguish that teamwork cannot be understood apart from the organisational context in which it is embedded (Hertel et al., 2005; Nikas and Poulymenakou, 2008; Sundstrom et al., 1990; Lurey and Raisinghani, 2001, Leenders et al., 2003). While Nikas and Poulymenakou (2008) highlight the interaction based on task independence in virtual teams, Peters and Manz (2007) emphasise the extensive use of a variety of technology-mediated communication that enable to coordinate individual efforts and inputs of geographically dispersed team members. Stevens et al. (2009) suggest that a virtual team is "[…] a functioning team that relies on technology-mediated communication while crossing several boundaries, such as geographical, time and organisational boundaries." The focus of this definition is set on the fact that a virtual team overcomes different boundaries with the help of technology. The degree of geographic dispersion within a virtual team can vary from different departments, organisations, towns, regions or countries. Shin (2005) broadens the aspect of dispersion in saying that "[…] a virtual team is a collection of individuals who are geographically or otherwise dispersed […]", focussing on space, time, culture and organisational boundaries.

To summarise, a virtual team is, like a traditional team, constituted of a multiple of individuals, it features task interdependence and exhibits at least one or more shared goals. It is important for virtual teams to communicate with other organisation units and to be embedded in an organisational setting. From these descriptions, we derived the general definition 2-4 of a virtual team.

Definition 2-4. Virtual Team

> *A virtual team consists of individuals who are temporally, geographically, organisationally and/ or culturally dispersed and act interdependently through technology to achieve a common goal. A virtual team is embedded in an organisational setting.*

In this work we consider virtual teams in the domain of NPD. Stevens et al. (2009) highlight three main advantages of a virtual team in the domain of NPD:

(1) Higher chance to match the demand of the international market, as team members have international backgrounds.

(2) Higher flexibility and rapidity in competencies that change constantly in a fast moving economy.

(3) Higher creativity based on the cultural diversity of their team members.

Further advantages concerning the virtual team building in the domain of NPD are presented in § 3.3 as survey of recurrent themes regarding their opportunities and risks (table 3-3).

Jassawalla and Sashittal (1998) analyse the concept of collaboration in the context of NPD by comparing different cross-functional linkages in NPD processes. In their opinion NPD processes are collaborative and not only integrative. They define "(…) NPD related cross-functional collaboration as a type of cross-functional linkage, which in addition to high levels of integration, is characterised by participants who achieve high levels of at-stakeness, transparency, mindfulness and synergies from their interactions" (Jassawalla and Sashittal, 1998).

These key features are according to Jassawalla and Sashittal (1998) described as follows:

- At-stakeness: a condition where participants have equitable interest in implementing jointly developed agendas and feel an equal stake in NPD related outcomes.
- Transparency: a condition of high awareness achieved as a result of intense communication and exchange of hard-data that makes motivations, agendas and constraints of all participants explicit.
- Mindfulness: a condition where new product decisions and participant actions reflect an integrated understanding of the breath and the often divergent motivations, agendas and constraints that exist, at all times.
- Synergy: the accomplishment as a result of cross-functional linkages of NPD outcomes that reflect capabilities significantly beyond those participants individually bring to the process.

The differentiation between interdepartmental integration and cross-functional collaboration based on Jassawalla and Sashittal (1998) is visualised in figure 2-4.

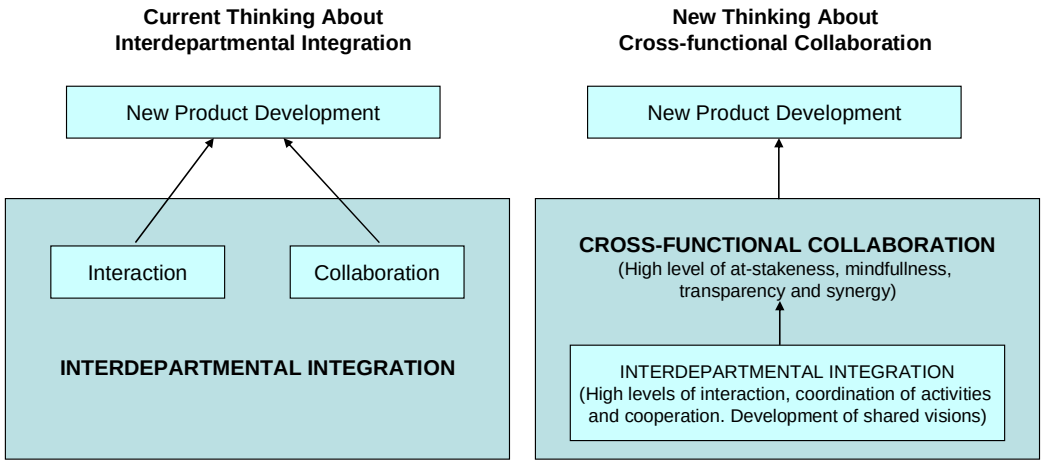


Figure 2-4. Differentiation between Integration and Collaboration (based on Jassawalla and Sashittal, 1998)

Jassawalla and Sashittal (1998) distinguish two key concerns for the current thinking about interdepartmental integration. They are:

(1) how to make NPD actions more effective by overcoming interdepartmental boundaries and structural and systemic barriers and

(2) how to overcome problems created by differences in participant's culture, orientation and functional affiliations.

For the new kind of thinking about cross-functional collaboration key concerns are:

(1) how to harness the efficiencies and synergies promised by flatter, boundary-less organisations that have overcome many of the structural and systemic barriers to integration and

(2) how to foster intellectual capital, manage learning and sponsor creativity in NPD processes.

Both concerns of this new kind of thinking are incorporated in § 3 of the setting and the main keywords of this work.

There are many different natures of virtual teams in the domain of NPD. McDonough et al. (2001) classify virtual teams in collocated, virtual and global NPD teams. Virtual teams have to moderate a level of physical proximity. That means that team members might be located in different regions of the same country or in the same building but on different floors (McDonough et al., 2001).

Other authors combine virtual and global teams and highlight the geographical aspect. They use the term virtual NPD team to refer to any virtual development team. Nikas and Poulymenakou (2008) define distributed NPD project teams that are composed "(…) of independently managed individuals (…) who possess complementary capabilities and who cooperate tempo-

rarily to meet predefined objectives within predetermined deadlines through a non-repetitious string of complex activities." Additionally, the term virtual global team is used, when a virtual team is in different countries dispersed and culturally diverse (Mazenvski and Chudoba, 2000; Donnellon, 1993). To summarise, the members of a global team are from multiple countries and have cultural different backgrounds. In this work we understand cultural diversity less narrow. Even if partners of a cross-functional project are members of the same organisation, but from different functional areas within this organisation, there might be cultural differences. For example, employees with a background in engineering use a different set of working processes than employees from marketing. This demonstrates that the aspect of cultural diversity is also found in virtual teams that are not in different countries dispersed.

Duarte and Tennant Snyder (2006) differentiate seven basic types of virtual teams.

- Virtual Networked Team: Team members work across distance, time and organisational boundaries. Often there is a lack of a clear definition between the networked team and the organisation which leads to diffuse and fluid memberships with team members who move in and out as their expertise is needed.
- Virtual Parallel Team: Team members work across distance, time and organisational boundaries. A parallel team is apart from the rest of the organisation on a short-term basis. It has a distinct membership. It is responsible for special assignments, tasks, or functions that the regular organisation is not disposed to handle. It gives recommendations for improvements in organisational processes or to give specific business issues.
- Virtual Project/ Product Development Team: Team members work across distance, time and organisational boundaries. Projects are conducted for costumers and end users with the result of a new product, service, system or organisational process. Unlike a parallel team, a project or product development team exists for a defined but longer period of time. It has to make decisions, not just recommendations. Different from a networked team, a project or product development team is better delineated from the rest to the organisation and a final product is explicitly defined. Nevertheless, team members may move in and out as their expertise is needed which expands the opportunities to leverage knowledge and expertise from wherever it resides to develop innovate and competitive new products.
- Virtual Work, Functional, or Production Team: Team members work across distance and time. They perform regular and ongoing work, usually just in one function like finance, training, or R&D. Its membership is clearly defined and it is easily to distinguish from other parts of the organisation.
- Virtual Service Team: Team members work across distance and time. Network service and technical support are continuous operations with team members located around the world dealing with network problems and upgrades around the clock.
- Virtual Management Team: Team members work across distance and time. They collaborate on a daily basis focused on the achievements of corporate goals and objectives.

- Virtual Action Team: Team members work across distance and organisational boundaries. They offer immediate responses, often to emergency situations.

This Phd thesis is situated in the field of Virtual Project/ Product Development Teams as the criteria NPD projects match the best with the virtual teams we handle. Detailed criteria of these teams are presented in our **proposition of determination** in table 2-1.

Table 2-1. Proposition of Determination of Virtual Project/ Product Development Teams

Proposition of Determination of Virtual Project/ Product Development Teams	
Criteria	**Specification**
Duration	Long- or middle-term Temporary or permanent Dynamic nature
Number of team members	Bilateral or multilateral
Kind of team members	Service providers, suppliers, end users etc.
Position of team members according to the product life cycle	Horizontal (from different phases of the product life cycle), Vertical (from same phases of the product life cycle),
Disciplines of team members	The same discipline or multidisciplinary (Engineering, Marketing etc.)
Competencies of team members	Complementary competencies
Contractual situation	Contractual or non-contractual relation
Time boundaries	One, two or more than two different time zones
Geographical boundaries	International, national, regional, departmental
Cultural boundaries	One, two or more than two different cultures
Organisational boundaries	Intra-organisational, inter-organisational

Virtual team work becomes more challenging as it takes on more of these characteristics. An example of an extreme type of Virtual Project/ Product Development Team can be seen in a multidisciplinary team composed of team members from different organisations, countries and cultures who respond highly on the temporal, geographical, cultural and organisational dispersion dimensions and have horizontal positions due to the product life cycle. The level of continuity may also be an important issue. It refers to the dynamic nature of a virtual team. Some virtual teams may have been initiated for a very specific purpose, while others might be permanent working on a series of different projects (Chamakiotis et al., 2010). Team members may float in and out of the project according to their complementary competencies. Other aspects like the number of team members, the kind of team members and the contractual situation might cause additional challenges.

The virtual teams in this work have to cope with three different life cycles at the same time: the NPD life cycle, the project life cycle and the team development life cycle itself. We take up the main keywords product, project and team to present these life cycles and their impact on virtual team building in following § 2.3.

2.3 Life Cycles of Virtual Project or Product Development Teams

Virtual Project/ Product Development Teams have to cope with three different aspects at the same time: the product, the project and the team itself. They work in conjunction with one another throughout the course of the beforehand defined Virtual Project/ Product Development Team that are located in projects in the domain of NPD. These three life cycles are the life cycle of team development, project management and NPD. Based on figure 1-1 that shows the inter-relation of the product, the project and the team, we provide a **proposition of scheme** that is presented in figure 2-5.

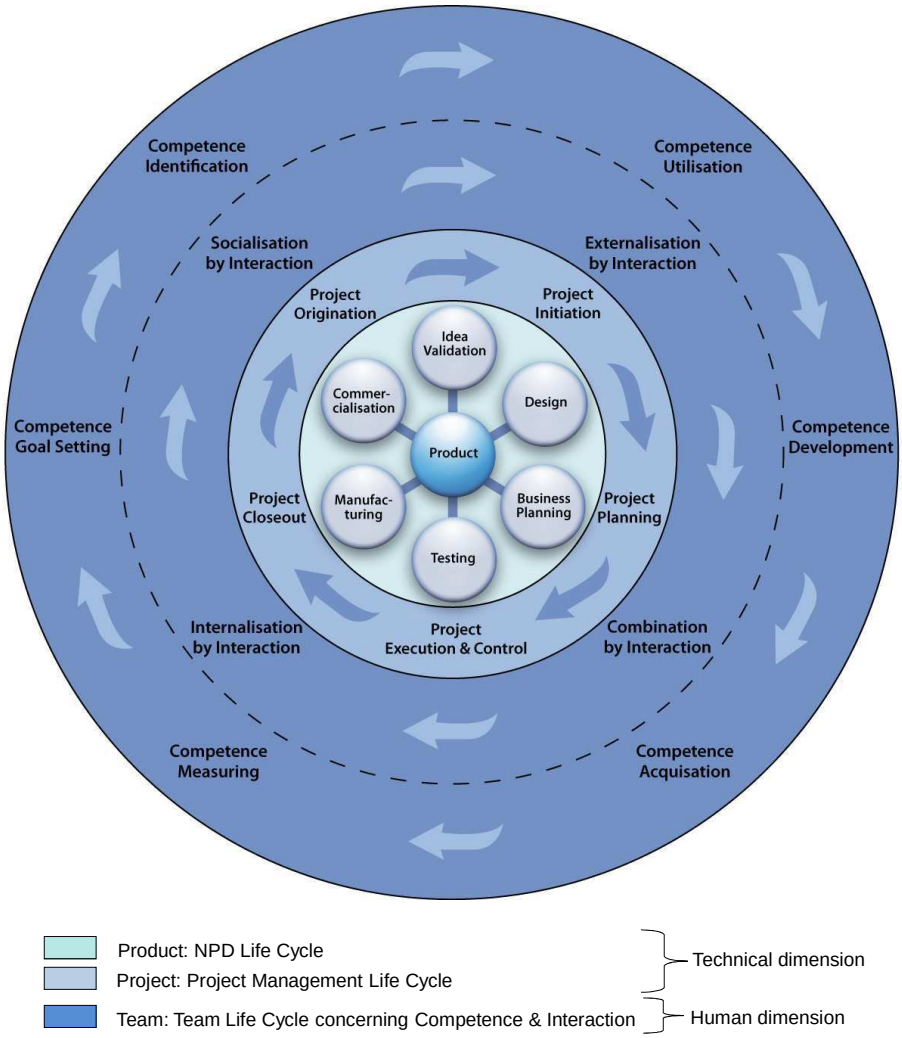


Figure 2-5. Proposition of Scheme: Life Cycles of NPD, Project Management and Team Development

One of the challenges of the VTB Support System is to understand how to align the team development life cycle with the specific life cycle of project management and NPD. Again, the technical and the human dimension of this work are interwoven in each other. NPD tasks and project management tasks are concurrent and ongoing, and can be associated by project management deliverables. The project schedule, e.g., contains both: NPD and project management

tasks. Phases in the three life cycles overlap, depending upon the project life cycle being employed. Users of the VTB Support System should to be aware of how the inputs and outputs of one life cycle affect and shape the other.

The different phases of each life cycle are explained in following §§ 2.3.1 - 2.3.3. Their contribution to the VTB Support System is presented. We first focus on the life cycle of product in § 2.3.1, then of the project § 2.3.2 and we end up with the team in § 2.3.3. We divide § 2.3.3 in two parts: § 2.3.3.1 considers CM and § 2.3.3.2 focus on VTI.

2.3.1 Product: New Product Development Life Cycle

Leenders et al. (2003) and McDonough et al. (2001) underline that NPD requires virtual teams in almost all businesses. It is important for an organisation to introduce continuously new products, services, systems or organisational processes to offer new products to the customer to remain innovative and competitive in long term (Chang, 2006). Innovation, with the meaning of doing something new or something known in a different way, is seen as the process of discovery and development that creates new products and services, production processes, organisations, technologies, and institutional and systemic arrangements (Galbraith, 1996). The focus of competitiveness is nowadays no longer only on time, costs and quality that are presented in the triple constraints model of project management (PMI, 2008). NPD should also devote on sustainability issues (Stoeckert et al., 2010). New product opportunities exist from the continuously changing environment based on economic, sociological, demographic, technological or political reasons (Awny, 2006).

According to McDonough et al. (2001) the process of developing and bringing new products to the market is becoming more and more complex. The de-centralisation and globalisation of NPD processes requires experts from different countries and functional disciplines or departments who work together in projects to create the highest-quality product in the shortest time. Leenders et al. (2003) highlight that existing knowledge and competencies are nowadays often inadequate to satisfy the requirements of the market for competitive new product advantages. Therefore virtual teams gain more and more importance. During the NPD process many parties are involved as a variety of competencies that is needed to match the demand of newness, relevancy and usability (Awny, 2006). Teams in NPD enable the integration of expertise and information across the organisation. New products should up value product features as quality, value, price, opportunity, profitability, reliability, usability, serviceability or availability to satisfy customer's needs. Some criteria, like high quality, low costs and short time-to-market, are indispensable in NPD. It is increasingly important that working results return quickly so that customers' and end user's needs can be responded rapidly. This helps to capture strategic market position for NPD (McDonough et al., 2001).

Thomas (1993 quoted in Awny, 2006) highlights different strategic scopes for NPD:

- Establishing long-run competitive advantage: new products satisfy the requirements of the market better than competing products.
- Reinforcing or changing strategic direction: new products become the basis for new strategic imperatives.

- Enhancing image: new products enhance the outreach of an organisation.
- Improving financial return: new products help to stay profitable.
- Increasing research and development effectiveness: new products enable to capitalise on technology.
- Improving utilisation of production and operation: new products strengthen the capacity utilisation.
- Leveraging marketing effectiveness: new products boost brand equity and create marketing economies of scale.
- Improving effective utilisation of human resources: new products improve and create job and career opportunities.

NPD should cover the entire NPD process from identifying a market opportunity to launching a successful new product (Holmes and Campbell, 2004). There are generally four main phases of a product life cycle that vary quite considerably. They are in relation to the market: introduction, improvement, maturity, obsolescence (Awny, 2006).

Shorter NPD life cycles reduce the time for getting new products to the market (Edmondson and Nembhard, 2009). The NPD life cycle describes the stages that must be completed to produce a product, service, system or organisational process. Based on the state of the art we distinguish product idea validation, product design, product testing, product business planning, product manufacturing and product commercialisation. There are represented in figure 2-5.

- Product Idea Validation: Assessment of market potential, idea generation and screening.
- Product Design: Design product's initial specifications according to its functions, the manufacturing processes and to its design. Assess design drawings, Prototyping.
- Product Business Planning: Analysis of the market, requirements, commerciality and costs. Development of marketing and business plan.
- Product Testing: Pilot production, test market, evaluation about strength and weaknesses.
- Product Manufacturing: Identification of long-term manufacturing solution, continuous information flow of feedback from the market to the organisation.
- Product Commercialisation: Marketing and Communication, full-scale production.

Inputs and outputs of the NPD life cycle affect and shape the life cycle of project management and virtual team development. NPD tasks and project management tasks can be associated by project management deliverables. The virtual teams that we are dealing with in this work are situated in the NPD life cycle stage of product design. The uniqueness of requirements of the NPD process where phases may overlap and change depending strongly on the respective product that should be developed is considered in the VTB Support System.

2.3.2 Project: Virtual Project Management Life Cycle

Vidal et al. (2010) postulates that "[…] a project is a temporary and unique endeavour undertaken to deliver a result." In their work the authors interpret this result always as a change of targets, resources and/ or environment in the organisation that consists in a gap between a start and an ending (Vidal et al., 2010). Time, costs and resources are expended to produce results in form of processes, performance, products or services. As the daily work life nowadays seems to be organised in projects and projects become more and more complex project management has been introduced as a formalised and structured methodology (Vidal et al., 2010).

Project management is the discipline of planning, organising and managing resources to achieve project objectives. The project management life cycle stresses the different phases of how to manage a project. While two projects are never exactly identical regarding the product or the project type, the project management life cycle is always the same. It takes into account different phases such as origination, initiation, planning, execution/ control and closeout that have been represented in figure 2-5. They are explained in detail in the following list:

- Project Origination: to solve an identified problem or address a need in the performing organisation based on a feasibility study.
- Project Initiation: to deliver the approved solution. Resources, team members and key project parameters like cost, scope, schedule and quality are fixed (CSSQ).
- Project Planning: to ensure that project activities are properly sequenced, resourced, executed and controlled. It builds on the work done in Project Initiation, through the development of a project plan. The project plan defines CSSQ in detail and factors aspects of risk management.
- Project Execution and Control: Team members are assigned to execute defined tasks. Activities, resources and expenditure required to each deliverable are monitored and controlled. Processes and plans prepared during the phases of project initiation and project planning are implemented to manage the project.
- Project Closeout: to assess the outcome of the project, to release the final deliverables and resources, to solicit and evaluate feedback and to communicate the closure of the project to all stakeholders. It is important to document best practices and lessons learned for use on future projects.

Even if the discipline of project management is well established and much literature is available, the focus is rarely set on distributed projects and in connection with them on VPM (Evaristo and van Fenema, 1999). VPM considers the management of dynamic collaborative projects, often also called collaborative project management. We define VPM as follows:

Definition 2-5. Virtual Project Management (VPM)

Virtual Project Management (VPM) is the discipline of planning, organising and managing resources within a virtual team to achieve project objectives.

The VPM process by which the project is carried out is herby very important. The revolution of CSCW, groupware and web 2.0 help VPM to be more flexible than traditional project management. Traditional project management solutions denote time and resource management. Traditional project management that is often organised in pyramid or matrix hierarchies obstructs the true potential and value of ICT. From centralisation of control and rigid hierarchies VPM moves to facilitation of interaction and collaboration with a bottom-up planning. While in traditional project management a project manager is placed in the centre of a project and all the information due to the project passes her/ him, each team member has access to the information in VPM. Instead of the management system it is the collaboration that drives the project forward. A structured approach in which project managers plan each task separately in carefully structured phases is too costly in terms of time and resources (Edmonson and Nembhard, 2009). In this sense, the negotiation and coordination of simultaneous work on related tasks is the key for success in VPM. A **proposition of a comparison** between traditional project management and VPM is provided in table 2-2.

Table 2-2. Proposition of a Comparison between Traditional Project Management and Virtual Project Management

Comparison between Traditional Project Management and Virtual Project Management	
Traditional Project Management	**Virtual Project Management (VPM)**
Face-to face team	Virtual team
Authoritarian environment	Collaborative environment
Centralisation of control	Decentralisation of control
Top-Down planning	Bottom-up planning
Complex and rigid tools that support traditional communication	Flexible tools that are easy to use and facilitate agile communication
Pre-defined tasks	Simultaneous tasking
Limited access to information	Unlimited access to information based on security levels and access rights

The authority aspect is one of two main differences that are presented in table 2-2. While traditional project management is embossed by an authoritarian environment with a centralisation of control and a top-down planning of tasks and processes, VPM is characterised by a collaborative environment that fosters a decentralisation of control and a bottom-up planning. The second main difference is found in the different tools that are used. The complex and rigid tools of traditional project management inhibit to simultaneous tasking and unlimited information access and increased communication. These are aspects that are fostered by VPM.

Liu and Burn (2009) and Hertel et al. (2005) differ between four task types that are shown in the following list:

(1) Generating tasks (idea finding): related to organisation's goals and objectives,

(2) Choosing tasks (decision making): related to solution of technical issues with regard to how to reach the organisational goals,

(3) Negotiating tasks (conflict management): related to conflict resolution and

(4) Executing tasks (production): related to execution of the requirement of organisational task.

The authors distinguish that tasks with a lower degree of physical work and a higher degree of information-based work might be the most suitable for high levels of virtuality. Virtuality seems to be advantageous for generating tasks, but difficult for decision tasks (Hertel et al., 2005).

Two further concepts of VPM are presented briefly: the Agile Project Management (APM) and Project Management 2.0 (PM2.0). In this work VPM is treated in a general way. It stresses generic aspects of APM as well as of PM2.0.

The concept of APM has been introduced to handle compact and lightweight short-cycle projects in the software industry that reject the traditional organisational structures. The main characteristics of APM are that all project members work actively together, projects are conducted collaboratively in small co-located teams.

The concept of PM2.0, also called Social Project Management, brings project management practices and collaborative Web 2.0 tools together. APM and PM2.0 are complementary, but while APM is more about lightweight project management practices, PM2.0 focuses on the ability to collaborate, share and communicate via social Web 2.0 technologies.

2.3.3 Team: Virtual Team Life Cycle

We consider a heuristics life cycle model of virtual teams (figure 2-5) to organise the different phases relevant to virtual team building.

In their research Hertel et al. (2005) and Stevens et al. (2009) focus on human resource issues and challenges that virtuality entails during virtual team development life cycle. Individuals who are working in virtual teams must be equipped with spanning competencies that provide a basis for virtual team building, learning and creativity, and finally innovation. The quality of interaction between people is one of the most important success factors to facilitate changes and to foster innovation. Innovation is an interactive process by which knowledge, competencies, expertise and learning abilities of the team and each individual are embodied in the product of the NPD process.

Inspired by Hertel et al. (2005) and Stevens et al. (2009) we distinguish two domains that are crucial for virtual team building: CM and VTI. They are presented in the following §§ 2.3.3.1 and 2.3.3.2.

2.3.3.1 Competence Management

Interestingly, little research has considered the need of integration of virtual teams and business processes with regard to human resource management. Although Hoogeweegen et al. (1999) declare that it is obvious that this process must be managed and controlled, other authors like Olsen, Hamsen and Friis (2008) emphasise that little empirical work is done on specific competencies related to product development. Boucher et al. (2007) point out that even if "competence is considered as an input data for project management or team building (…) it is

not integrated as a joint result." Furthermore, empirically-based prescriptions, guidelines and best practices for virtual team competencies are often missing.

Competence is seen as the basis of competitiveness, it enables an organisation to generate innovative new products, services, systems or organisational processes and to offer them to customers. Indeed this "new" way of understanding human resource requires a more precise formalisation of concepts like competence or skills, in order to be able to identify the competencies needed to work effectively in a virtual team environment and to assign team members' competencies efficiently to process activities. An advantage of teamwork over individual work is that a greater number and variety of concepts, knowledge and competencies are generated. Tuma (1998) suggests that this implies a mechanism of concentration for each team member on her/ his strategic competencies. But finding the right team members for a virtual team is, referring to Camarinha-Matos and Afsarmanesh (2007a), very costly in terms of time and efforts. Concepts of the field of CM may be helpful. Before defining CM we present definitions of competence.

Teece et al. (1997) distinguish that competencies are characterised by sets of knowledge, know-how and behaviour associated to a context and linked to an acting individual.

Competence is often used in the same context as knowledge. A clearer picture of the relation of knowledge and competence gives figure 2-6 according to North (2002).

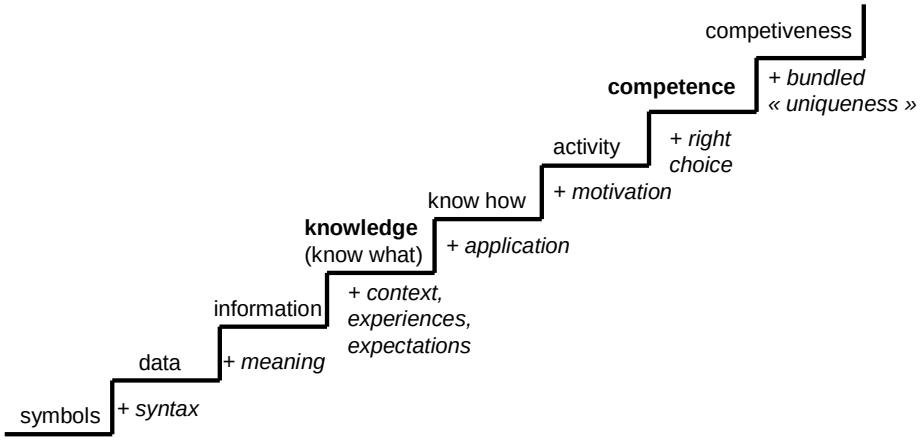


Figure 2-6. Stages of Maturity on the Competence Ladder (based on North, 2002)

The model represents the relation between knowledge and competence that is visualised as a ladder. It takes into account that knowledge is only valuable for an organisation if knowledge ("know what") is transformed into "know-how". This happens in the moment of application. Hence, knowledge is only measurable in form of activities ("know-whom"). The know-how enables one to act, but without motivation it does not turn in activity. With the right choice, which is adjusted to the requirements of the respective situation, competence is indicated. We refer to North (2002) who declaims that competencies are substantiated in the moment of knowledge application which means that competencies only exist when the knowledge meets a task. This underlines that competencies are always related to an activity and thus established in the moment of knowledge application. As a result, competencies do only exist when the knowledge meets a task. Thus, we speak of competence in the context of interpreted knowledge that is

contextualised by an individual or a group that confers an aptitude of decision to a respective activity (Bocquet and Stal-Le Cardinal, 2005). Teece et al. (1997) distinguish that knowledge builds the basis for competencies and that competencies are composed of knowledge, which occurs from learning that takes place within the organisational context.

Multiple authors focus on the aspect of technology that is linked to competencies because it offers easily learning opportunities (Dreyer, 1996, Coates and McDermott, 2002, Prahalad and Hamel, 1990, Kogut and Zander, 1992). Dreyer (1996) defines competencies as a system of human beings, using technology in an organised way and under the influence of a culture to create an output that yields a competitive advantage for organisations. The research of Coates and McDermott (2002) also indicates the importance of including technology management within the field of product competence when examining competitive priorities. In the resource-based perspective, competencies represent not only a combination of knowledge and skills that are difficult for competitors to duplicate, but also of technologies which provide learning opportunities to increase their competencies according to Coates and McDermott (2002). Prahalad and Hamel (1990) as well as Kogut and Zander (1992), support the aspect of the learning opportunity and estimate that competence is defined as learning process of an organisation of how to coordinate competencies and how to integrate technologies.

In parallel, Prahalad and Hamel (1990) as well as Winter (2003) highlight the importance of routines. In the opinion of Prahalad and Hamel (1990), capabilities of individuals, combined with others in teams and connected through structures and routines, form the building block of competence. Accordingly, competence includes the organisation of work, the involvement of individuals, the commitment to work and communicate across boundaries as well as the delivery of value to customers and other stakeholders. Winter (2003) considers that competencies are defined as a collection of routines, which refer to a behaviour that is learned, highly complex, repetitious and founded in tacit knowledge. Such so-called routines confer upon an organisation's management a set of decision options for producing significant outputs of a particular type.

Ritter and Gemünden (1997) use the term competence for organisations and explicitly their management of network relations. To differentiate dimensions of competence, Ritter (1999) supports the perspective of psychology and behavioural sciences which designate that the competence of an organisation is determined by the formal qualification of its employees and the extent of task fulfilment in the organisation. We speak from "individual competence" to deal with the competence of an individual, the expression "collective competence" focus on competence emerging from a group of individuals. Finally the expression "global competence" is used to describe the organisational ability of an organisation, also so-called core competencies (Boucher et al., 2007; Teece et al., 1997). Prahalad and Hamel (1990) emphasise that the concept of core competencies includes group and individual competencies as well and regard not only resources themselves but also how they are combined, connected and used. We define competence in this work as presented in definition 2-6.

Definition 2-6. Competence

> *A competence is composed of interpreted knowledge, that is contextualised by an individual or a group combined with others in teams and connected through structures and routines, and confers an aptitude of decision to a respective activity. Competence occurs from a learning process that takes place within the organisational context. We differentiate individual, collective and global competence.*

The strategic management field concentrates on the role of competencies that accumulate within an organisation. Many authors regard competence as an organisational phenomenon and direct their broad attention on core competencies in the context of organisational behaviour (Leiponen, 2000; Heene and Sanchez, 1997; Harzallah and Vernadat, 1999; Prahalad and Hamel, 1990; Teece, 1997; Wang et al., 2004). These authors opine that competencies have strategic potential and should enable organisations to diversify into new markets. Kogut and Zander (1992) point out that the right technology can be an essential part of resources needed in the core competence concept. We derived definition 2-7 of core competencies based on the state of the art.

Definition 2-7. Core Competencies

> *Competencies are referred as core competencies if they are regarded as critical for the achievement of competitive advantage. They have been built over time and are not easily imitable.*

One of the strategic reasons for virtual team building is that they allow combining different core competencies of experts from different locations to take advantage of market opportunities. In general, CM is the way in which organisations manage the competencies of the organisation, the groups and the individuals. CM takes acquired and required competencies into consideration to reach organisational goals.

One type of CM model aims at providing decision support systems to configure groups of actors. Individual competencies of actors are mapped with competencies requirements (Harzallah and Vernadat, 1999). But often collective competencies are not taken into account since the main focus is set on the temporal organisation of the project. It is assumed that individual competencies are available and that collective competencies are emerged from the sum of individual competencies. But to reach organisational goals a broad approach must be followed. Also, the competencies on the group level and finally on the organisational level, the core competencies, have to be incorporated. CM must therefore address the development of the "whole person" and the "whole organisation" and not only some of their competencies that are required for the next working period. In the field of project management the profile theory originally proposed by Plekhanova (2004) goes one step further. It provides tools to evaluate not only the capability of human resources, but also their mutual compatibility within a group. Following the resource-based concept of Barney (1991), organisations need to be capable to use their own resources to acquire competencies. By translating organisational goals into individual

objectives CM should thus not only set value on job performance and job skills training but should always be embedded in the context of supporting the individual and the organisation to grow and attain fulfilment.

According to Berio and Harzallah (2007), there are four different processes of CM: identification, assessment, acquisition and utilisation. We refer also to a model of Probst et al. (2000) called "Building Blocks of Knowledge Management" that is widely accepted in the domain of knowledge management. It includes the building blocks: goal setting, measuring, identification, utilisation, reservation, distribution, development and acquisition and is divided in an inner and an outer cycle. The **proposition of a CM model** that is presented in figure 2-7 is based on the work of Berio and Harzallah (2007) and Probst et al. (2000).

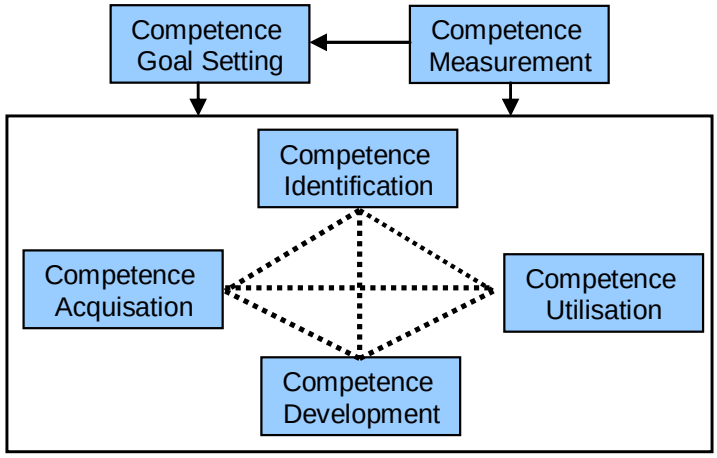


Figure 2-7. Proposition of Scheme: Competence Management Model

The presented model copes with the demand of a holistic concept of CM as it structures the management process in logical tasks and provides clues for intervention. It comprises goal setting, identification, acquisition, development, utilisation and measurement of competencies. Its arrangement follows certain principles. An inner cycle consists of the building blocks of identification, acquisition, development and use of competencies. An outer cycle consists of all these activities plus goal setting and measurement. This feedback cycle clarifies the importance of measuring of measurable variables in order to give distinction to objective-oriented interventions.

The functions of each building block are described in the following list:

- Competence Goal Setting: points the way for CM activities and determine the objectives in the field of CM.
- Competence Identification: analyses and describes the organisations' competence environment. Competence sources are localised and their importance for the execution of tasks is evaluated. When and how to identify and to define competencies required and implement strategies?
- Competence Acquisition: refers to which kind of expertise the organisation should acquire missing competencies from outside through relationship with customers, suppli-

ers, competitors and partners. How an organisation plans and decides how and when to acquire competencies.

- Competence Development: complements the process of Competence Acquisition by generating new competencies to implement new products, better ideas and more efficient processes.
- Competence Utilisation: consists of carrying out activities to make sure that the existing competencies are well applied for the benefit of all.
- Competence Measurement: completes the cycle, providing the essential data for the strategic control of CM. It is responsible for the regular adjustment between competence objectives and evaluated results of the sub-processes of CM.

According to the state of the art we propose definition 2-8 of CM at the end of this § 2.3.3.1.

Definition 2-8. Competence Management (CM)

Competence Management is the holistic way of managing competencies on an organisational, team and individual level by goal setting and measurement. It comprises identification, acquisition, development and utilisation of competencies.

VTI is presented in following § 2.3.3.2. In compliance with Hertel et al. (2005) and Stevens et al. (2009) it is next to CM the second crucial domain that is important during the virtual team development cycle.

2.3.3.2 Virtual Team Interaction: Knowledge Creation and Organisational Learning

Potter and Balthazard (2002) assert that three different interaction styles affect collaboration. The authors differentiate a constructive, passive and aggressive style. They are described in the following list:

- Constructive interaction style: focuses on personal and team outcomes, cooperation, creativity, free exchange of information and respect for others' perspectives. It considers needs for personal achievement as well as needs for affiliation.
- Passive interaction style: is mainly characterised by the fulfilment of affiliation goals by limiting information sharing, questioning and impartiality. Nevertheless, it tries to maintain harmony in the team.
- Aggressive interaction style: is displayed by greater emphasis on needs for personal achievement. Personal ambitions are placed above concerns for team outcomes. Aggressive teams demonstrate competition, criticism, interruptions and overt impatience.

According to Leenders et al. (2007) "[…] the core product in NPD is knowledge, and teams create knowledge through interaction." Hence, organisational knowledge emerges from interactions of individuals who bring their own repertoire of competencies, knowledge, skills and expertise. Individuals and organisations stand in a sequential reciprocal interaction and learn from

each other by an active exchange of their knowledge (Hagehülsmann and Hagehülsmann, 1998). This process of the interdependency is called organisational learning and leads to an enhancement of the knowledge basis of the individual and the organisation (Probst et al., 2000). While the learning process produces new knowledge, knowledge impacts future learning. The fundamental challenge of a learning organisation is the linkage of individual learning with the learning process of the organisation. Virtual teams have to invest in shared thoughts and actions to establish the change. In the first part of this § 2.3.3.2 we focus on the knowledge creation in the second part on learning processes. Both are based on interaction.

Referring to Nonaka and Takeuchi (1997) the creation of knowledge within organisations is the result of a continuous cycle of dynamic interactions between tacit and explicit knowledge. Individual tacit knowledge should be generated to organisational explicit knowledge (Nonaka and Takeuchi, 1997). Explicit knowledge is "only the top of the iceberg", as Polanyi (1974) metaphorically declares. Tacit knowledge is unarticulated, intuitive and non-verbalised. Polanyi's (1974) statement "we know more than we can tell" underlines that part of individual knowledge consists of insights, intuitions and experience that are not articulated into formal and explicit knowledge.

As only explicit knowledge is easy to share and to transfer, it is important to generate individual tacit knowledge to organisational explicit knowledge (Nonaka and Takeuchi, 1997). This is done by interaction processes. According to Kogut and Zander (1992) the knowledge base of an organisation is embedded in social processes that means in interaction of individuals. Only by interaction of individuals knowledge generation may be achieved. Virtual teams in the domain of NPD create progressively innovative solutions and design new products. Hereby tacit knowledge is considered as the key value-generating resource (Harvey et al, 2004). By diagnosing and articulating individual and organisational problems tacit knowledge is converted into explicit verbalised knowledge and becomes collective knowledge.

Nonaka and Takeuchi (1997) define four processes called *socialisation, externalisation, combination and internalisation* which are mutually complementary and interdependent. Their model of the "knowledge spiral", also called SECI model, presents the interrelations between these four processes (Nonaka and Takeuchi, 1997). We provide a **synthesis** that is demonstrated in figure 2-8.

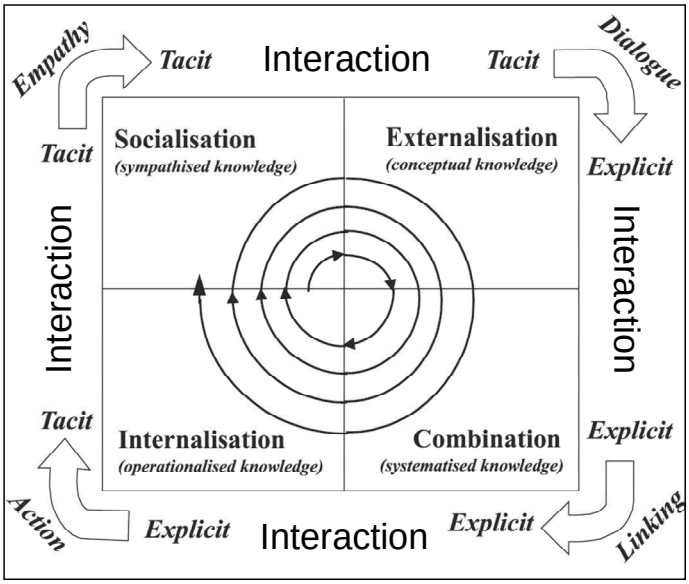


Figure 2-8. Synthesis of Knowledge Spiral (based on Nonaka and Takeuchi, 1997)

The knowledge spiral in figure 2-8 demonstrates how organisational knowledge is converted from tacit to explicit and vice versa, from individual to collective and back again through these four processes. The mentioned four processes are briefly explained in the following list:

- Socialisation (tacit to tacit): Shared information and communication of tacit knowledge between individuals is included. Knowledge sharing in the socialisation process takes place without producing explicit knowledge through face-to-face communication or shared experience, but by empathy. Knowledge is defined as sympathised knowledge.
- Externalisation (tacit to explicit): Through dialogues that foster conceptualisation and ultimate articulation, typically in collaboration, some proportion of the individual's tacit knowledge is captured in explicit form. Conceptual knowledge is created.
- Combination (explicit to explicit): Explicit knowledge can be shared in meetings, via documents, e-mails, etc., or through education and training. Usually there is a well established linking process in organisations to create this systematised knowledge.
- Internalisation (explicit to tacit): In order to react on information, individuals have to understand and internalise it, which involves creating own tacit knowledge. Closely linked to learning by doing, the explicit knowledge becomes part of the individual's knowledge base and becomes an asset for the organisation. This operational knowledge is based on actions.

In our context, externalisation and internalisation processes can be understood as aspects of organisational learning. It is important that all members of a virtual team are willing to share their knowledge in order to foster the organisational learning process. Beside this, they are supposed to know how they should perform, which postulates the need for superiors to inform subordinates about their performance. In this understanding, it is necessary that team leaders share responsibilities in order to build the knowledge basis. Nonaka and Takeuchi (1997) emphasise that the interchange of knowledge and learning processes takes place at four different

ontological levels: the individual, the group, the organisational and the inter-organisational level. Accordingly, it is rather necessary to create a structural and cultural frame of the virtual team and the organisation in which the virtual team is embedded. It should encourage the individual, the virtual team and the organisation as a whole, to learn from each other by sharing their knowledge (Schwarz and Beck, 1997; Desouza and Evaristo, 2004).

Although, collective knowledge is more than the sum of the individuals' knowledge, organisational learning is not only the process of sharing knowledge. Knowledge sharing has to be conceptually interlocked to initiate organisational learning (Thiel, 2002). Virtual teams offer conceptual frames of knowledge sharing and thus support the process of organisational learning. They can be seen as an instrument for the realisation of the "learning organisation" which offers specific starting points to integrate individuals, groups and organisations into learning processes to create an organisational knowledge basis.

The work of Argiris and Schön (1978) stresses individual and organisational learning. They differentiate three learning processes: single loop learning, double loop learning and deutero learning. They finalise in organisational results by interactions with the environment. A **synthesis** of the model of Argiris and Schön (1978) is shown in figure 2-9.

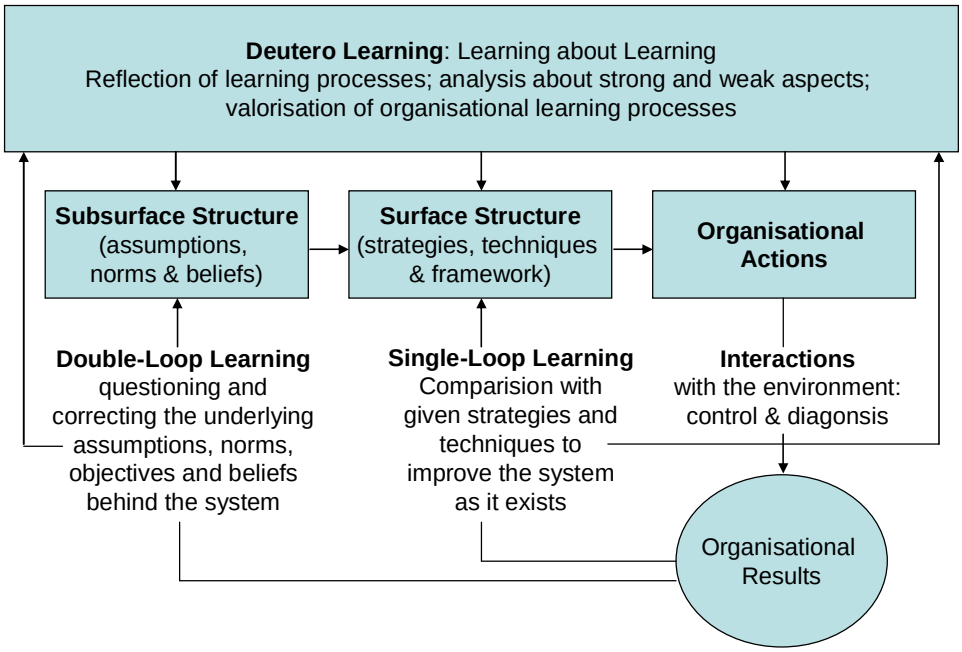


Figure 2-9. Synthesis of Model of Learning Processes (based on Argiris and Schön, 1978, Schüppel, 1997)

It is demonstrated in figure 2-9 that organisational learning takes place when organisations deliberate about single loop and double loop learning, which occurs during the deutero learning. The learning processes are explained as follows.

- Single-loop learning: concerns the simple problem solution that involves following routines and error-and-correction process of those routines. It implicates the generation of new action strategies to achieve existing governing values. Once the error is corrected

the organisation carries on its present policies or achieves its objectives of a present plan. The emphasis is on techniques and making techniques more efficient.

- Double-loop learning: occurs when the underlying system is questioned and rejected. It is more reflexive than single-loop learning. Errors in governing values are detected and corrected in ways that involve the modification of an organisation's underlying assumptions, norms, objectives and beliefs.
- Deutero learning: occurs when organisations learn how to carry out single-loop and double-loop learning. Deutero learning is concerned with the process of the why and how to change the learning processes of the organisation. It involves questioning the role of the framing and learning systems which underlie the actual subsurface and surface structure. In a larger understanding, deutero learning not only underlines the institutionalisation of learning processes, but is an incisive form of cognitive rethinking and critical reflection on organisational core assumptions.

Gathering data, following and testing and improving processes are actions in virtual teams in order to realise single-loop learning. Through a double learning loop virtual teams may design innovative solutions in NPD by internal and external interactions to other team members or costumers and consumers, by effective communication and an atmosphere of informal and formal discussions. Through effective communication teams exchange and create new knowledge. It is important to increase the capacity for double-loop learning for virtual teams. It enables the virtual team or the whole organisation in which it is embedded to make informed decisions in rapidly changing and often uncertain contexts. The deutero learning is important to transfer the knowledge of the virtual team to the rest of the organisation at the end of the project. If the specific project knowledge is not directly needed after the project, "organisational amnesia" might start.

We finish this § 2.3.3.2 with definition 2-9 of VTI.

Definition 2-9. Virtual Team Interaction (VTI)

Virtual Team Interaction (VTI) is defined in this work as cognitive, verbal and behavioural interactions between virtual team members and/ or their virtual environment that create tacit and/ or explicit knowledge by converting (through processes like socialisation, externalisation, combination and internalisation) input to outcomes to achieve a common goal. VTI is strongly connected with learning processes.

In the domain of VTI the model of Nonaka and Takeuchi (1997) (figure 2-8) highlights as well as the model of Argiris and Schön (1978) (figure 2-9) the importance of interaction. Knowledge generation takes place in the social processes that are based on interaction between individuals and the environment. Organisational learning is reflected in interactions that lead to organisational results. Even though the focus on competencies of virtual team members ensures that the required knowledge is available, the capacity to transfer this tacit knowledge may be limited. A virtual working environment must be built that helps to enhance knowledge generation double-loop learning and processes. The virtual team's ability to learn improves its functioning

therefore sustaining itself and its members while conducting its work over time. It focuses on the ability to perform in a future state.

A summary of patterns of each domain VPM, CM and VTI, which have an important input for the modelling of the VTB Support System is given in the following § 2.4.

2.4 Synthesis: Summary of Patterns

In this chapter 0 we have defined the context of our research that is set on CSCW, particularly on virtual teams in the domain of NPD, Virtual Project/ Product Development Teams.

Definitions of CSCW (definition 2-1), groupware (definition 2-2), web 2.0 (definition 2-3), different kinds of communication (definition A 2-1) and a virtual team (definition 2-4) have been given. We determine the virtual teams that we handle as Virtual Project/ Product Development Team (§ 2.2). To sum up we adapt definition 2-4 of virtual teams to Virtual Project/ Product Development Teams in NPD which leads to following description of virtual teams in this work.

We understand a virtual team in this PhD thesis as Virtual Project/ Product Development Team that consists of individuals that are temporally, geographically, organisationally and/ or culturally dispersed and act interdependently through technology to achieve a common goal like a new product, service, system or organisational process. The team members differ generally in their kind, position, discipline and competencies and their membership may be temporary or permanent according to the needs of a long- or middle-term project and its dynamic nature.

Furthermore, we identified the main domains of virtual team building in this work that are: NPD, VPM, CM and VTI and presented their respective life cycles (§§ 2.3.1 - 2.3.3.). Different patterns of the domains VPM, CM and VTI that have been presented are taken into account while building the VTB Support System. The following list underlines them:

- In the domain VPM the four tasks of projects presented by Hertel et al. (2005) should be considered by the VTB Support System to give holistic recommendations for virtual team building. These tasks are: generating, choosing, negotiating and executing (§ 2.3.2).
- In the domain of CM we refer to our proposition of a model of CM (figure 2-7) that highlights six different building blocks of CM: goal setting, identification, acquisition, development, utilisation and measurement. To structure the CM process in logical tasks and to provide opportunities of interventions the VTB Support System should take these building blocks into account.
- Based on § 2.3.3.2 the VTB Support System should take into account the four processes of the knowledge spiral presented by Nonaka and Takeuchi (1997) (figure 2-8). Considering VTI they are determined as: socialisation, externalisation, combination and internalisation.

3 Setting and Main Keywords

In this chapter 3 we refer to the new kind of thinking about cross-functional collaboration that has been presented in § 2.2 (figure 2-4):

(1) how to use efficiencies and synergies and

(2) how to foster intellectual capital, manage learning and enhance creativity in NPD processes.

In chapter 3 we are dealing indirectly with these two key concerns by presenting the setting of the VTB Support System on the three dimensions project, product and team. The focus is directed on the setting of the VTB Support System and main keywords of virtual team building. The setting is handled in § 3.1. It is based on an evaluation model of conception systems by Robin (2008) that is adapted to the VTB Support System. A determination of the technical and human dimension of virtual team building is represented and ascribed to the life cycles: product, project and team. After this, main recurrent themes of virtual team building are introduced in § 3.2 as keywords. They are structured according to the dimensions and its life cycles as well as to the setting and its domains: NPD, VPM, CM and VTI in §§ 3.2.1 - 3.2.3. We finish this chapter 3 with a synthesis in § 3.3 that provides a survey of these themes. It identifies opportunities and risks based on § 3.2.

3.1 Setting of the VTB Support System

This § 3.1 declines the setting of the VTB Support System. In compliance with the systemic approach the dimensions project, product and team are considered as subsystems that are in interrelation with the VTB Support System. We refer to the work of Robin (2008) who developed an evaluation model of conception systems that stresses three dimensions: processes, product and organisation. As the VTB Support System itself represents a conception system we translate Robin's evaluation model to the VTB Support System. Processes are represented in the subsystem project, product stays the same and organisation is translated to team. The setting of the VTB Support System related to the evaluation model of conception systems of Robin is visualised in figure 3-1.

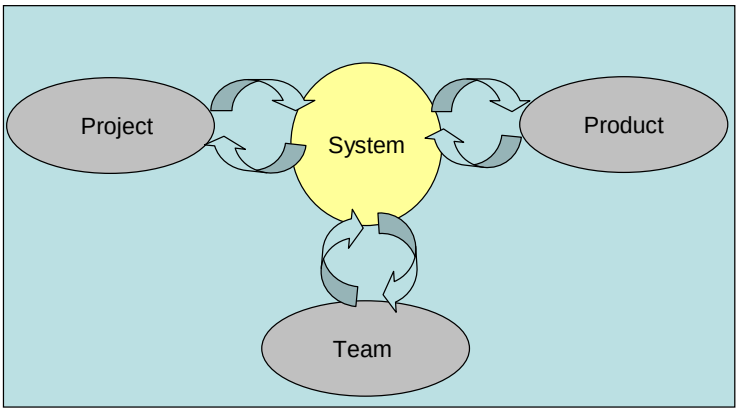


Figure 3-1. First Setting of the VTB Support System (related to the Evaluation Model of Conception Systems of Robin, 2008)

The arrows indicate the interrelation between the system, the project, the product and the team. Referring to Robin (2008) these three must be taken into consideration to cope with the demand of a conception system. In our case the system is the VTB Support System.

A consolidated view indicates that we are exploring in this work aspects of VPM in the dimension of the project and aspects of CM and VTI in the team dimension. Regarding the dimension of the product we claim the domain of NPD as the context of the VTB Support System. The virtual teams that we handle are active in virtual projects in the area of NPD. The dimension product is incorporated in the framework of NPD. Aspects according to this dimension are indirectly consolidated. The adaptation of the setting of the VTB Support System is shown in figure 3-2.

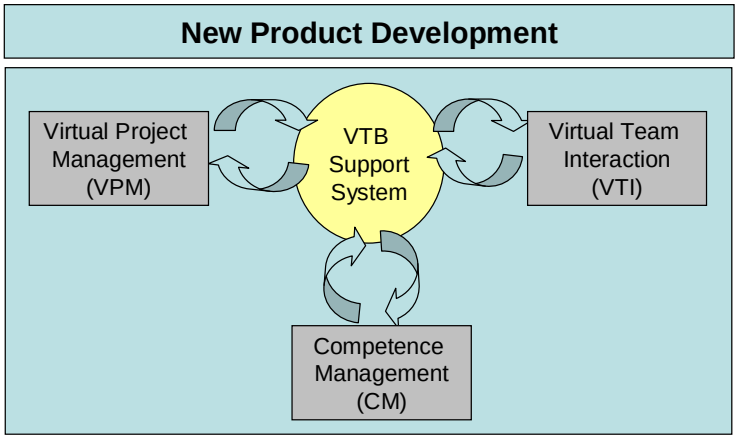


Figure 3-2. Adapted Setting of the VTB Support System

The figure 3-2 highlights that the VTB Support System is in interaction with the three systems of VPM, CM and VTI. All three systems are integrated as subsystems and framed by the context of the NPD. In this work we regard the virtual aspect in NPD processes that claim other demands than traditional projects in the domain of VPM. The arrows indicate that the VTB Support System functions as method that supports the three respective subsystems to create virtual teams by giving recommendations, guidelines and best practices. On the other hand the experi-

ence of these three subsystems can enhance the VTB Support System by giving recommendations. This is important for the functioning of the VPM and thereby as well for the NPD.

Numerous authors have studied the factors that lead to team effectiveness (e.g. Hackman, 1990, 2002; Rezgui, 2007; Staples et al., 2005; Cohen and Bailey, 1997). No single factor could lead to team effectiveness but a set of conditions should be provided that increases the chance that team members work effectively together (Hackmann, 1990, 2002).

Cohen and Bailey (1997) distinguish that four core dimensions are responsible for the effectiveness of teams: design factors, group processes, environmental factors and group psychosocial traits.

According to Cohen and Bailey (1997) environmental factors concern the organisation's environment and design factors deal with the feature of the task and the organisational context. The other two dimensions seem for us to be more crucial regarding a virtual environment: group processes focus on interactions within the team, between other team members and with outside constituents. Group psychosocial traits are constituted as shared mental models, with the same understanding, beliefs and culture.

Vakola and Wilson (2004; stated in Walker, 2006) find that four major organisational issues emerged for virtual teams: information sharing, organisational culture and team working, acceptance of change, and training.

Duarte and Snyder (2006) debate seven critical success factors for virtual teams that are associated with team success and reused in this work as essential factors for virtual team building:

- Human Resource Policies: recognise, support and reward virtual team member and leader by rewarding cross-boundary work and results, providing resources and support for virtual work and career development systems.
- Training and on-the-job education and development: a formal curriculum training to ensure access to continual online training and technical support and implemented systems of knowledge sharing.
- Standard organisational and team process: standard project management software packages may be developed to eliminate unnecessary reinvention of operating practices.
- Use of electronic collaboration and communication technology: ensure that the demanded technology is available and up-to-date and that experts are experienced in installing and supporting them.
- Organisational culture: sets norms focussing on cross-boundary collaboration that values teamwork, communication, learning, outcome-based performance and capitalising on diversity.
- Leadership support of virtual teams: must be open to change and to support virtual teamwork and report the benefits and results of virtual teams so those virtual teams are respected in the organisation. Establish clear expectations of the virtual work environment and objectives of the project.

- Team leader and team member competencies: special competencies are required, but over time, most people can develop the competencies that are needed with the help of adequate training, education, leadership support and feedback.

This PhD thesis proposes a determination of the technical and human dimension in compliance with the understanding of virtual team building that has been presented in table 1-1. These two dimensions are represented in this chapter 3 ascribed to the life cycle of § 2.3 by: product, project and team. They are adaptable to other authors' propositions for essential dimensions according to virtual team building. The dimensions of Cohen and Bailey (1997), issues of Vakola and Wilson (2004) and essential factors of Duarte and Snyder (2006) are incorporated in our **proposition of determination** that is presented in table 3-1.

Table 3-1. Proposition of Determination of Essential Dimensions according to Virtual Team Building

Determination of Essential Dimensions according to Virtual Team Building					
Dimensions		**Cohen and Bailey (1997)**	**Vakola and Wilson (2004)**	**Duarte and Snyder (2006)**	**Proposition of this work (2011)**
Technical Dimension	**PRODUCT**	Design factors			New Product Development (NPD)
	PROJECT	Environmental factors	Information Sharing Acceptance of change	Use of electronic collaboration and communication technology Standard organisational team process Leadership support	Virtual Project Management (VPM)
Human Dimension	**TEAM**	Group processes Group psychological traits	Organisational culture Team working Training	Organisational culture Human Resource Policies Training and on-the job education and development Competencies	Virtual Team Interaction (VTI) Competence Management (CM)

It is illustrated in table 3-1 that the technical and human dimensions are represented by product, project and team. They embed the essential dimensions according to team building of the works of Cohen and Bailey (1997), Vakola and Wilson (2004) and of Duarte and Snyder (2006). Our proposition of essential dimensions of virtual team building is: NPD, VPM, VTI and CM.

In § 3.2 we present main recurrent themes of virtual team building in the literature. To organise them we reuse the structure of product, project and team adapted to our proposition of essential dimensions of virtual team building: NPD, VPM, VTI and CM.

3.2 Main Recurrent Themes of Virtual Team Building

Virtual team building faces different recurrent themes. Their identification is based on the state of the art, on our personal experience in European projects and industry as well as national and international exchanges with experts. Insights about the important themes of virtual teams are given in this § 3.2 that are the most recurrent in the domain of virtual work. They are structured based on a sectioning in product, project and team that is drawn from its naming Virtual Project/ Product Development Team and the translated main keywords: NPD, VPM, CM and VTI. This work does not focus on traditional elements of team work. As presented in § 1.3.1 of related works Hlaoittinun et al. (2008) highlights the importance of soft factors like leadership, cohesion, relationship etc. and its influence of virtual team building. The themes that we consider are the main recurrent for this sectioning in product, project and team. They are visualised in figure 3-3.

Figure 3-3. Structure of Main Recurrent Themes of Virtual Team Building: Focus on Product, Project and Team

We illustrate briefly the research streams, the opportunities and risks of each respective theme in § 3.2. The focus on the aspect "product" is set with the themes: resources and requirements,

complexity and time and costs in § 3.2.1. In § 3.2.2 the aspect "project" is presented with the themes: technology, leadership, information sharing and agility. The third aspect "team" is declined in § 3.2.3 with the following themes: communication, trust, conflicts, cohesion, cultural diversity, creativity, psychological safety, team member satisfaction, sustainable relationships, knowledge and competencies and availability.

3.2.1 Product: New Product Development

We outline the themes resources and requirements, complexity, time and costs in this § 3.2.1 that are deducted from the time-cost-quality triangle that focuses on products (PMI, 2008).

Unfortunately quality is not as manageable as cost and time. If the costs are getting too expensive it is often possible to release the product with a smaller set of features. If time is limited it is possible to hire the best experts or to engage more staff to implement all the features faster. As the element quality seems to be very complex and depends on resources and requirements we handle it here with the themes resources and requirements as well as complexity. The structure of § 3.2.1 is shown in figure 3-4.

Figure 3-4. Structure of Main Recurrent Themes of Virtual Team Building: Focus on Product

The following list starts with time and costs, passes to complexity and finalises with resources and requirements:

- Time and Costs

Shortening product life cycles and the product-introduction frequency, answering rapidly to costumer requirements, effective coordination of competencies, improved product quality, fewer engineering hours for NPD, faster NPD process, energy reduction and resource efficient production, faster time to market, improved manufacturability are only some causes or consequences of trying to minimise costs and time.

The aspect of virtuality helps virtual teams to reduce significantly costs in the domain of NPD. Organisations share the costs of development and production collaboratively. According to Jassawalla and Sashittal (1999) collaborative NPD teams introduce new products earlier than scheduled and achieve significant reduction in costs. Cost savings are based on cross-functional transfer of information on the way to market (Edmondson and Nembhard, 2009). Team members keep their organisations, departments etc. updated on the product development and obviate in doing so corrections of the NPD process that are costly and enable them to prepare for the market launch. Also the costs of travel and relocation costs are omitted (Stevens et al.,

2009, Hertel et al., 2005). Chang (2006) considers that NPD changes from being a traditionally co-located process to fast-paced remote-global process. The process of NPD has to be faster, the product costs lower and the customer value higher. The answer is a NPD process toward the 24/7 mode, that means 24 hours a day and seven days a week, including experts from all over the world (Chang, 2006). As virtual team members are often located in different time zones asynchronous technologies make an around the clock working possible. Referring to May and Carter (2001) time savings achievable via greater simultaneous engineering arising from business process re-engineering results in a faster time to market. Nevertheless, a gap between query and answer may be challenging in time critical projects (Lee-Kelley and Sankey, 2008).

- Resources and Requirements

Any organisation or project in the domain of NPD faces the important challenge of allocating resources to requirements. Reducing time-to-market by matching rapidly requirements of customers and end users to resources of an organisation or a project are indispensable in NPD (Lipnack and Stamps, 2000; May and Carter, 2001; Stevens et al., 2009). Requirements of the market continue to shift and create new demands. The linkages and the identification of resources to these requirements promise competitive advantages (Lurey and Raisinghani, 2001). It is increasingly important that working results return quickly and customer's and end user's requirements are responded in order to capture rapidly a strategic market position for NPD (McDonough et al., 2001).

- Complexity

CSCW operates in a complex environment (Ouni, 2009; May and Carter, 2001). Complexity in the field of NPD is rising in view of the increasing requirements (Stevens et al., 2009). One of the most important reasons for this matter of fact is the complexity of the product itself and the associated complexity due to processes, methods, information flow, customer relationship, customer's needs etc. Eigner and Stelzer (2009) distinguish that the complexity of new products is mainly related to multiple requirements of customers and end users whom the product has to satisfy. Furthermore new products are developed to get not only in multiple variations to the market, but in particular to multiple variations of markets, without being obliged to make many changes or adaptations. Products are seen as multi-market-compatible. Another point considers the technological side of new products that gets continuously more and more elaborated (Eigner and Stelzer, 2009). According to Stanoevska-Slabeva and Hoegg (2006) the work in virtual teams is another reason for complexity. They cross boundaries related to time, geography and organisation and use ICT to collaborate which make the virtual working complicated. More and more organisations move towards networked organisations with complex relations between employees, customers, suppliers or stakeholders. Needs of globally distributed customers are as difficult to identify as the competencies of distributed team members (McDonough et al., 2001). The complexity based on time pressure, the ambiguity about customer needs etc. can transform virtual teams to a high-stress environment.

3.2.2 Project: Virtual Project Management

The presented elements in the category "project" are distinctive from traditional methods of project management. The themes agility, technology, leadership and information sharing are illustrated in this § 3.2.2. Its structure is seen in figure 3-5.

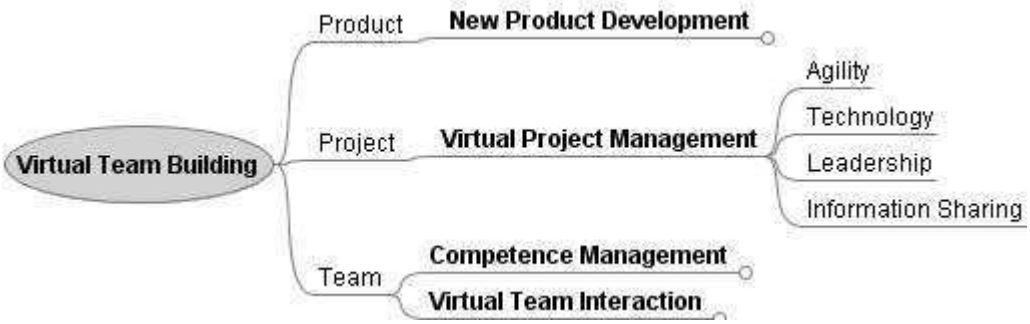


Figure 3-5. Structure of Main Recurrent Themes of Virtual Team Building: Focus on Project

Agility is considered in this work as a very important factor in the category project. It is the basis for the learning organisation, adaptability, flexibility and compatibility between the different methods of VPM. The elements technology, leadership and information sharing are seen as the most recurrent themes to obtain this agility.

The following list begins with agility and presents than technology, leadership and information sharing:

- Agility

One of the most important organisational competencies is learning to adapt to a new performance landscape (Harvey et al., 2004). Adaptability requires the corporate structure to be simultaneously fixed and flexible. These two attributes enable to respond to new opportunities emerging in a dynamic environment. In a rapidly changing global environment in which competition is strong, organisations need to evolve quickly and to base their management on performance key factors, among which competencies, knowledge and skills play a major role (Kaplan and Norton, 1998). Agility is needed to adapt competencies, knowledge, skills and expertise required for tasks in the NPD process rapidly and at very low costs. Therefore a resilient operational infrastructure must be provided and management should be adaptive in consideration of the needs of the virtual team and its respective team members. In practice, adaptive management involves identifying uncertainties and finding the solutions to eliminate them. Agility relies on the concept of the learning organisation which includes that it does not only help to change the system but to learn from it.

The distribution of productive activities among a set of independent but collaborative partners requires new coordination mechanisms characterised by real flexibility in the process due to potential changes of team members. This raises specific challenges linked to competence-oriented management of processes. As virtual teams are project based and team members are selected based on their competencies and respective tasks, their membership is often tempo-

rary and the team boundaries stay fluid. Team members float in and out. This flexibility allows projects to be staffed by adequate experts (Edmondson and Nembhard, 2009).

Also the increased complexity due to projects in the domain of NPD is responsible for the acquired agility. Edmondson and Nembhard (2009) postulate that NPD teams often consist of core members who own the ultimate responsibility for outcomes and of team members who intervene on temporary basis. This is why virtual teams profit not only from the advantages of team cohesion but also avoid its pitfalls. Cohesion may provoke team members to neglect the external environment because they are internally focussed. Also Jassawalla and Sashittal (1998) affirm that the higher is the propensity to change among the team members in the NPD process, the better is the extent of NPD related cross-functional collaboration.

- Technology

A variety of ICT-Technology has been developed over the years to support CSCW. Hertel et al. (2005) categorise them according to the required coordination efforts or their implicit interdependence. Tools with low interdependence emphasise mainly the exchange of information and communication (like video-conferencing, data exchange etc.), while tools with high interdependence mainly support the coordination of activities (decision support systems, risk management systems, ranking or voting systems, brainstorming systems etc.) (Hertel et al., 2005).

The choice of technology and collaboration tools depends on individual experiences and preferences, their feasibility of different functions and the urgency of the task (Robey et al., 2000). Another important point is the competence to use electronic communication and collaboration technology effectively, often called media competence. Virtual teams seem to be able to adapt the technology and the collaboration tools to the requirements of their communication. In reality, they often take the technology that is available and try to handle it as the lowest common dominator. Research in the area of "technophobia" deals with the anxiety of individual's to accept technology in work life and with its negative impact upon virtual team effectiveness (Korukonda, 2005). It assists in understanding the discomfort with technology in general (Walczuch et al., 2007). Kayworth and Leidner (2000) indicate virtual teams that use a various number of different technologies and collaboration tools are more efficient than others. As a consequence, technology has to foster the communication among team members to support relationship building. This is only possible if team members trust in the chosen technology (Thatcher et al., 2007). The fact that even frequent use of rich media communication does not guarantee team success helps to remember that technology is simply the medium and not the message of virtual work.

- Leadership

Although leadership and management are sometimes regarded as synonyms they have to be differentiated. While management sets value on concrete performance measures, the concept of leadership deals more with activities and processes. A traditional manager bears her/ his authority. But in virtual teams and especially in the domain of VPM, the importance of a leader lays in creating a collaborative atmosphere which cannot be imposed by authority but by communication. It is important that team leaders maintain an inspiring and collaborative working environment so that all team members try to innovate for the overall success of the NPD effort

(Chang, 2006). The engagement of all team members is crucial. The diversity of team members may require a flexible leadership style that is based on values, attitudes and understanding and may lead to a higher efficiency (Kayworth and Leidner, 2000).

Delegative principles might be advantageous as they cover the challenge of distributed work by conveying managerial functions to team members. While delegative management approaches are based on a formal team leader, it is possible that virtual teams might be absolutely self-managing, self-motivated and dissolved by themselves without any external structure (Hertel et al., 2005; Lee-Kelley and Sankey, 2008). Despite this fact, researchers agree that most virtual teams need some guidance. This might be in form of the role of a moderator, who might be responsible for the organisation of meetings, and facilitates communication and information sharing (Hertel et al., 2005). Jassawalla and Sashittal (1998) highlight when the leader of a project is selected the extent of the NPD related cross-functional collaboration is higher as when the team leader is appointed.

A team leader of a distributed NPD team has to meet tangible objectives that are directly related to project performance (like bills of material, time schedule etc.) as well as intangible objectives (like trust building or a common understanding). Effective leaders should stimulate sustainable relationship and be flexible and willing to let other team members lead when necessary (Jarvenpaa and Leidner, 1999). Other competencies that might be needed include the ability to facilitate the communication among team members by animation of a variety of different technologies. Virtual team leaders have to create clear structures, ensure objective congruence among team members, enhance mutual trust by maintaining socio-emotional interactions, inspire and motivate team members, foster role clarity and solve conflicts (Kayworth and Leidner, 2000; Chang, 2006; Lee-Kelley and Sankey, 2008). They should stimulate cohesion and psychological safety, trust development and creativity. A training in conflict management is highly recommended for team leaders. A detailed list of main required competencies is given in table 3-2.

- Information Sharing

Chang (2006) suggests that information sharing is one of the success factors to the challenging environment of virtual NPD. Information sharing and collaboration are two inseparable components. To work collaboratively, team members have to be up-to-date at any time of the current state of the project. To work virtually increases the ability to send greater amounts of information, at faster rates of transmission (Gaudes et al., 2007). There are different criteria to choose the right form of information sharing like speed, format, security, ease of use, number of concurrent users and compatibility with the legacy system of the organisation (Chang, 2006). Security levels and transparency are highly important for information sharing. Doubts about that information exchange based on ICT may not be secure have a negative impact upon virtual team effectiveness (Walczuch et al., 2007). Security levels are essential in virtual teams to be sure to work in a trustworthy environment. Virtual team work involves exchange and modification of sensitive information and data via Internet, therefore security levels are an important issue (May and Carter, 2001). Commitments, laws, contracts, rules and norms as well as the effect of legacy systems and data aid to structure the virtual work and contribute to psychological safety, cohesion sustainable relationship building and trust development.

Leenders et al. (2007) distinguish the unidirectional information flow where one team member provides another one with information and the reciprocal information flow where information is exchanged from both sides. Hameri and Nihtilä (1997) conclude that most information sharing in successful NPD processes is reciprocal between the upstream and downstream development activities.

As the process of virtual decision-making is slowed down, virtual teams need longer to make a decision. Computer-mediated decision making takes more time compared to face-to-face conditions and is less successful in attaining group consensus (Hertel et al., 2005; Leonard and Haines, 2007). Beyond this, less information is exchanged and team members are less satisfied (Hertel et al., 2005). On the other hand, Leonard and Haines (2007) affirm that some virtual team members appreciate the fact to be not face-to-face. They feel free to speak without interruptions and to hear everyone's viewpoint (Leonard and Haines, 2007). Teams might be more effective if they are communicating via technology rather than face-to-face to take decisions at a strategic level (Schmidt et al., 2001). They consider that virtual teams seem to make more effective NPD decisions concerning the quality of the results than traditional face-to-face teams, because of cognitive limitations in the information process of NPD projects and social influences (Schmidt et al., 2001). Shim et al. (2002) state also that virtual teams tend to be more task-oriented and exchange less social–emotional information than traditional teams. Indeed, in a virtual team, team members are less influenced by social aspects and can easier take decisions on their own. Then, if necessary, compromises have to be made between the different propositions.

3.2.3 Team: Competence Management and Virtual Team Interaction

Different recurrent main themes are presented in § 3.2.3 that are allocated to the branch team under the aspect of virtuality. To structure them we take the beforehand given definition 2-4 of a virtual team as filter for the principal aspects.

A virtual team consists of (1) individuals who are (2) temporally, (3) geographically, (4) organisationally and/ or (5) culturally dispersed and act (6) interdependently through technology to achieve a common goal. A virtual team is embedded in an (4) organisational context.

We allocate for (1) individuals the themes: knowledge and competencies, and sustainable relationship. The aspect (2) of temporally dispersion includes in our opinion: availability. Availability is also a recurrent theme for (3) geographically dispersion. While the (4) organisational dispersion as well as the (4) organisational context is represented by psychological safety and team member satisfaction. Culturally dispersion (5) is incorporated by the themes cohesion, cultural diversity and creativity. As themes of (6) interdependent acting are communication, trust and conflicts presented. An overview of all themes deducted from the aspect "team" is depicted in figure 3-6.

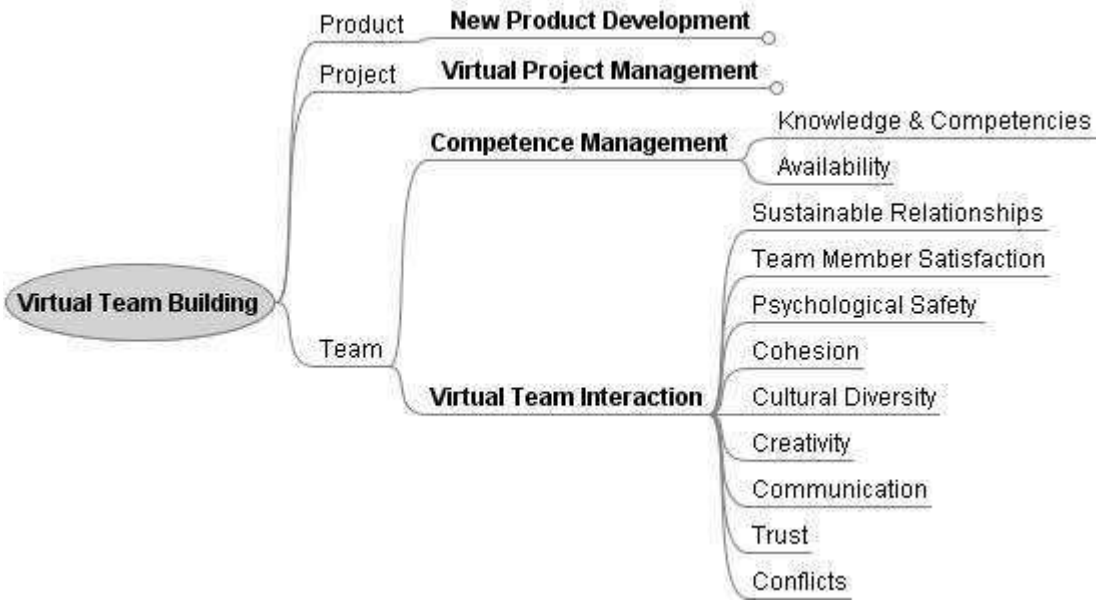


Figure 3-6. Structure of Main Recurrent Themes of Virtual Team Building: Focus on Team

- Knowledge and Competencies

Each team member brings acquired competencies, knowledge and skills of her/ his own field to the collaborative project. Main selection criteria for virtual team members might be their professional and technical knowledge, competencies and expertise. As presented in the competence ladder (figure 2-6) competence is in our understanding interpreted knowledge that is shown as adjusted activity in a respective situation (§ 2.3.3.1). As knowledge is seen as basis for competencies we are concentrating more on competencies than on knowledge in this work.

There are some authors who make a difference between three areas of competencies: product, process and market (Coates and McDermot, 2002; Ford and Saren, 2001; Leonard-Barton, 1992; Winter, 2003). While product competence adheres to routines related to the properties and characteristics of the value created by the firm for customers, process competence considers routines related to the properties and characteristics of the value-creation process of the firm. Market competence stresses routines related to the properties and characteristics of the value transfer between the firm and its environment. One other classification of competence is to differentiate technical, contextual and behavioural competencies (IPMA, 2006).

Winter (2003) differentiates three levels of competencies: ad hoc, operational and dynamic. Ad hoc competencies can be defined as an organisation's spontaneous reaction to sudden changes in the environment or other unpredicted events. Both, operational and dynamic competencies may benefit from ad hoc competencies as they disrespect routines under certain circumstances in order to increase flexibility. Depending on the nature of the time-frame (short-term vs. long-term), the organisation either falls back to its operational competencies or uses the ad hoc experience as input into its dynamic competencies to develop new operational competencies.

There are many different suggestions for required competencies of virtual teams. We are referring to Kleef and Roome (2007), Fisher and Fisher (1997) and Duarte and Snyder (2006) to describe following competencies for virtual team members and virtual team leaders in table 3-2.

Table 3-2. Main Required Competencies for Virtual Team Members and Virtual Team Leaders

Main Required Competencies for Virtual Team Members and Virtual Team Leaders	
Virtual Team Members	**Virtual Team Leaders**
Working across cultural and functional boundaries (Duarte and Snyder, 2006).	Leading in a cross-cultural environment (Duarte and Snyder, 2006).
Networking across functional, hierarchical, and organisational boundaries (Kleef and Roome, 2007; Duarte and Snyder, 2006; Fisher and Fisher, 1997).	Networking across hierarchical and organisational boundaries (Duarte and Snyder, 2006).
Using electronic communication and collaboration technology effectively (Duarte and Snyder, 2006).	Selecting and appropriately using electronic communication and collaboration technology (Duarte and Snyder, 2006).
Setting personal boundaries and being assertive about being included (Duarte and Snyder, 2006).	Coaching and managing performance without traditional forms of feedback (Duarte and Snyder, 2006).
Managing one's time and one's career (Duarte and Snyder, 2006; Fisher and Fisher; 1997).	Managing the performance, development and career development of team members (Duarte and Snyder, 2006).
Project management techniques (Duarte and Snyder, 2006).	Developing and adapting organisational processes to meet the demands of the virtual team (Duarte and Snyder, 2006).
High level of interpersonal awareness (Duarte and Snyder, 2006).	Building and maintaining trust (Kleef and Roome, 2007; Duarte and Snyder, 2006).
Problem solving (Kleef and Roome, 2007; Fisher and Fisher, 1997).	Decision making (Fisher and Fisher; 1997).

Even if there might be an overlap a difference between competencies of team members and team leaders should be considered. Competencies of virtual team leaders might be similar to competencies of traditional team leaders as competencies of virtual team members might be similar to competencies of traditional team members.

- Availability

Availability of a flexible and configurable infrastructure becomes a crucial factor in agile virtual teams. This enhances the possibility that at least one team member is always available. Experts can float in and out of projects whenever their competencies might be needed. There is much research in the field of computer-mediated communication that understand "presence" as social richness (e.g. Panteli, 2004). Panteli (2004) identifies three different articulations of presence: present availability, absent unavailability and silenced availability. Present availability indicates that team members are available to work on the project, and of course have the skills to perform the required tasks. Absent unavailability focus on the case when team members are temporarily unavailable to work on the team project and have to be absent. Silenced availability means that team members are expected to be available to work on the project but despite this they remain silent and do not answer to demands.

- Sustainable Relationships

Even if community members do not necessarily know each other or maintain personal contacts, the virtual community is characterised as social relationship (Walker, 2006). In view of Liu and Burn (2009) it is crucial that team members construct a framework wherein relationship building is possible. Sustainable relationships enhance team member satisfaction, virtual team performance and thereby effectiveness. If team members spend only time on task-orientated activities, the lack of relationship building may result in frustrated team members (Liu and Burn, 2009). As a result of a study of Lurey and Raisinghani (2001) team members' relations present the strongest positive correlation to team performance and team member's satisfaction.

- Team Member Satisfaction

A virtual team has, as a social network, an additional responsibility beyond satisfying the assigned task: it must also care for its members and increasing the team member satisfaction by providing the right opportunities for personal development and growth (Lurey and Raisinghani, 2001). Lurey and Raisinghani (2001) state that a virtual team cannot be effective if the team members themselves are not satisfied with the way the team interacts and functions.

The level of satisfaction in virtual teams is often less than in traditional face-to-face teams (Hertel et al., 2005). According to Hertel et al. (2005) virtual teams with high team member's satisfaction are characterised by

(1) opportunities to meet face-to-face at early stages of the project,

(2) non-job-related communication and

(3) constructive conflict management.

Non-task-related and non-job-related communication can facilitate social sustainable relationships in virtual teams what increases also the team members' satisfaction. Other aspects that may influence the satisfaction of team members are conflict management, trust, transparency and security levels, as well as cohesion and psychological safety. Also an adaptive management by objectives and performance related feedback may increase satisfaction and performance of team members.

DeLuca et al. (2006) emphasise on the project life cycle. They declaim that the disbanding process in virtual teams is very important to maintain high satisfaction and motivation among team members. Achievements and acknowledge should be communicated and lesson learned and best practices can be passed to future projects (DeLuca et al., 2006). This is in line with the concept of the learning organisation.

- Psychological Safety

Psychological safety is referring to Edmonson (2003) defined as "[…] a climate-like shared belief among team members that the team is a safe context for interpersonal risk taking." In this understanding, psychological safety promises security that the team do not impeach a team member for expressing her/ his thoughts truthfully. Interpersonal risks of appearing incompetent, confrontational or disagreeable (Edmondson, 2003) might hinder the performance of the virtual team. Team members who feel less psychological safety become less engaged in project

tasks. Psychological safety is essential for virtual team members to express truthful ideas and solutions that are critical to enhance the NPD process.

Often the concept of psychological safety is related to learning behaviour and VTI (Edmondson, 2003). It is a concept that is similar to trust development. Edmondson (2009) distinguishes psychological safety from trust in terms of focus, time-frame and level of analysis.

Stevens et al. (2009) consider that asynchronous communication could lead to less biased use of shared information and therefore to a higher psychological safety. Preserving security levels for data exchange during the information flow like norms, rules and commitments is essential to create psychological safety and trust.

- Cohesion

Virtual teams have to evolve a shared sense of identity and should feel equal stake in NPD related outcomes. Bollen and Hoyle (1990 - stated in Liu and Burn, 2009) develop a subjective conceptual model of cohesion that has two dimensions: sense of belonging and feelings of morale. Further, Liu and Burn (2009) distinguish two kinds of cohesion: (1) task cohesion, which improves personal competencies but has no improvement in team performance and (2) social cohesion, which might facilitate the quality of the team work.

Cohesion enhances the team member satisfaction. Developing cohesion and team identification can be difficult in virtual teams in consequence of reduced face-to-face contact. Both are usually lower in virtual teams compared to face-to face teams. Team members may retire easily from their responsibilities and do not contribute (Liu and Burn, 2009). Even a small degree of distance of some metres can negatively affect cohesion. Technologies may hinder the development of cohesion. Studies have evinced that especially in the beginning of a virtual team, cohesion building is much lower than in a traditional team (e.g. Chidambaram, 1996). But over time the discrepancy gets much smaller. The longer team members work together, the better are the outcomes. This might be connected to the fact that cohesion and a working culture is established and a memory of knowledge exists. A team is characterised by a membership that is clearly established and known by all team members (Hackman, 1990). This fosters cohesion and team culture. Edmondson and Nembhard (2009) refer to Katz (1982) who distinguishes that teams feature a higher effectiveness only up to three years. After two or three years a stable team membership constitutes a negative effect on performance in NPD teams due to the fact that communication about less relevant issues increases (Katz, 1982). The results of a study of Hambley et al. (2007) provide evidence that communication media do have important effects on team cohesion and that using the right technology helps to minimise the difficulty of developing cohesion.

- Cultural Diversity

Hofstede (1980) defines culture as "the collective programming of the mind which distinguished the members of one group from another." Lee-Kelley and Sankey (2008) differentiate culture into national, organisational and functional. In the domain of virtual teams the cross-functional culture is often highlighted because of the interdisciplinarity of its team members. However, the national and organisational culture should also be considered.

Under the circumstances of globalisation NPD involves automatically diverse team members of technical disciplines, company orientation, geographical locations or engineering practices, thus, dissimilar cultural contexts (Chang, 2006). Those contexts comprise different views regarding norms and values defining the rules for social behaviour and technical outcomes of the organisational setting (Araujo, 2009). Limited communication opportunities in virtual teams might hinder a constructive use of cultural diversity and amplify challenges of intercultural team work.

Numerous studies have examined the impact of cultural differences among team members which are common in global virtual teams. According to Kayworth and Leidner (2000) high cultural diversity leads to less effectiveness, less cohesion and less trust and creates more conflicts. Team performance suffers; dissatisfaction and stress may rise. Another negative point is that teams with a high cultural diversity fail to realise their potential to make complex decisions. Even worse, the cultural diversity may conclude in stereotyping, misunderstanding and misattributions of behaviours based on the dissimilarity of values, and inhibits the knowledge transfer, the decision making process and the progress of the NPD (Araujo, 2009; Edmmodson and Nembhard, 2009). Team members who share similar values agree more easily about objectives, tasks and procedures thus increasing collaboration.

Conversely, cultural diversity impacts higher levels of creativity and more ideas, solutions and alternatives to a problem. Diversity of members allows the consideration of a broader range of expertise, competencies and perspectives in the product design and process. According to Hertel et al. (2005) diversity is often associated "[…] with the hope of "synergistic" effects, assuming that different expertise and perspectives increase the team effectiveness." Team members get a better understanding of the whole project by adjusting divergent ideas due to the respective perspective of the diversity of members. As the markets are international and the costumer geographically as distributed as the team member of the virtual team, virtual teams are supposed to multiply the chances to provide products and services that fit the requirements. Staples et al. (2005) claim that diversity of resources, perspectives and competencies in virtual teams contribute to creativity and team effectiveness.

The negative effects should be compensated by team members with high intercultural competencies who try to make an effort to actively understand and operate the differences. All apart from intercultural differences, it is important to create one's own culture within the team that boosts processes for learning. Leadership must aim to foster an information-sharing culture with frequent communication and respectful interaction with the aim of turning creative tensions and conflicts in innovative products. A collaborative culture sets store by a community that consists of relationships between people.

To add another line of thought the question is if certain cultural backgrounds might have more advantages for virtual teams than others. Based on the work of Hofstede (1980), Jarvenpaa and Leidner (1999) did not find clear answers if individualistic or collectivistic cultures are more advantageous for virtual teams. While in individualistic cultures team members might be more receptive for trust building processes and cope better with isolated work conditions, collectivistic cultures identify themselves easier with a group and overcome isolation by seeking actively contact with other team members (Hertel et al., 2005).

- Creativity

Creativity in virtual teams is an important aspect that helps team members with idea generation and solution finding (Lurey and Raisinghani, 2001). It is often based on risks and conflicts. Chamakiotis et al. (2010) suggest a classification of creativity in three different levels that are widely accepted in research: the individual, the team and the organisational level. While individual creativity is interpreted as divergent thinking and personal traits, team creativity depends on team interaction and group characteristics. Organisational creativity is closely associated with the organisational culture (Chamakiotis et al., 2010). It is also admitted that referring to the higher level of creativity virtual teams may develop more and better alternative solutions to a problem and might enhance on long term the effectiveness of a virtual team. (Stevens et al, 2009).

- Communication

To increase the effectiveness of a virtual team, its information must be effectively exchanged. Communication between team members without interferences is critically important for the success of the virtual team and NPD in general. Numerous articles give distinction to the significance of effective communication (e.g. Lee-Kelley and Sankey, 2008; Anderson et al., 2007). It is crucial to have excellent communicators in a virtual team, to select the right technology and to be aware of communication difficulties created by a virtual environment. A virtual environment includes critical challenges for a virtual team like uncertainties about security levels, time delays in sending feedback, lack of non-verbal communication, problems of understanding or interpretation of written text, etc.

Time delays may be distracting but Liu and Burn (2009) highlight that when adequate time is allowed, misunderstandings of written messages are less often. Contrary to the expectations, the authors state that asynchronous communication in virtual teams may be more effective because the delay between response and feedback may implicate more reflection (Liu and Burn, 2009).

Another challenge is the lack of non-verbal communication. Sproull and Kiesler (1991) indicate that non-verbal communication is an important component of team communication in general. Computer-mediated communication is according to DeLuca et al. (2006) often considered as information transfer missing social aspects of human communication. As effective communication is referring to Liu and Burn (2009) coupled with personal relationship it seems to be crucial that team members construct a framework wherein relationship building is possible. Virtual teams have to find other ways in which they can communicate effectively with the benefits of non-verbal interactions. Communicants of virtual teams perceive to make compensatory adaptations to their messages in order to make them more richly in form of language and social cues. Virtual teams often develop implicit or even explicit norms and rules of communication and implement explicit sanctions and punishments for team members who are not following those (Montoya-Weiss et al., 2001). Because the possibilities of virtual communication are more limited than for traditional teams, virtual teams tend to be more task-oriented and exchange less social–emotional information as stated by Shim et al. (2002). This slows the development of relational links down.

DeLuca et al. (2006) point out that even if technologies often pose obstacles to communication for virtual teams, they overcome these obstacles by the right choice of technologies. In matters of the media richness theory communication media vary in the level of information richness (Daft and Lengel, 1986 – quoted in Panteli, 2004). It depends on the capacity for immediate feedback, the number of social cues and channels utilised, personalisation and language variety (Panteli, 2004). Pertaining to the media richness theory email as a written and asynchronous form of communication is determined as a lean medium. DeLuca et al. (2006) accent media of low richness because virtual teams adapt their communication to this "lean" media "[…] to be more focused, clear, precise, neutral, concrete, concise, persuasive, considerate and complete […]" (DeLuca et al., 2006). The information exchange is priority what leads to the presumption that there might be advantages to an absence of nonverbal cues. Cross-cultural misinterpretations of nonverbal cues may be minimised.

Communication is a critical factor for effectiveness, performance, team member satisfaction, psychological safety, cohesion and sustainable partnerships. CSCW relies on communication, as well as transparency, information sharing, leadership, animation, trust development and conflict management. Communication provides the necessary agility to reduce the complexity of relationships and to lower the transaction costs. Communication is the basis of the VTB Support System and therefore linked with most of its other environments.

- Trust

Trust development is a crucial aspect for the success of virtual teams and a significant challenge regarding the assessment of team members' trustworthiness without ever having met them, especially if the lifetime of virtual teams is mostly very limited. Gaining and maintaining trust is understood as the most important factor in the creation of excellent interactions. As interactions contribute to a better performance, trust is also a strong index of performance, as well as team member's satisfaction (Liu and Burn, 2009). Jarvenpaa and Leidner (1999) prove in their study that even short-term teams are able to develop high trust anyway if they foster social communication early. Virtual teams that communicate on an interpersonal social level achieve fast a high level of trust. However, the process of trust development seems often to be slower in traditional teams than in virtual teams where it tends to be set up right from the start (Jarvenpaa and Leidner, 1999). Additionally, it is admitted that trust within virtual teams changes dynamically over time (Kanawattanachai and Yoo, 2002). It is role and context specific (Lee-Kelley and Sankey, 2008). In the early beginning of a virtual teamwork trust is supported by social aspects while in the course of the project trust is determined by process- and task-related aspects (Jarvenpaa and Leidner, 1999). Kanawattanachai and Yoo (2002) give distinction to the term of "swift trust" that focus on trust between team members who need to accomplish their tasks by trusting other members from the beginning on the basis of their background, professional credentials and affiliations, not on past experiences.

Greenberg et al. (2007) provide three components of trust: ability, integrity and benevolence. They identify which of these are critical to each life cycle stage of a virtual team to develop trust within the team. The authors adhere that trust traditionally arises in two ways. The first type of trust is based on rational assessments of evidence of performance reliability and competence - called cognitive trust. In this case it has been modelled as a function of the other per-

son's integrity and ability. The second type of trust is affective trust. It is based on emotional ties and results of the social bonds developed in a reciprocal relationship. The affective trust is based on assessments of benevolence (Greenberg et al., 2007). The relative importance of cognitive trust and affective trust varies depending on the context and the type of relationship among team members.

Differently from this, Wu and Li (2009) suggest three main areas of trust: relationship, technology and third-party. Ability, integrity and benevolence are referring to Wu and Li (2009) components of the area of relationship where trust shows its effect. According to them trust ameliorate to reduce social uncertainties in the relationship of partners and to reduce risks in technology related issues (Wu and Li, 2009). Msanjila and Afsarmanesh (2008) distinguish that trust is based on following aspects: technological, structural, economical, social and managerial aspect.

Trust development is linked with most of the other environments of the VTB Support System. It is a critical factor for communication, information sharing, psychological safety, cohesion, sustainable relationships, team member satisfaction, performance and effectiveness.

- Conflicts

Each team member may have honest disagreements regarding the NPD process, the information flow, the choice of material and technology or the product itself. In consequence of reduced communication and the involved interferences, conflicts are not rare in virtual teams and tend to be more frequently in virtual contexts than in traditional settings (Shin, 2005). Hertel et al. (2005) point out that they are based on misunderstandings and not on aggressive acts. It's straightforward that the way virtual teams manage internal conflict is critical to their success (Shin, 2005). Conflicts may be used positively as opportunities to explore new options, innovative solutions and scenarios that extend team member's thinking and creativity. However, Shin (2005) emphasises that conflict resolution in virtual teams generally takes longer than conflict resolution in traditional teams.

Montoya-Weiss et al. (2001) adhere that social pressure can often lead to explicit sanctions and punishment in cases of conflict. In their research they are dealing with the five traditional conflict management modes: avoidance, accommodation, competition, collaboration and compromise (Montoya-Weiss et al., 2001). There is need for guidance on conflict prevention and conflict management adapted to conditions of virtual teams because recent studies on virtual teams demonstrate that the way virtual teams manage internal conflict is critical to their success. First, suggestions can be found in conceptual work and case studies (e.g. Shin, 2005; Paul et al., 2004). Virtual team leaders should be trained in conflict management.

The list of the recurrent themes of the literature does not claim to be exhaustive. The presented topics are significantly important for this work and function as basis for the identification of the VTB Support System's environments (§ 4.1.3.) They can easily be enlarged in compliance with specific needs of an application field. In following § 3.3 a synthesis of chapter 3 is provided where opportunities and risks of the presented main recurrent themes of virtual team building (§§ 3.2.1 - 3.2.3) are visualised in a survey (table 3-3).

3.3 Synthesis: Survey of Opportunities and Risks

In this chapter 3 we have explored relevant literature related to the setting of the VTB Support System. The dimensions project, product and team of the evaluation model of conception systems by Robin (2008) have been translated to the three subsystems VPM, CM and VTI as well as to the context of the VTB Support System, NPD. They have been set in relation to other propositions of essential dimensions on the basis of virtual team building and allocated to the technical and human point of view of this work. A proposition of determination of the technical and human dimension of virtual team building is represented and ascribed to the life cycles: product, project and team.

After this, main recurrent themes of virtual team building from the literature, from our personal experience in European projects and industry as well as national and international exchanges with experts have been briefly illustrated according to the proposition of essential dimensions based on virtual team building and the setting of the VTB Support System. They are structured in compliance with these dimensions and its life cycles as well as with the setting and its domains: NPD, VPM, CM and VTI.

The setting of the VTB Support System and the classification of the recurrent themes according to the defined essential dimensions of virtual team building: NPD, VPM, CM and VTI are considered in the part of modelling of the VTB Support System. The presented main recurrent themes of § 3.2 are incorporated in our model as influencing aspects. While conducting the functional analysis they are considered as environments of the VTB Support System and build the basis of its functions (§§ 4.1.3 - 4.1.4).

Contemplating on § 3.2 we summarise in table 3-3 the recurrent themes of virtual team building according to the structure that has been presented in figure 3-3. Additionally, we provide a survey presenting their opportunities and risks regarding virtual team building. The survey about opportunities and risks of these environments help to merge results about recommendations and technical solutions that have to be respected by the VTB Support System in the modelling part (§ 4.2.2).

Table 3-3. Survey of Recurrent Themes of Virtual Team Building regarding their Opportunities and Risks

Survey of Recurrent Themes of Virtual Team Building regarding their Opportunities and Risks		
New Product Development (NPD)		
Environment	**Opportunities**	**Risks**
Time & Costs	Reducing time and costs by overcoming the limitations based on time and geographical aspects (McDonough et al. 2001; Lipnack and Stamps, 2000; Harvey et al., 2004; Shin, 2005).	Little efficiency in terms of time and costs.

Survey of Recurrent Themes of Virtual Team Building regarding their Opportunities and Risks		
New Product Development (NPD)		
Environment	**Opportunities**	**Risks**
Resources & Requirements	Reducing time-to-market and matching rapidly requirements of customers and end users (Lipnack and Stamps, 2000; May and Carter, 2001; Stevens et al., 2009). Improved customer service (Shin, 2005). Competitive advantages (Lurey and Raisinghani, 2001).	Difficulty to assign resources and requirements correctly based on the distance.
Complexity	Complexity as source of creativity and intellectual value.	Complexity due to the requirements of the product, processes, information flow, cultural diversity, task and workflow uncertainty etc. are salient (e.g. Harvey et al., 2004; Eigner and Stelzer, 2009). Collaboration issues are complex and multiples: e.g. organisational, technological, functional, cultural and human issues (Ouni, 2009).
Virtual Project Management (VPM)		
Environment	**Opportunities**	**Risks**
Agility	Empower organisations with agility, respond quickly to changing environments (Lurey and Raisinghani, 2001; Harvey et al., 2004). Higher degree of freedom and personal flexibility team members increase in productivity.	Team members may miss a certain stability.
Technology	Benefits based on technology for cross-functional projects that need cross boundary input (Lee-Kelley and Sankey, 2008; Lurey and Raisinghani, 2001). Improved collaboration (Gaudes et al., 2007). Special training for team members and leaders (Greenberg et al., 2007; Shin, 2005; May and Carter, 2001).	Technophobia: team members who are uncomfortable with technology (Korukonda, 2005, Walczuch et al., 2007). Virtual team members are often not familiar with the strengths and limitations of the relevant technologies.
Leadership	Virtual teams need some guidance: Leadership should maintain an inspiring and collaborative working environment (e.g. Hertel et al., 2005).	Not adapted leadership can result in the failure of the virtual team (e.g. Hertel et al., 2005).

Survey of Recurrent Themes of Virtual Team Building regarding their Opportunities and Risks		
Virtual Project Management (VPM)		
Environment	**Opportunities**	**Risks**
Information Sharing	Greater amounts of information, at faster rates of transmission (Gaudes et al., 2007). Higher team effectiveness (Lurey and Raisinghani, 2001): higher quality of results based on more formal task-oriented than social-emotional and exchange. (Leonard and Haines, 2007; Hertel et al., 2005; Schmidt et al., 2001, Paul et al., 2004).	Security levels are an important issue as the work includes exchange and modification of sensitive information and data (May and Carter, 2001; Walczuch et al. 2007).
Competence Management (CM)		
Environment	**Opportunities**	**Risks**
Knowledge & Competencies	Access to resources like experts, mutal sharing of knowledge and competencies, attract better employees (Harvey et al., 2004; Greenberg et al., 2007; Paul et al., 2004 ; Rice et al., 2007; Lipnack and Stamps, 2000). Competence matching to use the best expertise and knowledge regardless to geographical barriers (Harvey et al., 2004; Stevens et al., 2009).	Finding the right team members for starting collaboration may be very costly in term of time and efforts (Camarinha-Matos and Afsarmanesh, 2007a).
Availability	Availability is not limited by the traditional work 9/5 day schedule but goes toward the 24/7 mode based on the different time zones (Chang, 2006).	Responsibility Ambiguity: Team members may easily retire from responsibilities (Liu and Burn, 2009; Shin, 2005). Reduced team member awareness (Rice et al., 2007).
Virtual Team Interaction (VTI)		
Environment	**Opportunities**	**Risks**
Sustainable Relationship	Sustainable relationships are the key to virtual team working. They should be established, maintained and leveraged.	Lack of relationship building may result in frustrated team members (Liu and Burn, 2009).
Team Member Satisfaction	Improved team member's satisfaction promises higher team effectiveness (Hertel et al., 2005; Lurey and Raisinghani, 2001).	Team member's satisfaction is challenging in virtual teams (Hertel et al., 2005; Lurey and Raisinghani, 2001).
Psychological Safety	Promises security to express truthfully ideas and solutions and to become more engaged in the project (Edmondson, 2003). Positive changes in organisational culture resulting in integration and commitment.	Psychological Safety takes time to be built (Edmondson, 2003; Stevens et al., 2009).

Survey of Recurrent Themes of Virtual Team Building regarding their Opportunities and Risks		
Virtual Team Interaction (VTI)		
Environment	**Opportunities**	**Risks**
Cohesion	Using the right technology helps to develop cohesion (Hambley et al., 2007) Cohesion building is in the beginning of a project lower than in traditional teams, over the time the discrepancy gets smaller (Chidambaram, 1996).	Cohesion development and team identification takes more time due to the reduced face-to-face contact (Liu and Burn, 2009; Chidambram, 1996; Hambley et al., 2007).
Cultural Diversity	Cultural diversity may have a "synergistic effect": higher potential to take the right decisions. Diversity of team members may increase the creativity and enhance team effectiveness (Hertel et al., 2005; Staples et al., 2005).	Cultural diversity may hinder trust, cohesion building and decision making and provoke conflicts, team member's dissatisfaction and less effectiveness (Kayworth and Leidner, 2002; Aroujo, 2009; Edmmodson and Nembhard, 2009).
Creativity	Boosting creativity leads to innovation (Leenders et al., 2003; Stevens et al., 2009; Lurey and Raisinghani, 2001; Chamakiotis et al., 2010).	Creativity involves taking risks. Those could make the project fail.
Communication	Asynchronous communication may be more effective because it may implicate more time of reflection (Liu and Burn, 2009). Obstacles of communications can be overcome by the right choice of technology and by constructing a framework wherein social aspects of communication might be possible (Liu and Burn, 2009; DeLuca et al., 2006).	Limited communication opportunities, lack of non-verbal communication, problems of understanding or interpretation of written text, time delays in reponses etc. (Liu and Burn, 2009; Sproull and Kiesler, 1991; DeLuca et al. 2006; Greenberg et al., 2007).
Trust	Trust is considered as the most important factor in creation of interactions, performance, satisfaction and effectiveness (Liu and Burn, 2009). If social communication is fostered early even short-term virtual teams are able to develop trust (Jarvenpaa and Leidner, 1999).	Trust development is challenging (Greenberg et al., 2007; Griffith et al., 2003; Jarvenpaa and Leidner, 1999; Kanawattanachai and Yoo, 2002).
Conflicts	Conflicts serve as potential of idea creation of innovative solutions.	Conflicts based on disagreements or misunderstandings may be counterproductive (Kayworth and Leidner, 2002; Hertel et al., 2005; Montoya-Weiss et al., 2001; Paul et al., 2004). Internal sanctions and punishments in case of conflicts can restrain their success (Montaya-Weiss, 2001).

Part II: Modelling

4 Modelling of the VTB Support System

Several approaches, methods and tools exist in the scientific literature in order to develop new models, systems and functions in an industrial engineering process (Martin, 2001). Models are not only used to analyse an existing system but also to construct the system itself. As we explore the conceptual design of a VTB Support System, we use models and tools that support product design. We need a model that deals with a central objective and is applicable to our need to build a VTB Support System. It should propose tools that facilitate to create the VTB Support System.

We chose the V-diagram that is a model of System Engineering of l'AFIS (Agence Nationale de L'ingéniérie Système). It is an interdisciplinary approach to realise successful systems in all kinds of project development (Meinadier, 1998). The V-diagram is named for its "V" shape. A central objective stands at the top, with theoretical and conceptual information for decomposition and definition along the left side, and integration, verification and validation in light of the objective along the right side that demonstrates the operations and maintenance, changes and upgrades, and ultimate retirement of the system. It proposes different tools for each respective step of the creation of a system. Its strength lies in its powerful tools like the functional analysis and the Quality Functional Deployment (QFD). The V-diagram according to Bocquet (2011) is shown in figure 4-1.

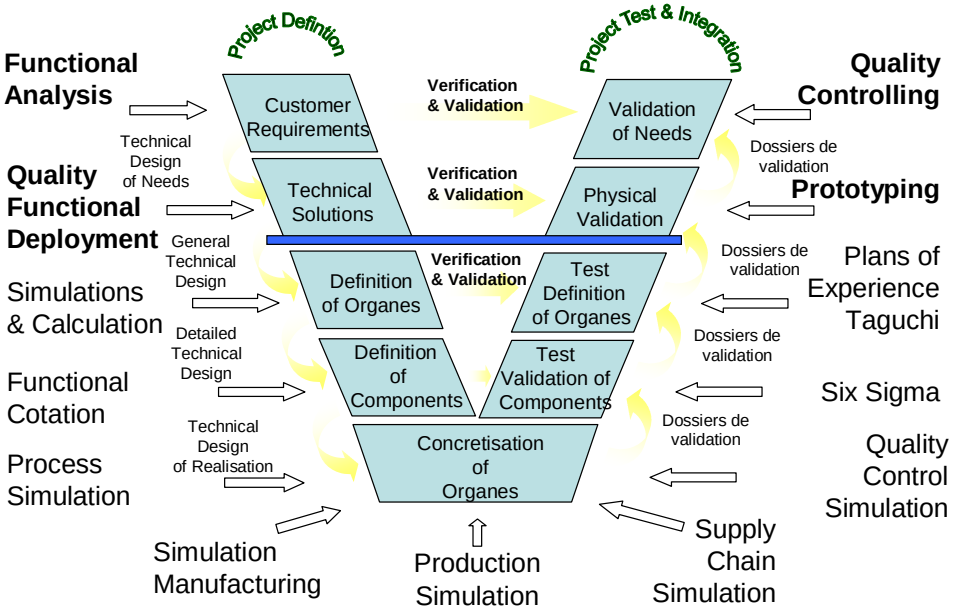


Figure 4-1. V-diagramm (based on Bocquet, 2011)

As seen in figure 4-1 the system definition that is developed on the left side of the V-diagram is used to validate the system on the right side. For example, the customer requirements that are identified through the functional analysis are the basis for the validation of the quality controlling that is used to validate the system at the end of project development. The connections

between the left and right side are indicated by the arrows that cross the "V". They highlight the continuity between the beginning and end of the project and present how plans developed on the left side implicate in the process on the right side.

We concentrate in this PhD thesis on the two first steps that are indicated in the V-diagram to build the VTB Support System. The presented tools that cope with these steps are the functional analysis and the house of quality, based on the QFD.

Our research approach is set in the conceptual design. Needs are designed with the help of the functional analysis (§ 4.1) and concepts are generated with help of the house of quality (§ 4.2) to provide a preliminary design of a VTB Support System. Those concepts are evaluated by different applications in chapter 5. The methodological positioning of the research approach is presented in figure 4-2.

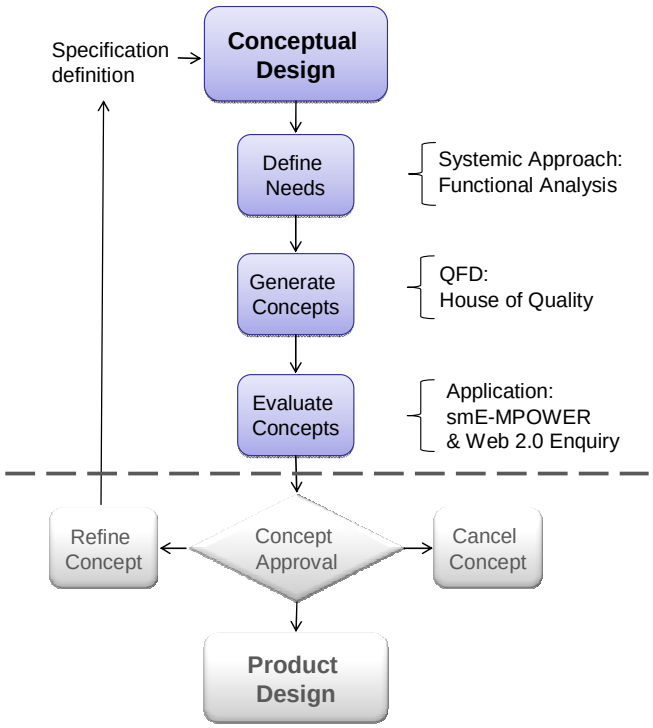


Figure 4-2. Methodological Positioning of the Research Approach

The methods of the functional analysis and the house of quality are used in coherence with the systemic approach that is presented in § 4.1. The functional analysis is conducted to get a most exhaustible vision of the requirements of the system. The system is validated (§ 4.1.2), environments are identified (§ 4.1.3), functions are build (§ 4.1.4) and characterised (§ 4.1.5). A list of the entire functions is given in § 4.1.5. It reflects the hierarchical order of the functions that is also represented in figure 4-10.

The tool of the house of quality is used to translate the requirements of the VTB Support System in recommendations and technical solutions that are proposed to satisfy the requirements (§ 4.2). We behold the identification of customer requirements (§ 4.2.1) and quality characteristics (§ 4.2.2). A catalogue of examples of quality characteristics is given in table 4-7. After-

wards, the assessment of relationship is exposed in § 4.2.3 and the adjustment of correlation is handled in § 4.2.4. In chapter 5 the concepts are evaluated with different applications.

The chapter 4 closes with a synthesis about the presentation of the methodological approach of the VTB Support System in § 4.3.

4.1 Functional Analysis

In order to provide a VTB Support System, we choose the holistic approach of the functional analysis to get information from a systemic point of view. The functional analysis is the tool that we use to be as objective, generic and exhaustive as possible. We aim to describe all functions of the VTB Support System that are reflecting requirements. The functional analysis consists in connecting the customer needs to the functional domain. To do so, we identify the functional requirements of the VTB Support System that are defined as a minimum set of independent requirements characterising the system. One of the benefits of the functional analysis, that seems to be the most important for this PhD thesis, is that it sets priorities on the environment of the system. This fosters the holistic view by covering all elements that have an important impact on the VTB Support System. Based on the systemic approach, the VTB Support System is handled as a system. Snodgrass (1986) emphasises that a system cannot be determined or explained by its components alone but only by the interdependencies of each component that interacts constantly with the others. The fact that it is considered as a whole settles the claim of a holistic approach. By putting the different elements of the system in relation functions are provided that describe the VTB Support System. Another benefit of the functional analysis for this work is that it assists to emphasise the importance of all properties of a given system. The analysis is performed to establish the system's functions and to control the distribution and maintenance of these functions in a systematic and useful manner. The functional analysis supports to define a hierarchy of all functions that have an important impact to the system.

The functional analysis is, referring to Snodgrass (1986), often chosen as an instrument of NPD processes. Referring to the APTE® formalism for conducting a Value Analysis, it takes into account the various points of view of different research domains as well as the environmental aspects influencing a system (Apte, 2000). The power of the functional analysis lies in its ability to take different ideas and apply a united symbolism and theory to deal with the important central features of the problem (Snodgrass, 1986). It identifies needs and requirements, indicates interrelations of the system and its properties and underlines its importance. It fosters to gain a clear picture about functionalities and usability of a new product, service or organisational process and assists in identifying main actors in the field. This leads to the establishment of sustainable research results. The product, service or organisational process that is intended to design is determined as a system. This system interacts with all its components and is described by functions. Based on the APTE® formalism a function is an action that is to respect to realise a product, a service or a organisational process that satisfy the requirement of the user (Apte, 2000). Functions should have a single definite purpose and have a declarative structure. They should rather say "what" is to be done rather than "how". Referring to the APTE® formalism for conducting a Value Analysis and based on "value engineering", it takes into consideration the

various points of view of different research domains as well as the environmental aspects influencing the system (Apte, 2000).

4.1.1 Systemic Approach: Functional Representation of the System

We distinguish two distinct paradigms of an epistemology related to Engineering Sciences: positivism and constructivism (Le Moigne, 1999). The positivistic epistemology points out that the research object has an independent reality with an own existence that is unchangeable according to its nature (Jankovic, 2006). The constructivist epistemology postulates an object-subject hypothesis that is based on early works of Piaget (Piaget, 1968 – stated in Le Moigne, 1999). Knowledge is dependent on the observer and conceived by her/ him in her/ his interactions with the phenomenon that she/ he comprehends and develops (Le Moigne, 1999). While knowledge in the positivism is understood as objective and unchangeable, in the constructivism knowledge is perceived as subjective and contextual (Jankovic, 2006).

In our research we are following the systemic approach that is one of the paradigms of the constructivist epistemology. It helps to model a phenomenon that is considered as complex system. Referring to the systemic approach of Le Moigne (1977) following definition A 4-1 of a system is given.

Definition A 4-1. System (based on Le Moigne, 1977)

> A system can be defined as active (does something), stable (has a structure) and evolutionary (changes over time). It acts in an environment (interacts with subsystems) with some purpose (there is a reason for the system' existence) (Le Moigne, 1977).

Perron (2002) interprets this general terminology in the context of an industrial system. His definition of an industrial system is shown in definition A 4-2.

Definition A 4-2. Industrial System (based on Perron, 2002)

> An industrial system is constituted by its means, operates through processes, evolves in a life cycle, fits in a defined environment and generates an added value (Perron, 2002).

Both definitions are reflected in the following viewpoints: ontological, functional, evolutionary and teleological. They are represented as axis in figure 4-3.

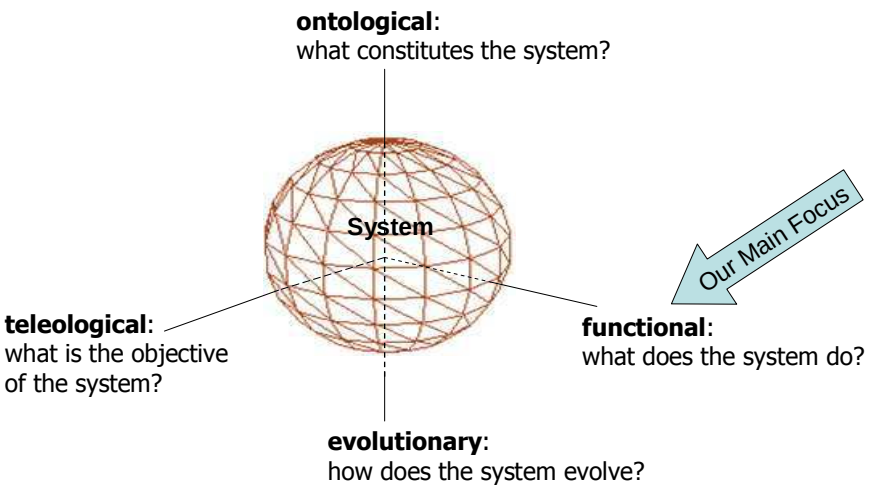


Figure 4-3. Presentation of a System on its four Axis: Ontological, Functional, Evolutionary and Teleological

To handle the complex behaviour of a system and to cope with the holistic approach of the functional analysis it is necessary to consider these four different viewpoints. The following list shows the representation of the VTB Support System taking the different axis into account. The main focus of this work lays on the functional viewpoint:

- Ontological: what constitutes the system?

The ontological viewpoint adheres a structure-oriented and contextual analysis of the system that is represented in sub-systems. The ontological viewpoint gives consideration of the context, the structure, the taxonomic group and the interactions of the system and its subsystems as well as about the means by which it is constituted. It is stressed in the first part of the functional analysis regarding the validation and the environmental structure of the system. The context of the VTB Support System is set in the Virtual Team Development Life Cycle that is strongly connected with the Product- and the Project Life Cycle.

- Functional: what does the system do?

The functional viewpoint represents the global process of the VTB Support System. It allows a function-orientated analysis and indicates for whom/ what the system is used. In general it is to say that the system gives recommendations and technical solutions that foster to build virtual teams. We cope with the functional issue in a more detailed way by conducting the step of the identification of functions of the functional analysis. It helps to define functions which characterise the system's actions.

- Evolutionary/ transformational: how does the system evolve? What does it become?

A transformation-orientated analysis is made which highlights that the VTB Support System can go through several states. The analysis factors the system's appropriation as well as the incidences that are crucial. The VTB Support System copes with the evolution of needs of a virtual team according to the project's phases.

- Teleological/ intentional: what is the purpose or the intention of the system?

The teleological viewpoint allows an objective-directed analysis. It points out the added value generated by the system and the environments in which the system fits in. The intention of the VTB Support System is to support the building of virtual teams that are active in NPD projects by providing recommendations, guidelines and best practices.

Even if all viewpoints are respected in our approach, the main focus of this PhD thesis is set on the functional viewpoint and the question "what does the system do?" To cope with its demand we use the tool of the functional analysis. We pursue the following steps and tools of the functional analysis that are presented in figure 4-4.

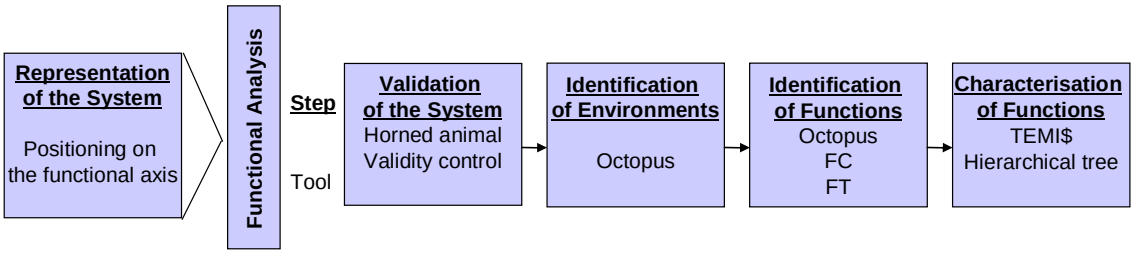


Figure 4-4. Steps and Tools of the Functional Analysis in this Work

The different steps and tools of the functional analysis are taken into account in following §§ 4.1.2 - 4.1.5. Tools are presented and adapted directly to the VTB Support System to make them easily understandable.

4.1.2 Validation of the System

The validation of the system is the first step of the functional analysis that is conducted to cope with the demand of the setting of the VTB Support System on the functional axis. The representation of the system permits to position this work on the functional axe which is related to the questions of the validation. Main questions are discussed and analysed. In order to find the global function of the system and to validate its interest the tool of the "horned animal" is used which has its roots in the APTE® formalism of the Value Analysis method (Apte, 2000).

The "horned animal" allows the formalisation of a system by discussing following questions:

(1) who takes advantage of the system?

(2) what does the system act on?

(3) what is the system's purpose?

The technique of the horned animal serves as a first approach to determine the scope of the system and to understand the opportunities and limitations of its framework. It is crucial to know directly at this stage the target group, the reason for its existence and its intention. If it was not possible to answer these questions, the system would not have the legitimation to exist. The horned animal is visualised in figure 4-5.

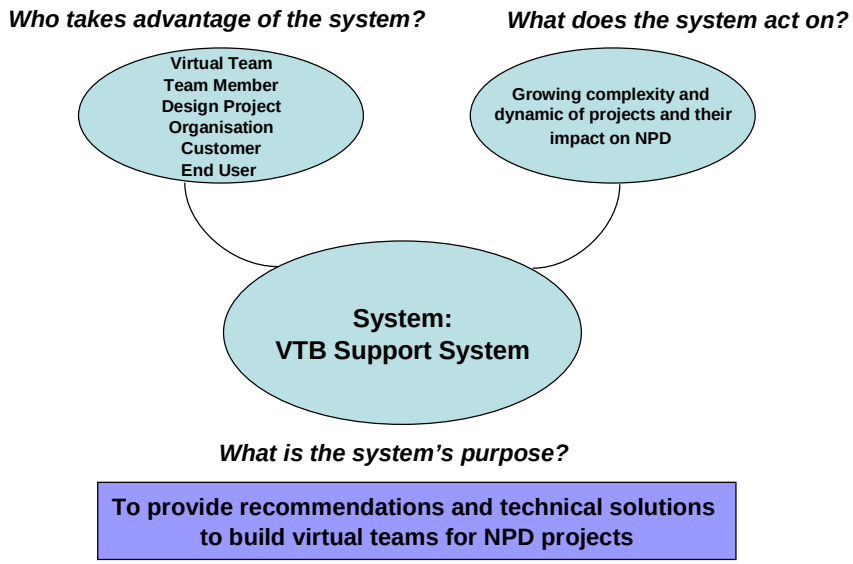


Figure 4-5. Horned Animal according to the VTB Support System

The reason for existence of the system is the need to react on the growing complexity and dynamic of engineering tasks and the improvements in the NPD and project management process. The integration of the Internet and e-collaboration, three-dimensional (3D) computer-aided-design (CAD) and a global network of suppliers, manufacturers and customers have allowed organisations to develop products at much faster rates using fewer resources in a virtual environment.

The intention of the VTB Support System is to provide recommendations, guidelines and best practices that help to build virtual teams for NPD projects. The system should be applicable to a wide range of organisations in the domain of NPD, to various application domains and to different projects. Limits of the system are set in terms of time restriction of short-term projects.

After this step we pass a validity control to analyse the cause of the system (because), the objectives it aims for (for) and the risks of evolution or disappearance of the need (risk). The validity control is described in table 4-1.

Table 4-1. Validity Control of the VTB Support System

Validity Control of the System		
Which are the reasons for the system's existence?	"because"	A support system that provides recommendations, guidelines and best practices to build virtual teams adapted to their specific needs is missing. There is a need to structure technical solutions in compliance with the requirements of a respective organisation or project. A support system that helps to reduce "ramp-up" costs at the start of the project by adapting the framework is needed.

Validity Control of the System		
Which are the objectives and aims of the system?	"for"	to provide recommendations, guidelines and best practices that help to build virtual teams in NPD projects. to provide a method allowing to assign different needs in matters of virtual team building with coherent technical solutions. to support organisations and projects to set up virtual teams.
For which reasons the system could become useless and disappear?	"risk"	Development of new collaboration forms, which make virtual team work needless.

The validity control provides information about the reasons, the objectives and the risks of the VTB Support System. In the next step of the functional analysis we identify environments of the system (§ 4.1.3).

4.1.3 Identification of Environments

Through a tool named "octopus" we get a holistic picture of all decisive components that have an important impact on the system. These components are called environments as they take the environmental aspects into account. They are defined in definition 4-1.

Definition 4-1. Environment

> *An environment is defined in this work as surrounding system that is in interrelation with a complex system and its other surrounding systems to influence the complex system's behaviour.*

By identifying the environments of the VTB Support System we detect its components and even of its behaviour. In general, the step of the functional analysis is conducted within a brainstorming process in multi-disciplinary teams. It is a relevant instrument to support innovation processes within an organisation as it assists to establish a common view on a new product, service or organisational process and the identification of opportunities that have been neglected thus far. To give consideration to this demand of multidisciplinarity about 100 articles of different sciences that are dealing with the topic of "virtual teams" were analysed. Additionally a body of experts within the framework of the European projects smE-MPOWER, Knowledge Board and IST-EC2 has been involved to validate the identified environments and to enlarge the list. During this process it was essential to be as open-minded and inclusive as possible.

Based on our experience and the main recurrent themes emerging from the literature (§ 3.2) we defined in a multi-disciplinary brainstorming process 5 main environments and 27 sub-environments that permit us to take different concepts, critical terms and conditions into account. They are ordered on the basis of figure 3-2 that presents the setting of this work and the respective domains that are in touch with Virtual Team Building. Also figure 3-3 is taken in consideration that gives a structure of the main recurrent themes. Clusters represent the main elements that have been identified. Sub-clusters are built whenever similar specifications were seen. The identified environments of the VTB Support System are seen in figure 4-6.

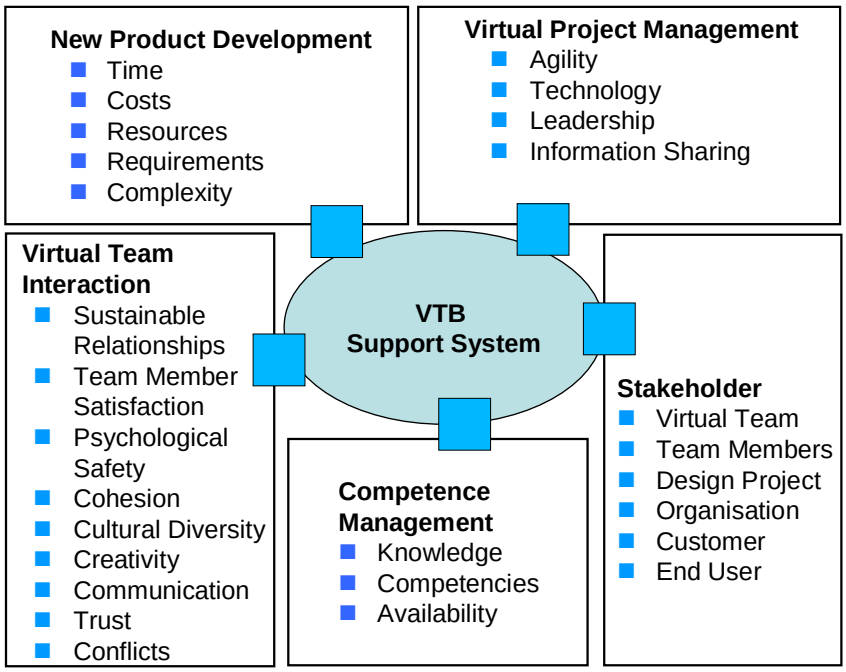


Figure 4-6. Environments according to the VTB Support System

The list of environments is not exhaustive but can be enriched in compliance with the needs of a particular organisation or a project. In order to get a structure of the complexity of the identified environments they are arranged according to the setting of the VTB Support System (figure 3-2): NPD, VPM, CM and VTI.

As fifth main cluster we establish the stakeholders as they are highly diverse in a virtual team environment. The stakeholders are in interrelation with all the other environments why we preferred to highlight them in a separate cluster. There is the virtual team itself that got its framework in a NPD project. Then there are its team members who may be recognised as experts, service providers and employees of an organisation, project partner or even suppliers. We do not differentiate between "normal" team members and team leaders. Leadership is perceived as an environment itself. The organisation is another key player because a virtual team should be embedded in an organisational setting. Finally, the customer and the end user are also part of the stakeholders. They counteract the risk that team members become isolated from current market conditions and its customers' requirements. Also end users, who are regarded in this PhD thesis as consumers, should be implicated.

To demonstrate the interrelations among the environments we provide a synthetic view of them in figure 4-7. Snodgrass (1986) indicates that a system cannot be determined or explained by its components alone but only by the interdependencies of each component that interacts constantly with the others. This fact is reflected in figure 4-7.

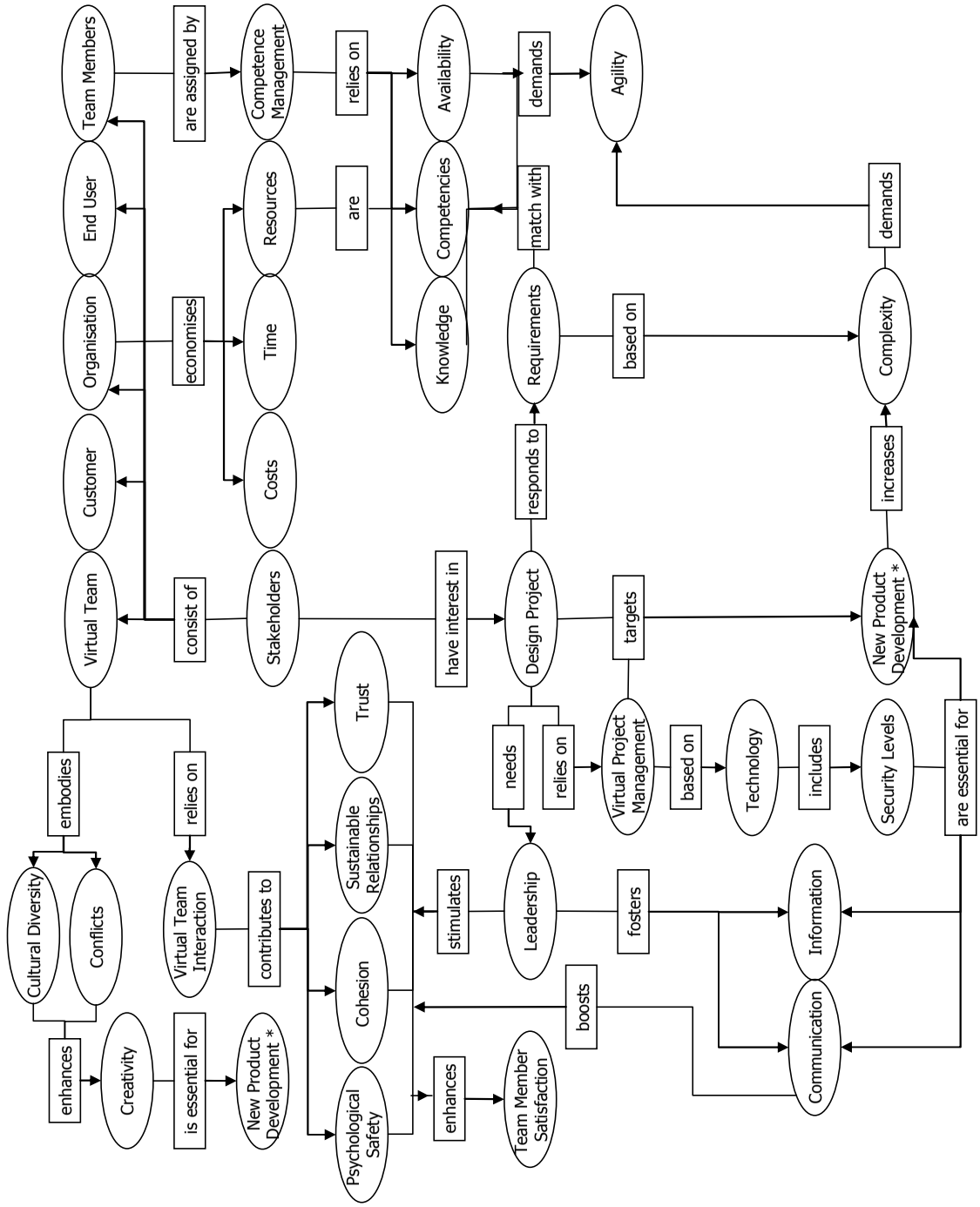


Figure 4-7. Synthetic View of Environments' Interrelations

To visualise that this is exclusively an extract of interrelations, the environment NPD appears exemplary twice, tagged with an asterisk. Also other environment may appear several times in the picture. Not all interrelations that have been mentioned in § 3.2 could be shown in figure 4-7 for reason of visualisation, but the synthesis gives a clear overview of some of the interdependencies regarding the environments of the VTB Support System. We identify functions that are based on the environments in following § 4.1.4. They are not only based on the relations between the environments but on their interactions.

4.1.4 Identification of Functions

In a second step the tool of octopus highlights functions related to the environments. We aim to get a holistic picture of all decisive components that have an important impact on the VTB Support System. By identifying the different interactions of the system's environments we provide the functions that describe the VTB Support System. These functions describe the optimum behaviour of the system and its terms of usability.

There are different conceptual approaches of functions in engineering. Vermaas (2009) states that these approaches are not in competition but co-exist side-by-side because the different meanings of functions are valuable to engineering. Vermaas (2009) argues on the basis of a general model of technical devices by Brown and Blessing (2005 – stated in Vermaas, 2009) five key concepts that describe the devices. These are: structure, behaviour, function, action and goal. Depending on the different way to cascade down the full description of devices the meaning of function may change from desired behaviour to desired effects of this behaviour or to desired goal. In this PhD thesis functions as follows in definition 4-2.

Definition 4-2. Functions

> *Functions are considered as requirements of the system that are based on the environmental surrounding systems. They describe the optimum behaviour of the system by establishing interrelations between the environments.*

The tool of the octopus is very powerful and enables to exhaustively characterise the system by relevant functions. Referring to Snodgrass each component of an open and living system interacts constantly with its environment (Snodgrass, 1986). This implies that it is not enough to take only the system itself into account, but the whole interaction between the system and its environments.

An extract of the tool of octopus according to this research is seen in figure 4-8.

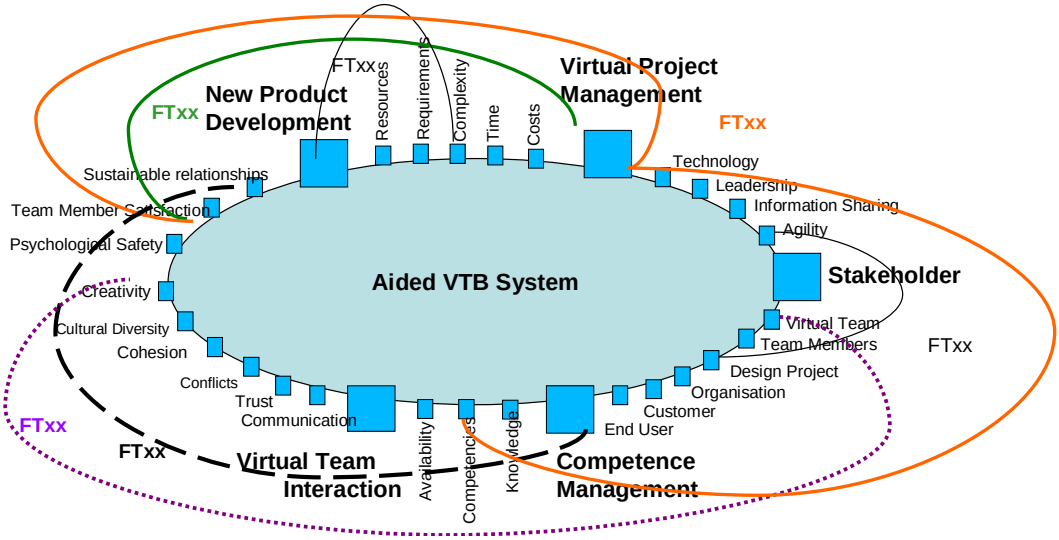


Figure 4-8. Extract of Octopus according to the VTB Support System

An extract of the identification of functions on the basis of the identified environments is visualised in figure 4-8. This step of the method of octopus is important in order to describe the elements of the system's environment. We identified 150 transfer functions (FT) and 50 constraint functions (FC) by regarding each environment of the system that interacts constantly with its environment. Transfer functions include at least two different environments that interact by the means of the system while constraint functions are generated by only one environment (Apte, 2000). The transfer functions represent the environmental expectations while the constraint functions represent the constraints that are imposed by the environment.

An extract of the detected FT and FC functions of the VTB Support System is seen as follows.

- FC1 The system should help to generate tasks of **VPM**.
- FC5 The system should help to determine objectives of **CM**.
- FT9 The system should support **organisations** and **projects** in the domain of **NPD**.
- FT15 The system should help that **technology** fosters **communication** and **information sharing** among **team members**.
- FT27 The system should help to determine **resources** like **time, costs, knowledge, competencies** and **availability** according to the **NPD** process.
- FT28 The system should help to determine **stakeholders** and their **resources** to **requirements**.

To describe the maximum behaviour of the system and its terms of usability we defined in a collaborative negotiation process 84 key functions out off the 200 functions. They represent main aspects of the system and have been chosen in consideration of following selection criteria: importance, recurrence, validation and redundancy. Each domain VPM, CM and VTI is typified by 28 functions. In total 70 FT functions and 14 FC functions have been identified. They are presented in the end of the following § 4.1.5.

4.1.5 Characterisation of Functions

Each key function is characterised with quantitative data in term of time, energy, material, information and costs with a generic tool called TEMI$ in the last step of the functional analysis. TEMI$ has been developed by a French consulting society called Covalence as tool of their approach SWING for the Functional Analysis. TEMI$ supports the characterisation of functions in a global way and provides a definition of main quantitative aspects of the functions. An example of how the tool can be applied is given in table 4-2.

Table 4-2. Characterisation of FT15 through TEMI$

TEMI$					
FT15 The system should help that technology fosters communication and information sharing among team members.					
FT15	**technology**	**communication**	**information sharing**	**team members**	**conclusion**
Time	reduce time	asynchronous and synchronous	asynchronous and synchronous	are flexibility in terms of their schedules	It is important that team members are trained in the chosen technology to overcome obstacles like misunderstandings in communication to profit of the benefits like time flexibility, greater amounts of information at faster rates of transmission and lower costs.
Energy	electricity	human capital	greater amounts of information at faster rates of transmission	cognitive efforts	
Material	new ICT, equipment, soft-and hardware	experts, team members			
Information	special training for team members.	challenge of misunderstanding	more task-orientated than social-emotional	security levels are important	
Costs	electricity costs, hard- and software	lower costs by overcoming geographical aspects	lower costs by overcoming geographical aspects	personnel costs	

As the results of this characterisation depend on the needs of each virtual team we give exclusively an example showing how the tool TEMI$ might be applied. In this research we are focussing mainly on the qualitative characterisation of the functions, what is done by the hierarchisation of the functions.

Based on the key findings, in the final step of the functional analysis the focus lays on the qualitative characterisation of the functions. The importance of the key functions is measured in terms of percentages with the tool of the "hierarchical tree".

The tree structure provides a clear visibility of the large number of functions making up the system. It facilitates to measure the importance of the functions in a qualitative way and to represent the system in a hierarchical form and to formulate substantiated qualitative recommendations.

To determine the different basic categories of the top level of the hierarchical tree we structure the key functions in a first step. This permits us to get a first overview of potentially clusters to highlight the sum of the functions that describe the system. Therefore, different categories should be established which imply several functions. They are regrouped here in the hierarchical tree. The extract of the hierarchical tree of the VTB Support System represents the sectioning in NPD, VPM, CM and VTI as basic categories in following figure 4-9.

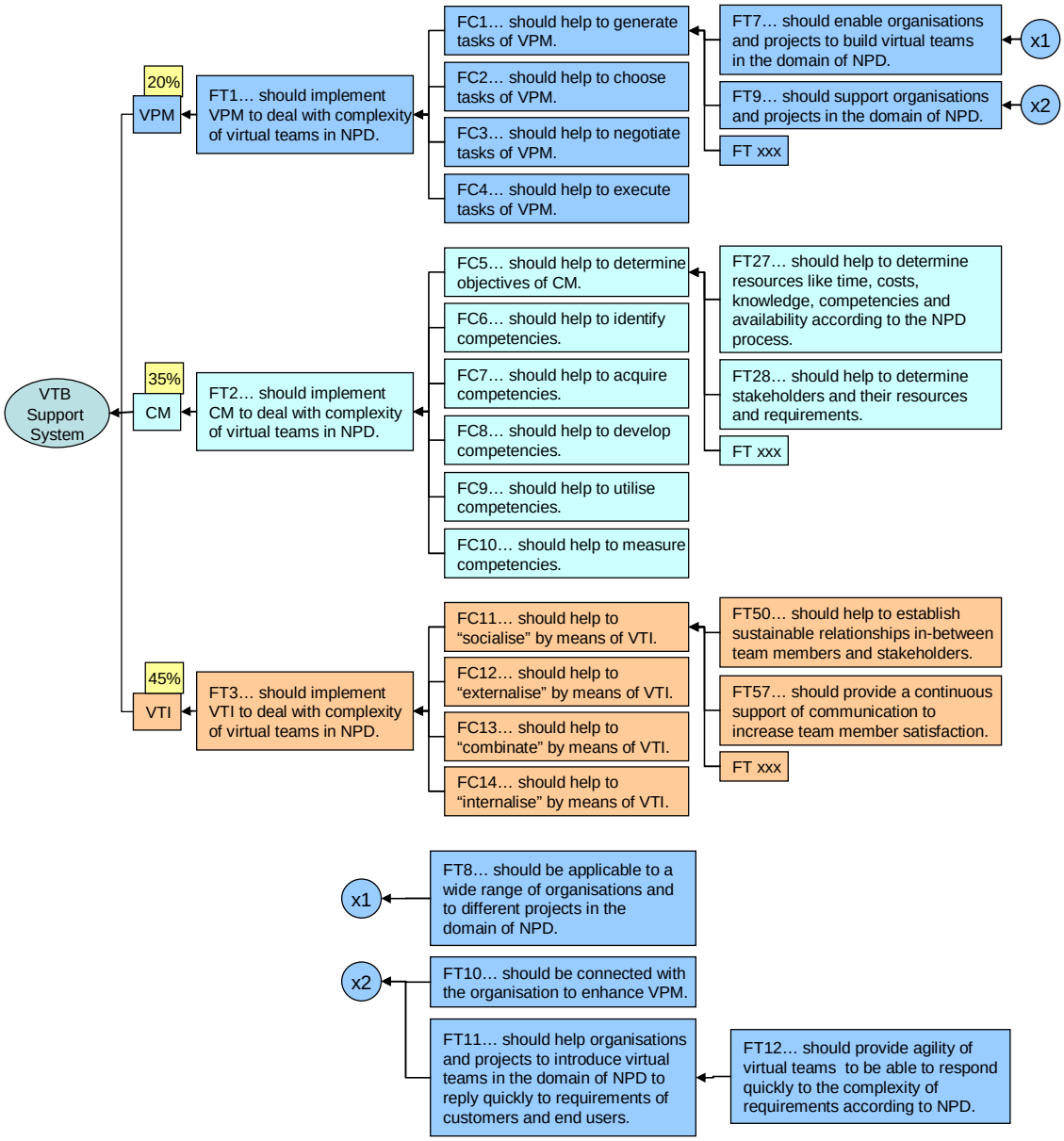


Figure 4-9. Extract of the VTB Support System’s Hierarchical Tree

It starts at a top level with a high importance and breaks down the functions to lower levels in different branches. A function, which is passed to a lower level, is a higher level function for the recipient level. With the breaking-down in lower levels also the importance of the respective functions gets lower. In the first step, the top level functions are defined and thereafter decomposed to lower level functions. A function of a lower level can be required by a number of main functions which means that it may appear several times in different branches or levels of the hierarchical tree according to their respective interdependencies with other functions.

The importance of the hierarchical tree is derived and translated into percentages while building the project team. They depend on the purpose of the specific needs. In figure 4-9 the percentages are noted as examples in the first level of the hierarchical tree. Normally, they would be broken down into each level. In general, they are defined during the constitution of the virtual

team. The fact that the hierarchy of the functions is fixed allows to say that the importance of the functions decrease from the left to right with each lower level. This gives insights about their importance even if the percentages of importance are just noted as examples in figure 4-9. The complete hierarchical tree of the VTB Support System is presented in the following list.

4.1.5.1 Functions of Virtual Project Management

FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.

- **FC1 The system should help to generate tasks of Virtual Project Management.**
  - FT4 The system should help organisations and projects to benefit of customer's changing requirements by introducing virtual teams in the domain of NPD.
    - FT5 The system should help to cope with knowledge intensive tasks that NPD comprises.
  - FT6 The system should help to reduce in a long term time and costs of NPD by constituting virtual teams.
  - FT7 The system should enable organisations and projects to build virtual teams in the domain of NPD.
    - FT8 The system should be applicable to a wide range of organisations and to different projects in the domain of NPD.
  - FT9 The system should support organisations and projects in the domain of NPD.
    - FT10 The system should be connected with the organisation to enhance VPM.
    - FT11 The system should help organisations and projects to introduce virtual teams in the domain of NPD to reply quickly to requirements of customers and end users.
      - FT12 The system should provide agility of virtual teams to be able to respond quickly to the complexity of requirements according to NPD.

- **FC2 The system should help to choose tasks of VPM.**
  - FT13 The system should help to choose resources to satisfy the requirements of the stakeholders.
  - FT14 The system should help to choose the right technology to insure effective VPM.
    - FT15 The system should help that technology fosters communication and information sharing among team members.
      - FT16 The system should enforce communication and information sharing by the right choice of technology.

- **FC3 The system should help to negotiate tasks of VPM.**
  - FT17 The system should help to work against conflicts to contribute to cohesion and to build sustainable relationships.
    - FT18 The system should help to implement technology that support efficient communication to counteracts conflicts.
  - FT19 The system should help to manage virtual teams with cultural diversity.

- **FC4 The system should help to execute tasks of VPM.**
  - FT20 The system should help that customer and end user communicate their requirements to value the NPD (process).
  - FT21 The system should provide that VPM is based on agility.
    - FT22 The system should consider agility to adapt knowledge and competencies required in NPD in faster time and at low costs.
  - FT23 The system should help that leadership enhance VPM.
    - FT24 The system should enforce leadership dealing with virtual teams.
      - FT25 The system should provide an adaptive leadership of projects that is able to react with agility to the complexity and the cultural diversity.
      - FT26 The system should ensure that leadership emerges competencies of each team member by agility.

4.1.5.2 Functions of Competence Management

FT2 The system should implement CM to deal with complexity of virtual teams in NPD.

- **FC5 The system should help to determine objectives of CM.**
  - FT27 The system should help to determine resources like time, costs, knowledge, competencies and availability according to the NPD (process).
  - FT28 The system should help to determine stakeholders and their resources to requirements.
  - FT29 The system should consider knowledge and competencies of team members as a rare resource which has to be applied in NPD.

- **FC6 The system should help to identify competencies.**
  - FT30 The system should help to identify required resources of organisations and projects.
  - FT31 The system should help to make knowledge and competencies accessible and useable for organisations and projects.
    - FT32 The system should help to describe competencies of team members in a generic way.

        - FT33 The system should help to represent competencies that are acquired by team members.
    - FT34 The system should help to staff team members in projects with the support of CM.

- **FC7 The system should help to acquire competencies.**
    - FT35 The system should help organisations and projects to complete missing resources.
        - FT36 The system should allow to add competencies if needed regarding the requirements of the project.
        - FT37 The system should help to acquire missing competencies through sustainable relationships with stakeholders.
        - FT38 The system should foster that team members offer voluntary their knowledge, competencies and their availability regarding the activities of the NPD.
            - FT39 The system should help that agility allows to staff projects with adequate competencies of team members.

- **FC8 The system should help to develop competencies.**
    - FT40 The system should help to generate new competencies to implement new resources in the NPD (process).
    - FT41 The system should help team members to adopt their competencies in the NDP (process).
        - FT42 The system should allow virtual teams to adapt continuously their competencies to the requirements of the project by agility.

- **FC9 The system should help to utilise competencies.**
    - FT43 The system should help carry out activities of NPD to make sure that the existing competencies are well applied.
    - FT44 The system should respond systematically to competence requirements of projects to create virtual teams.
    - FT45 The system should help to assign competencies of team members to activities of NPD.
        - FT46 The system should assign resources (like time, costs, competencies, knowledge and availabilities) to specific requirements of projects.

- **FC10 The system should help to measure competencies.**
    - FT47 The system should help to provide a strategic control of CM to measure if competencies are conform with the NPD (process).

4.1.5.3 Functions of Virtual Team Interaction

FT3 The system should implement VTI to deal with complexity of virtual teams in NPD.

- **FC11 The system should help to "socialise" by means of VTI.**
  - FT48 The system should create sympathised knowledge by fostering
    - Trust
    - Cohesion
    - Psychological safety
    - Sustainable relationships
    - Team member satisfaction
  - FT49 The system should provide trust by fostering psychological safety.
  - FT50 The system should help to establish sustainable relationships in-between team members and stakeholders.
    - FT51 The system should consider trust as important factor to build sustainable relationships.
  - FT52 The system should provide a continuous support of psychological safety to increase team member satisfaction.
  - FT53 The system should help to generate cohesion to enhance team member satisfaction.
  - FT54 The system should embark communication to boost trust development by adapted technology.
  - FT55 The system should provide technology that may help to develop cohesion.
  - FT56 The system should help to foster communication by establishing sustainable relationships.
  - FT57 The system should provide a continuous support of communication to increase team member satisfaction.
    - FT58 The system should help to profit of cultural diversity by communication.
      - FT59 The system should help to optimise creativity of virtual teams based on their cultural diversity.

- **FC12 The system should help to "externalise" by means of VTI.**
  - FT60 The system should help that leadership captures knowledge of virtual team members in VTI.
  - FT61 The system should provide a continuous support of communication to conceptualise knowledge.
  - FT62 The system should counteract the impact of cultural diversity among team members by enhancing/ externalising information sharing and communication.

- **FC13 The system should help to "combinate" by means of VTI.**
  - FT63 The system should facilitate the communication among team members by VTI supported by a variety of different technologies.
  - FT64 should deal with team members who act interdependently through technology to create systematised knowledge.
  - FT65 The system should provide that technology fosters communication among team members to support sustainable relationships.
  - FT66 The system should help to overcome obstacles regarding the use of technology to minimise the difficulty to breed trust.
  - FT67 The system should help to share knowledge between stakeholders with the help of technology.

- **FC14 The system should help to "internalise" by means of VTI**.
  - FT68 The system should help to embed virtual teams in the organisation.
  - FT69 The system should help to improve the organisation in which the virtual team is embedded.
  - FT70 The system should foster VTI to enhance knowledge of the organisation.

4.1.5.4 Hierarchical Tree – Figure

To finalise this § 4.1 we provide in figure 4-10 the hierarchical tree of the VTB Support System.

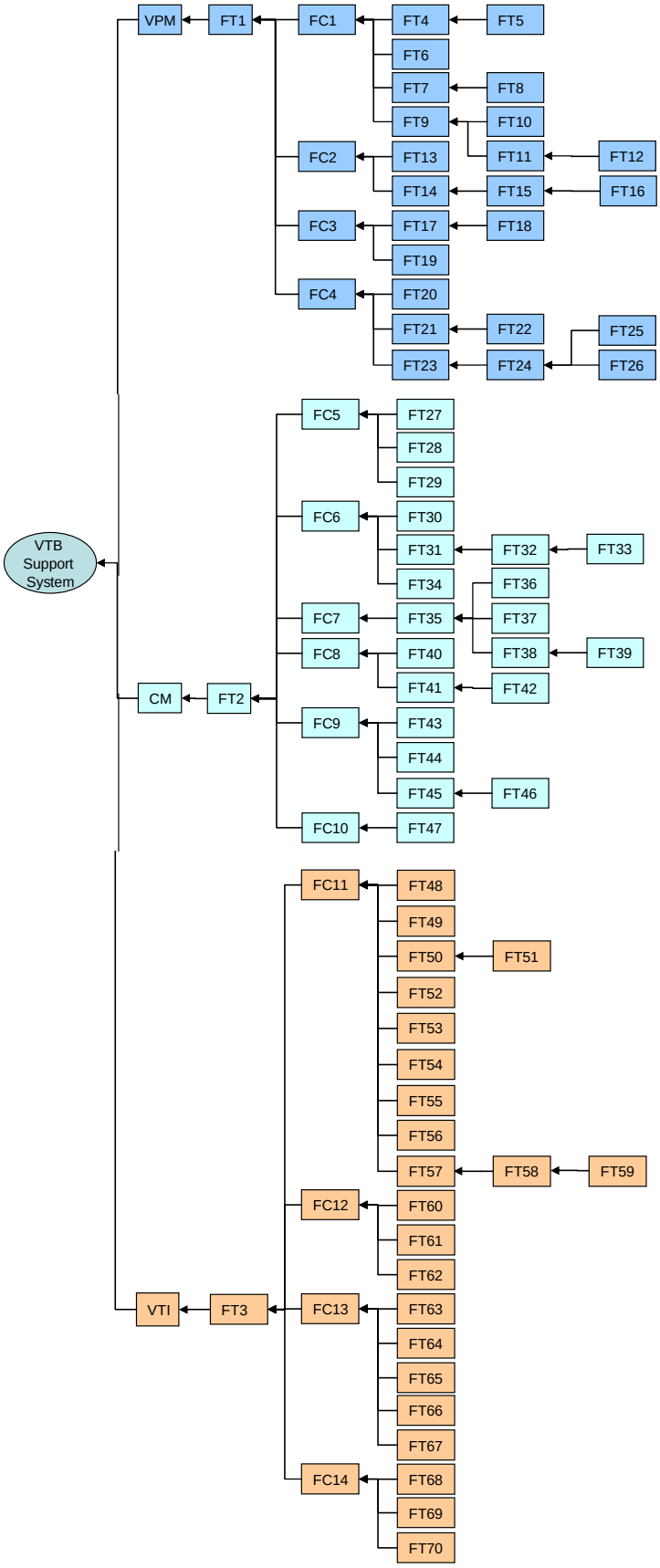


Figure 4-10. Hierarchical Tree of the VTB Support System

4.2 House of Quality

The tool of the "house of quality" is used to translate the defined essential functions in existing recommendations and technical solutions in the domains VPM, CM and VTI. With the help of this tool these detected solutions are put in relation with the functions to appoint if they satisfy their demand and at which degree. On the one hand, the results of this critical analysis point out strengths and weaknesses of the existing technical solutions concerning the demand of the functions that could be adapted easily to the VTB Support System. On the other hand, through this approach those functions are identified whose demands are difficult to achieve.

The house of quality is a graphic tool for defining the relationship between customer requirements and quality characteristics (Hauser and Clausing, 2009). It is part of the Quality Function Deployment (QFD). QFD is a method to transform customer requirements into design quality by setting up the characteristics that form quality (Akao, 1991; Hauser and Clausing, 2009; Carnevalli and Miguel, 2008).

QFD was introduced as a concept for NPD in the shipbuilding industry in the 1970s in Japan (Akao, 1991). It has been used successfully for many years as a quality assurance methodology as well as to find originality in NPD. Hauser and Clausing (2009) consider a QFD as "[…] a kind of conceptual map that provides the means for interfunctional planning and communication." Cohen (1995) describes QFD as a method for structured product planning and development. Its ability to be adapted to the requirements of each particular problem or system makes it a very reliable tool to use. The potential of QFD is huge. It can be utilised in different ways and can be adapted to solve a great number of design problems.

The QFD includes the construction of matrixes known as "quality tables". The house of quality is one of these matrixes. Cohen (1995) postulates that it helps to specify clearly the customer's requirements and to evaluate each proposed quality characteristics systematically in terms of its impact on meeting the requirements. It is a graphic tool that enables to translate customer requirements into a pertinent number of quality characteristics by defining the relationship between them. As this "voice of the customer" drives the development, the risk that time and costs are spent in developing insignificant functions and features is reduced. Another benefit of the house of quality is the documentation part. During the QFD process a knowledge base is built that reflects the decision-making process.

Carnevalli and Miguel (2008) whose work presents a review, analysis and classification of the literature on QFD list following main benefits and main challenges:

- Benefits:
  Tangible: improvement in reliability, reduction in time and costs, increased revenue, reduced complaints.

  Intangible: being a flexible tool, improvement in communication, aid in decision making and priority definition, increased customer satisfaction.

- Challenges:
  large size of matrixes, defining customer requirements and the identification of the most important customer requirements.

Related works confirm that QFD can not only be applied in cases of devolvement of material new products but also in an enlarged sense of giving distinction to intern customers (Carnevalli and Miguel, 2008; Schleidt and Eigner, 2010). Schleidt and Eigner (2010), for example, aim to assign personal and social competencies with identified criteria of working conditions in Cross Enterprise Product Design. Based on the QFD and the house of quality they analyse how working conditions and competencies can be matched to increase the efficiency of cooperation.

This approves that QFD is transferable to each design problem where solutions can be structured and evaluated regarding customer requirements. The customer requirements are personate by the functions defined through the functional analysis (§ 4.2.1). The quality characteristics are in our case detected recommendations and technical solutions in the domains of VPM, CM and VTI (§ 4.2.2). A catalogue of examples of recommendations and technical solutions as quality characteristics is given in § 4.2.5. NPD functions as context of the VTB Support System (figure 3-2) and is reflected in the recommendations and technical solutions that we propose to satisfy the requirements of the system.

When transferring the approach of the house of quality to the needs of the "House of a VTB Support System", we aim to assign and harmonise on the one side the functions that make up the requirements of the system and on the other side detected recommendations and technical solutions of the four reported domains that are handled as quality characteristics. They are required to response to the demand of the functions.

The basic construction of the house of quality is made up of four major building blocks that compose the form of a house (Akao, 1991; Hauser and Clausing, 2009). These include customer requirements, quality characteristics, a relationship matrix and a correlation matrix. An overview of the basic structure of the house of quality is presented on the left side of figure 4-11. The right side of figure 4-11 shows the steps and perspectives of the house of quality according to this research.

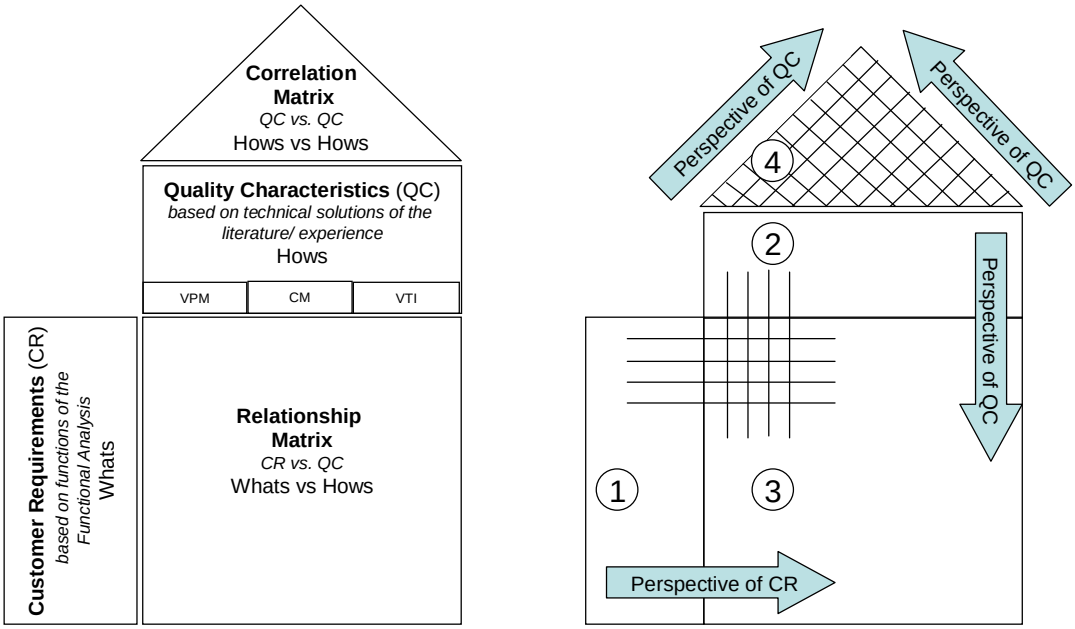


Figure 4-11. House of Quality according to the VTB Support System

The customer requirements are labelled "Whats" because they describe what should be implemented, whereas the quality characteristics are described with "Hows". They point out how the requirements should be implemented and give precise recommendations. The basic construction of the house of quality is made up of four major building blocks that compose the form of a house (Schleidt and Eigner, 2010). These include customer requirements, quality characteristics, a relationship matrix and a correlation matrix. A table with "Whats" on the left and "Hows" on the top is presented in figure 4-11. The roof is composed as diagonal matrix of "Hows vs. Hows" which stresses the correlation among different quality characteristics. The body of the house builds a matrix of "Whats vs. Hows". It facilitates to draw conclusions in which degree the proposed quality characteristics respond to the demand of the customer requirements and underlines their relationship. The difference between "relation" and "correlation" in view of the house of quality is the following:

- Correlation takes on values between the negative and the positive. Negative values indicate that the correlation between the quality characteristics is indirect and have a negative shape. There are incompatible. Positive values indicate a positive shape. If there is no correlation we say that the quality characteristics are uncorrelated.
- Relationship instead has not a negative occurrence. Either there is a relationship that may differ in its degree or there is not.

In this context, the "house of the VTB Support System" can be understood as an instrument for analysis, communication and planning, based on a tabular structure. It helps to give recommendations, guidelines and best practices for virtual team building. We come back to the numbers that label the building blocks in figure 4-11. They describe the steps that we pursue in figure 4-12.

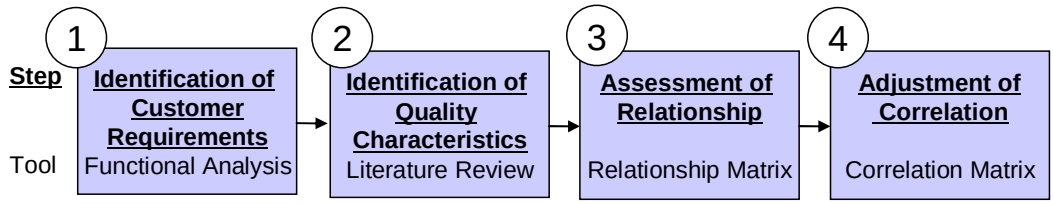


Figure 4-12. Steps and Tools of the House of Quality according to this Work

Each step and tool of the presented figure 4-12 is explained in detail in consideration of the VTB Support System in following § 4.2.1.

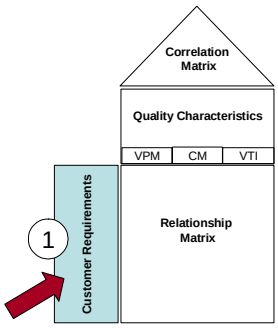
4.2.1 Identification of Customer Requirements

The customer requirements are labelled "Whats" because they describe what should be implemented. The identification of customer requirements sets the value on the contact to the real customer. Not only end users, the external customers, are considered as consumers, but also intern customers, what implies all persons who are in touch with the results of processes of the QFD. Carnevalli's and Miguel's (2008) summarise in their literature review concerning QFD that "interpreting the customer's voice" is one of the most difficult challenges. In our case the work-

ing sessions with experts in the frame of the European project are incorporated as well as our personal experience of industry. Additionally, national and international exchanges with experts are taken into consideration during the process of identification of customer requirements.

In order to provide a VTB Support System we chose the holistic approach of the functional analysis to define its requirements. The statements of the experts that are considered as customers of the VTB Support System have influenced the choice of environments that are the fundament of the detected functions. Hence, the customer requirements of the VTB Support System are based on functions detected by the functional analysis. Transferred as customer requirements, those functions are realised in applicable solutions, called quality characteristics, with the help of the house of quality. An extract of customer requirements is presented in table 4-3.

Table 4-3. Extract of Customer Requirements according to the VTB Support System

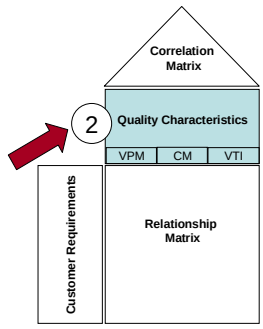
Extract of Customer Requirements	
	➢ FT13 The system should help to choose resources to satisfy the requirements of stakeholders. ➢ FT14 The system should help to choose the right technology to insure effective Virtual Project Management. ➢ FT21 The system should provide that Virtual Project Management is based on agility. ➢ FT23 The system should help that leadership enhances Virtual Project Management. ➢ […]

4.2.2 Identification of Quality Characteristics

While the quality characteristics are generally identified within a brainstorming process in multidisciplinary teams, we give consideration to this demand of multidisciplinarity by analysing the scientific literature of different sciences that are dealing with the topic of "virtual team building". We focus on recommendations and technical solutions defined in different already well-developed methodologies. Additionally, we use recommendations and technical solutions that are deducted from our personal experience in European projects and industry as well as national and international exchanges with experts. Recommendations and technical solutions are described with "Hows" because they point out the way how customer requirements should be implemented and give precise recommendations.

The identified recommendations and technical solutions are determined as quality characteristics in the house of quality. They are structured in the domains of VPM, CM and VTI as illustrated in the extract in table 4-4.

Table 4-4. Extract of Quality Characteristics in the domains VPM, CM and VTI.

Extract of Quality Characteristics	
	
Virtual Project Management (VPM)	
VPM1	Provide a common architecture and shared platform elements (Marion and Schumacher, 2009).
VPM2	Support and guide team members about task (Greenberg et al., 2007; Picard, 2009).
VPM3	Provide task-related evaluation of the data.
Competence Management (CM)	
CM1	Emphasise compatibility and similarity of team members to facilitate the successful combination of complementary assets (Heimericks and Schreiner, 2002).
CM2	Propose an integrating architecture for CM based on a unified and shared model of competencies (competence ontology).
CM3	Identify quantitative and qualitative requirements for competencies (Duarte and Snyder, 2006).
Virtual Team Interaction (VTI)	
VTI1	Express flexibility and empathy towards virtual team members (Kayworth and Leidner, 2000).
VTI2	Reduce the sense of physical and psychological distance (Kanawattanachai and Yoo, 2002).
VTI3	Ensure that team leaders enact and maintain a sufficient level of socio-emotional interactions among their team members (Kanawattanachai and Yoo, 2002).

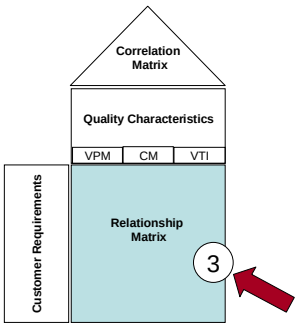
The quality characteristics are then critically analysed in the context of the customer requirements and analysed in the relationship matrix in terms of meeting their demands. It is important to note that the quality characteristics are not an "either-or" choice. They function as a matter of assessing existing recommendations and technical solutions and filling the gap of missing solutions by self-developed techniques. The methodology has been to identify recommendations and technical solutions, which are needed for a VTB Support System.

4.2.3 Assessment of Relationship

The body of the house of quality builds a matrix of "Whats vs. Hows". It facilitates to draw conclusions at which degree the proposed quality characteristics respond to the demand of the customer requirements. The relationship matrix describes what must be achieved to satisfy the

demands of the VTB Support System. The main purpose of the relationship matrix is to establish a connection between customer requirements and quality characteristics. The relationship matrix permits to get a clear picture of whether the quality characteristics have a specific impact on the realisation of the customer requirements. By establishing a relation between the customer requirements and the quality characteristics we detect whether recommendations and technical solutions match the demand of the requirements and in what degree. We differentiate between strong, moderate, weak or no relationship with the values 9, 3, 1 or 0. An extract of the relationship matrix is presented in table 4-5.

Table 4-5. Extract of Relationship Matrix according to the VTB Support System

Extract of Relationship Matrix									
									
Quality Characteristics / Customer Requirements	VPM1	VPM2	VPM3	CM1	CM2	CM3	VTI1	VTI2	VTI3
FT13	Θ	O	O	Θ	Θ	Θ	▲	▲	▲
FT14	Θ	Θ	O	▲	▲	▲	▲	O	▲
FT21	Θ	▲	O	O	O	▲	▲	▲	▲

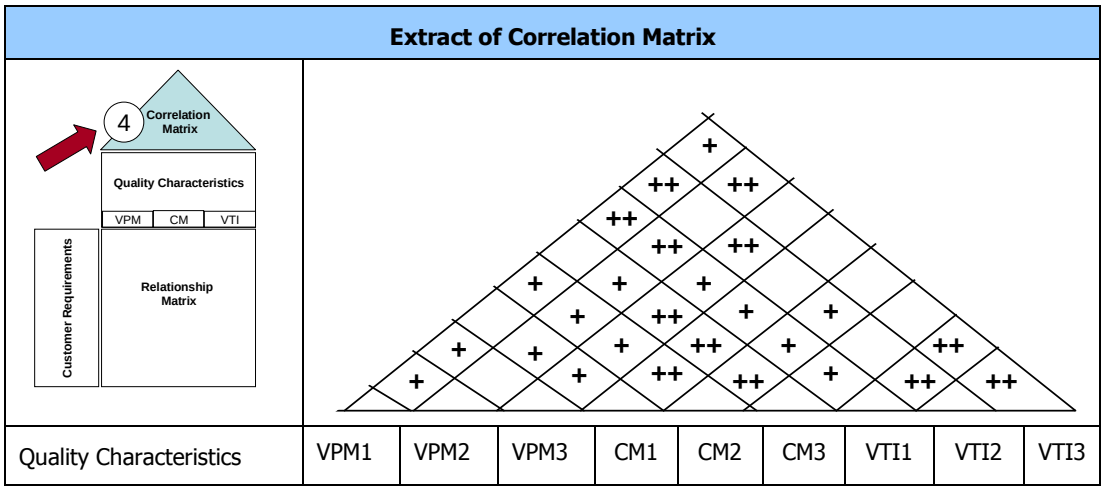
Legend: Θ Strong Relationship (9); O Moderate Relationship (3); ▲ Weak Relationship (1)

On the one hand, this helps to find out strengths and weaknesses of the existing recommendations and technical solutions related to customer requirements that could be adapted easily to the VTB Support System. On the other hand, through this approach we bring these requirements to light whose demands are apparently difficult to achieve.

4.2.4 Adjustment of Correlation

The roof is composed as diagonal matrix of "Hows vs. Hows" which explores the correlation among the quality characteristics based on recommendations and technical solutions of the literature as well as our personal experience in European projects and industry as well as national and international exchanges with experts. The pair wise correlations are determined with five attributes: strong positive correlation (+2), positive correlation (+1), strong negative correlation (-2), negative correlation (-1) and no correlation (0). By concentrating on the upper part of the house of quality, the compatibility of quality characteristics is exposed transparently. An extract of the correlation matrix is shown in table 4-6.

Table 4-6. Extract of Correlation Matrix according to the VTB Support System



Legend : ++ Strong Positive Correlation (+2) + Positive Correlation (+1)

\- Negative Correlation (-1) ▼ Strong Negative Correlation (-2)

The correlation matrix gives insights of compatibility or conflicts among the quality characteristics of VPM, CM and VTI. Fields may stay empty if there is no correlation at all. This part specifies if those quality characteristics have a specific rapport among each other and whether they could be realised together. Recommendations and technical solutions should be compatible and coherent among themselves. In table 4-6 no negative correlation could be identified. Negative correlations should be handled with special attention. Conflicts should be resolved.

4.2.5 Catalogue of Quality Characteristics

Examples of recommendations and technical solutions are given in following table 4-7. While the recommendations are listed as headlines the technical solutions are directly allocated to them as itemisation. Both are structured into recommendations and technical solutions characterising especially virtual team building or team building in general.

Table 4-7. Catalogue of Examples of Recommendations and Technical Solutions according to Customer Requirements of the VTB Support System

Examples of Recommendations and Technical Solutions according to the Customer Requirements		
Functions	**Virtual Team Building**	**Team Building in General**
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
FC1 The system should help to generate tasks of Virtual Project Management. FT4 The system should help organisations and projects to benefit of customer's changing requirements by introducing virtual teams in the domain of NPD. FT5 The system should help to cope with knowledge intensive tasks that NPD comprises. FT6 The system should help to reduce in a longterm time and costs of NPD by constituting virtual teams. FT7 The system should enable organisations and projects to build virtual teams in the domain of NPD. FT8 The system should be applicable to a wide range of organisations and to different projects in the domain of NPD. FT9 The system should support organisations and projects in the domain of NPD. FT10 The system should be connected with the organisation to enhance Virtual Project Management. [...]	Determine overall tasks and subtasks. o Define process and technical methods needed for the project (Chang, 2006). o Separate subtasks to reduce coordination requirements and to provide task interdependences in the beginning of virtual teamwork (Hertel et al., 2005). Ensure that stakeholders share a common understanding of the project work processes, operational procedures, objectives and plans (Ollus et al., 2009). o Provide a team charter that defines the project planning, team's mission, scope, objectives, time frame and consequences (Duarte and Snyder, 2006). o Make people aware of the effects of their actions and helping them apply meaningful and intentional purposes to each action. o Provide leadership in form of the role of a moderator who might be responsible for the organisation of meetings to facilitate communication and information sharing (Hertel et al., 2005). [...]	Determine how to make the project planning. o Provide a project calendar and help to keep on schedule (Nikas and Poulymenakou, 2008; Evaristo and van Fenema, 1999; McDonough, 2001). o Analyse development tasks. Define product specifications (Chang, 2006). o Identify customer needs in an early stage (McDonough, 2001; Marion and Schumacher, 2009). o Determine typical characteristics. Develop the scope statement of the project. Implement a management by objectives. o Emphasise on goal setting, participation and feedback about task fulfilment (Hertel et al., 2005). o Ensure project objectives remain stable and transparent (McDonough, 2001). [...]

Functions	Virtual Team Building	Team Building in General
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
[...] FT11 The system should help organisations and projects to introduce virtual teams in the domain of NPD to reply quickly to requirements of customers and end users. FT12 The system should provide agility of virtual teams to be able to respond quickly to the complexity of requirements according to NPD.	[...] Adapt team processes to the demands of a virtual environment. o Provide structure for virtual team work with formal procedures and structured processes (Lurey and Raisinghani, 2001; Rice et al., 2007). o Provide standardisation of IT systems, terminology and codes (Walker, 2006). o Provide 1-PC-to-1-participant (Rice et al., 2007). o Provide uniform audio levels (Rice et al., 2007). o Ensure that Technology Systems are reliable and easy to use (May and Carter, 2001). o Provide common PC screen resolutions and clear video images (Rice et al., 2007). Ensure that each team member has been trained on the IT system and has PC with headset, microphone and camera (Rice et al., 2007).	[...] Have sufficient resources (McDonough, 2001). o Estimate costs procurement and stay on budget (Duarte and Snyder, 2006; McDonough, 2001 o Provide risk management (Wu and Li, 2009).
FC2 The system should help to choose tasks of Virtual Project Management. FT13 The system should help to choose resources to satisfy the requirements of the stakeholders. [...]	Provide a common architecture and shared platform elements (Marion and Schumacher, 2009). o Implement Web 2.0 applications (Marion and Schumacher, 2009).	Support and guide team members about task (Greenberg et al., 2007; Picard, 2009). o Provide leadership (Greenberg et al., 2007; Picard, 2009). o Organise Kick-of-meeting to clarify team objectives, roles, functions, general rules for the team work (Hertel et al., 2005)

Functions	Virtual Team Building	Team Building in General
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
[...] FT14 The system should help to choose the right technology to insure effective Virtual Project Management. FT15 The system should help that technology fosters communication and information sharing among team members. FT16 The system should enforce communication and information sharing by the right choice of technology.		[...] Provide task-related evaluation of the data. o Define and modify product concepts continuously based on customer feedback (Chang, 2006). o Check and monitor the status of all committed. o tasks for re-evaluation purposes (Namin et al., 2006). o Present and refine ideas on screen (Chang, 2006). o Provide cross-fertilisation of ideas (Leenders et al., 2007). Procure positive confirmation of decisions (Rice et al., 2007). o Publish protocols sampled, discussed and agreed upon by the virtual team (Rice et al., 2007). Combine communication and decision support tools to support processes of problem formulation and solution finding (Paul et al., 2004). o Use collaborative decision support systems that support the NPD process (Paul et al., 2004). Establish various kinds of voting tools in "decision rooms" for a short, defined meeting period focussing on one or two kinds of tasks in a session (Paul et al., 2004).

Functions	Virtual Team Building	Team Building in General
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
FC3 The system should help to negotiate tasks of Virtual Project Management. FT17 The system should help to work against conflicts to contribute to cohesion and to build sustainable relationships. FT18 The system should help to implement technology that supports efficient communication to counteract conflicts. FT19 The system should help to manage virtual teams with cultural diversity.	Support virtual team leaders to maintain an inspiring and collaborative working environment so that all team members try to innovate for the overall success of the NPD effort (Chang, 2006). o Support virtual team leaders to be flexible and willing to let other team members lead when necessary (Jarvenpaa and Leidner, 1999). o Identify meeting virtual team leader for each meeting (Rice et al., 2007). o Elect the virtual team leader (Jassawalla and Sashittal, 1998).	Improve the quality of communications. Develop and adopt conflict resolution systems suitable for virtual teams (Shin, 2005). o Resolve workplace conflicts by using methods like negotiation, mediation, facilitation, arbitration and litigation (Shin, 2005). o Train virtual team leaders in conflict management. Integrate data management tools with workflow and change notification tools in order to enable data use to be integral with engineering processes (May and Carter, 2001). o Provide Process Management with ▪ Resource and Portfolio Management (Chang, 2006) ▪ Cost Estimation and Quote Manager (Chang, 2006) ▪ Data management (May and Carter, 2001; Chang, 2006) ▪ Data exchange (Chang, 2006) ▪ Central "shared" database, where single correct copies of files are held and version control is managed. (May and Carter, 2001) ▪ Technical publishing (Chang, 2006) ▪ Document manager (Chang, 2006) ▪ Electronic Meeting Systems ▪ Prototyping ▪ Technical Analysis and Design ▪ Code Generation ▪ Code Library Generation and Maintenance [...]

		▪ QA (Test Management, Reviews, Inspections, Audits) ▪ Configuration Management ▪ Incident Reporting, Tracking and Resolution ▪ Product Installation Controlling (Duarte and Snyder, 2006)
Functions	**Virtual Team Building**	**Team Building in General**
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
FC4 The system should help to execute tasks of Virtual Project Management. FT20 The system should help that customer and end user communicate their requirements to value the NPD (process). FT21 The system should provide that Virtual Project Management is based on agility. FT22 The system should consider agility to adapt knowledge and competencies required in NPD in faster time and at low costs. FT23 The system should help that leadership enhance Virtual Project Management. FT24 The system should enforce leadership dealing with virtual teams. FT25 The system should provide an adaptive leadership of projects that is able to react with agility to the complexity and the cultural diversity. FT26 The system should ensure that leadership emerges competencies of each team member by agility.	Update the technology over time. o Secure commitment from the organisation to keep technology up-to-date. o Established information system staff whose members are experienced in installing and supporting electronic collaboration technology. (May and Carter, 2001). Establish a help-desk to provide assistance. o Secure that the organisation has a well-maintained corporate network to meet the needs of more complex systems and users. Boost animation by virtual team leader or team members. o Use various number of different technologies and collaboration to be more efficient (Kayworth and Leidner, 2000). o Support virtual team leaders to use advanced forms of communication technology. o Provide access to a global network of experts by allowing multiple users to add project info (Marion and Schumacher, 2009). [...]	Measure the ongoing project activities. o Monitor and control the project variables (cost, time, scope, etc.) against the project management plan. o Identify corrective actions to address issues and risks properly and correct errors. o Influence the factors that could circumvent integrated change control so only approved changes are implemented. o Encourage team members to identify a need for modification of the process instance they are involved in (Picard, 2009). o Provide feedback between project phases in order to implement corrective or preventive actions to bring the project into compliance with the project management plan. o Carry out repeatedly analyses of partial tasks to determine changed requirements for competencies during the process run due to the non-deterministic characteristic of development processes during project. [...]

Functions	Virtual Team Building	Team Building in General
Virtual Project Management *FT1 The system should implement Virtual Project Management to deal with complexity of virtual teams in NPD.*		
	[...] Facilitate rapid adaptation of the virtual team to new conditions by agility (Picard, 2009). o Change the set of virtual team members and of tools if needed (Picard, 2009). o Provide real-time collaboration (Chang, 2006). Ensure role-based information access control: assign access constraints to roles rather than to individuals to provide exchange and modification of sensitive information and data (Rezgui, 2007). o Manage access to the data via security levels (May and Carter, 2005). o Determine access to the data for different groups of users (May and Carter, 2005). o Provide commitments, laws, contracts, rules and norms as well as the effect of legacy systems to structure the virtual work.	[...] Promote public interaction (Marion and Schumacher, 2009). o Publish statements relevant to current discussion topic, use chat for off topic points (Rice et al., 2007) Procure Workflow Management. o Storage and share information concerning the specific project work, its functions and other administrative processes to support the automation of work processes by routing information among different actors (Nikas and Poulymenakou, 2008). Select, implement and administrate project tools. o Evaluate project tools required to support chosen management and technical methods. o Establish automatic configuration of tools (May and Carter, 2001). o Introduce new tools and working methods at the beginning of a new product programme since the impact of legacy systems and data will be minimised (May and Carter, 2001).

Examples of Recommendations and Technical Solutions according to the Customer Requirements		
Functions	**Virtual Team Building**	**Team Building in General**
Competence Management *FT2 The system should implement Competence Management to deal with complexity of virtual teams in NPD.*		
FC5 The system should help to determine objectives of Competence Management. FT27 The system should help to determine resources like time, costs, knowledge, competencies and availability according to the NPD (process). FT28 The system should help to determine stakeholders, their resources and requirements. FT29 The system should consider knowledge and competencies of team members as a rare resource which has to be applied in NPD.	Determine the network structure. o Identify the needed collaborative relationship. o Define the collaboration intensity (Eschenbächer et al., 2009). o Form "teams of excellence" consisting of specialists from different areas (Kjiellberg; 1999; Shpitalni et al., 2005). Determine the activities needed to complete those deliverables and networking the activities in their logical sequence.	Determine competencies. o Define competencies as a set of competence resources by concerning one or several aspects of the organisation. o Define requirements pertaining to the team's competencies in relation to task needs. o Identify competencies according to roles and responsibilities needed for the project. Provide process-oriented human resources planning. o Model the product development process in a way that takes the cognitive aspects of competencies as well as those related to product development into consideration. Determine types and numbers of team members resources needed to meet project roles, responsibilities and competence requirements. Determine staffing sources. o Use existing organisational resources, contractors, new hires. Determine deliverables and create the work breakdown structure.

Functions	Virtual Team Building	Team Building in General
Competence Management *FT2 The system should implement Competence Management to deal with complexity of virtual teams in NPD.*		
FC6 The system should help to identify competencies. FT30 The system should help to identify required resources of organisations and projects. FT31 The system should help to make knowledge and competencies accessible and useable for organisations and projects. FT32 The system should help to describe competencies of team members in a generic way. FT33 The system should help to represent competencies that are acquired by team members. FT34 The system should help to staff team members in projects with the support of Competence Management.	Emphasise compatibility and similarity of team members to facilitate the successful combination of complementary assets (Heimericks and Schreiner, 2002). Propose an integrating architecture for Competence Management based on a unified and shared model of competencies (competence ontology). o Develop Competence Management software on the basis of a competence ontology that can be used as a decision support tool in skill gap analysis, project team building, recruitment planning and training analysis (Stader and Macintosh, 2000). o Use ontology manager in order to create ontologies (Stader and Macintosh, 2000). o Differentiate the ontology into four different types of competencies: technical, physical, project specific and business competencies (Stader and Macintosh, 2000). o Define roles and store them as templates in the system (Stader and Macintosh, 2000) o Store ontologies together with process descriptions, process flows and order information. o Allow that relations of similarity between the elements of the ontology can be used. o Increase competence of a team member for a requested task the more similar the requested activity is to an object for which she/ he has already acquired a certain degree of competence.	Identify quantitative and qualitative requirements for competencies (Duarte and Snyder, 2006). Identify competencies in relation to the project-related recording of the activities. o Select team members according to their core competencies that fit to the requirement of the task. o Focus as a first step of team member selection on individual competencies such as technological specialities or expertise needed for the task at hand (Ulbrich et al., 2009). o Focus on individual competencies that should adaptable to group and core (strategic) competencies in further steps. Avoid to model all the different competencies of each team member. o Represent only the required competencies while acquired ones are defined as required competencies that are acquired by some individuals. o Be aware of two main elements for modelling required competencies: the enterprise model that provides the reason to require a competence and the definition of the competence itself. Support each individual team member to establish her/his competence profile in relation to the given ontology (Stader and Macintosh, 2000). […]

Functions	Virtual Team Building	Team Building in General
Competence Management *FT2 The system should implement Competence Management to deal with complexity of virtual teams in NPD.*		
		[...] Connect the competence ontology directly to a workflow management system in order to record specific tasks data automatically. Use inner fuzzy modifiers in order to represent the difference of competence with respect to similar activity objects.
FC7 The system should help to acquire competencies. FT35 The system should help organisations and projects to complete missing resources. FT36 The system should allow to add competencies if needed regarding the requirements of the project. FT37 The system should help to acquire missing competencies through sustainable relationships with stakeholders. FT38 The system should foster that team members offer voluntary their knowledge, competencies and their availability regarding the activities of the NPD. FT39 The system should help that agility allows to staff projects with adequate competencies of team members.	Establish fluid boundaries and fluid team memberships. o Substitute an unavailable team member by another one (Picard, 2009).	Associate the set of the competence resources to an individual and compare them to the set of competence resources defining that competence.
FC8 The system should help to develop competencies. [...]	Encourage lesson learned: During their engagement in the project, the team members increase their own capabilities and pass them along to the other team members (Kjiellberg, 1999). [...]	Identify possible needs for training/coaching. o Analyse the profiles of potential team members related to the given competencies and the requirements for competencies. [...]

Functions	Virtual Team Building	Team Building in General
Competence Management *FT2 The system should implement Competence Management to deal with complexity of virtual teams in NPD.*		
[...] FT40 The system should help to generate new competencies to implement new resources in the NPD (process). FT41 The system should help team members to adopt their competencies in the NDP (process). FT42 The system should allow virtual teams to adapt continuously their competencies to the requirements of the project by agility.	[...] Develop appropriate team training concepts to prepare and support the team members for the specific challenges of virtual teamwork (Hertel et al., 2005). o Train team members in the use of project methods o (management and technical), communication skills, technology and tools. o Train team members in the use of various tools and system features (Kayworth and Leidner, 2000; Rice et al., 2007). o Train team members with the help of genetic algorithms based on an ontology developed within the project (Shpitalni et al., 2005). o Train team members in conflict resolutions skills (Shin, 2005). o Provide initial training and ongoing support for users (May and Carter, 2001). Provide inexperienced virtual team members with an experienced coach. Help virtual team members to offer voluntarily their competencies to take new tasks as occasion that helps to develop their performance.	[...] o Visualise the comparison results and generate hints for a medium-term human resource planning.
FC9 The system should help to utilise competencies. [...]	Utilise "yellow pages" to find relevant experts and expertise (Probst et al., 2000).	Consider partner profiling as an important issue in regard of identification of the right combination of competencies, team member staffing and human resource management. [...]

Functions	Virtual Team Building	Team Building in General
Competence Management *FT2 The system should implement Competence Management to deal with complexity of virtual teams in NPD.*		
[...] FT43 The system should help carry out activities of NPD to make sure that the existing competencies are well applied. FT44 The system should respond systematically to competence requirements of projects to create virtual teams. FT45 The system should help to assign competencies of team members to activities of NPD. FT46 The system should assign resources (like time, costs, competencies, knowledge and availabilities) to specific requirements of projects.		[...] Identify competence requirements during the planning phase of product development. Carry out repeatedly analyses of partial tasks and determine changed requirements for competencies during the process run. Determine competencies directly related to the project-related recording of the activities that are carried out in a company. Keep maintenance efforts of the ontology as small as possible. Connect the ontology to a workflow management system in order to record specific tasks data automatically.
FC10 The system should help to measure competencies. FT47 The system should help to provide a strategic control of Competence Management to measure if competencies are conform with the NPD (process).	Provide checklists that highlight social and personal aspects of the arranged virtual teams. These should help to arrange a well fitting team constellation based on established general rules of teamwork. The final decision remains in the competence of the manager. Implement performance improvements.	Describe competence qualitatively and quantitatively. o Ensure that the qualitative evaluation differentiates the degree of expertise in "no knowledge", "basic knowledge", "independent work on the task" and "expert". o Ensure that the quantitative evaluation asks for the frequency of certain activities in a design process or in relation to a defined time frame. Check and monitor the status of all committed tasks for re-evaluation purposes (Namin et al., 2006). Measure the team and individual performance based on project values/expectations.

		Monitor project staffing and competencies requirements. Maintain necessary staffing levels and/or re-assigning roles and responsibilities. Provide methods of supervising (Jarvenpaa and Leidner, 1999).
Examples of Recommendations and Technical Solutions according to the Customer Requirements		
Functions	**Virtual Team Building**	**Team Building in General**
Virtual Team Interaction *FT3 The system should implement Virtual Team Interaction to deal with complexity of virtual teams in NPD.*		
FC11 The system should help to "socialise" by means of Virtual Team Interaction. FT48 The system should create sympathised knowledge by fostering ▪ Trust ▪ Cohesion ▪ Psychological safety ▪ Sustainable relationships ▪ Team member satisfaction FT49 The system should provide trust by fostering psychological safety. FT50 The system should help to establish sustainable relationships in-between team members and stakeholders. FT51 The system should consider trust as important factor to build sustainable relationships. FT52 The system should provide a continuous support of psychological safety to increase team member satisfaction. […]	Instil and exhibit a sense of cultural awareness (Kayworth and Leidner, 2000). Create teams from complementary cultures (Kayworth and Leidner, 2000). Ensure infrastructure compatibility among geographic locations. Express flexibility and empathy towards virtual team members (Kayworth and Leidner, 2000). o Include a social and fun element in computer-mediated interactions to create stronger relationships (Panteli, 2004). Reduce the sense of both physical and psychological distance (Kanawattanachai and Yoo, 2002). Ensure that team leaders enact and maintain a sufficient level of socio-emotional interactions among their team members (Kanawattanachai and Yoo, 2002). […]	Emphasise continuous communication (Kayworth and Leidner, 2000). o Provide Kick-off meetings to oppose anonymity and improve the communication (Schütze et al., 2009). Encourage social aspects of communication (Greenberg et al., 2007). Stimulate swift trust to achieve high performance and lasting trust among team members (Kanawattanachai and Yoo, 2002). Foster participation in a learning process (Ollus et al., 2009). Boost context awareness (Prinz, W. et al.). Encourage participation in organising (Greenberg et al., 2007). Encourage participation from all members (Greenberg et al., 2007). […]

Functions	Virtual Team Building	Team Building in General
Virtual Team Interaction *FT3 The system should implement Virtual Team Interaction to deal with complexity of virtual teams in NPD.*		
FT53 The system should help to generate cohesion to enhance team member satisfaction. FT54 The system should embark communication to boost trust development by adapted technology. FT55 The system should provide technology that may help to develop cohesion FT56 The system should help to foster communication by establishing sustainable relationships. FT57 The system should provide a continuous support of communication to increase team member satisfaction. FT58 The system should help to profit of cultural diversity by communication. FT59 The system should help to optimise creativity of virtual teams based on their cultural diversity.	o Use more face-to-face interaction and other group communication technologies, such as group telephone and on-line computer conferencing as well as video conferencing to enhance personal connections between team members (Lurey and Raisinghani, 2001).	o Recognise and encourage leadership (Greenberg et al., 2007). o Discourage domination and cliques (Greenberg et al., 2007). o Avoid excluding non-contributing members (Greenberg et al., 2007). o Prohibit unsanctioned subgroups from communicating without including entire appropriate group (Greenberg et al., 2007). Require timely and substantive responses (Greenberg et al., 2007).
FC12 The system should help to "externalise" by means of Virtual Team Interaction. FT60 The system should help that leadership captures knowledge of virtual team members in Virtual Team Interaction. FT61 The system should provide a continuous support of communication to conceptualise knowledge FT62 The system should counteract the impact of cultural diversity among team members by enhancing/ externalising information sharing and communication.	Capture a vision of what effective virtual collaboration will look like. o 10-point plan on how the virtual team will collaborate. Help to change from pulling-in resources and information to pushing in: team members drive actively input to the project rather than respond to active request (Marion and Schumacher, 2009).	Establish "rules of engagement" for communication and interaction (Greenberg et al., 2007; Kayworth and Leidner, 2000). o Foster intra-team communication by rating and selecting proposed industrial concepts (during conceptual development, industrial concepts can be shared and be commented by the virtual team) (Marion and Schumacher, 2009). [...]

Functions	Virtual Team Building	Team Building in General
Virtual Team Interaction *FT3 The system should implement Virtual Team Interaction to deal with complexity of virtual teams in NPD.*		
		[...] o Provide continuous value-added performance feedback throughout the life of the project that should be frequent, concrete and timely (Kayworth and Leidner, 2000; Marion and Schumacher, 2009; Hertel et al., 2005). Set meeting schedules (Kayworth and Leidner, 2000). o Establish interim deadlines and celebrate when met (Greenberg et al., 2007). Avoid ambiguity concerning task, role and responsibility (Shin, 2005). Set clear team objectives. Provide suggestions and advise to solicit team member's opinions (Kayworth and Leidner, 2000). Evaluate communication patterns (Greenberg et al., 2007). Acknowledge and commend suggestions of individual members to the whole team(Greenberg et al., 2007).
FC13 The system should help to "combinate" by means of Virtual Team Interaction. FT63 The system should facilitate the communication among team members by Virtual Team Interaction supported by a variety of different technologies. [...]	Encourage team leaders to make compensatory adaptations (smileys, emotion icons etc.) to their messages in order to make them more richly in form of metaphorical language and social cues.	Validate technical/functional role in team (Greenberg et al., 2007). Establish socio-cognitive constructs such as transactive memory and collective mind (Kanawattanachai and Yoo, 2002). Provide documentation and document sharing (Duarte and Snyder, 2006). [...]

Functions	Virtual Team Building	Team Building in General
Virtual Team Interaction *FT3 The system should implement Virtual Team Interaction to deal with complexity of virtual teams in NPD.*		
[...] FT64 should deal with team members who act interdependently through technology to create systematised knowledge. FT65 The system should provide that technology fosters communication among team members to support sustainable relationships. FT66 The system should help to overcome obstacles regarding the use of technology to minimise the difficulty to breed trust. FT67 The system should help to share knowledge between stakeholders with the help of technology.		[...] Provide reporting (Duarte and Snyder, 2006). Provide communication protocols (Rice et al., 2007). Encourage transparency to all project team members: o Foster transparency of project mission and individual team assignments. o Foster transparency of the process (Chang, 2006). o Foster transparency of project values/expectations - quality, quantity of work, communication, teamwork, etc. o Foster transparency of project status, issues, problems and changes. o Foster transparency of agenda (before the meeting) and minutes (after the meeting) (Rice et al., 2007). o Foster transparency of effectiveness of project methods, tools and work environments. Highlight positive outcomes to strengthen the relationship (Ulbrich et al., 2009). Give feedback as a potential input for a new project (Ulbrich et al., 2009). Identify what plans and strategies have not worked in the past and why and resolve to not repeat them.

Functions	Virtual Team Building	Team Building in General
Virtual Team Interaction *FT3 The system should implement Virtual Team Interaction to deal with complexity of virtual teams in NPD.*		
FC14 The system should help to "internalise" by means of Virtual Team Interaction. FT68 The system should help to embed virtual teams in the organisation. FT69 The system should help to improve the organisation in which the virtual team is embedded. FT70 The system should foster Virtual Team Interaction to enhance knowledge of the organisation.	Help virtual team members to learn from virtual collaboration experiences to adapt their behaviour accordingly (Ulbrich et al., 2009). o Conduct regular periodic face-to-face meetings: Activities before and after collaboration meeting are higher (Kayworth and Leidner, 2000; Hameri and Nihtilä, 1997). o Punctuate the end of the organising stage and the beginning of the task with an "event" (Greenberg et al., 2007). Communicate about experiences and lessons learned in the whole organisation. o Provide list of + and – points of the project. Present milestones and final results of the project in the whole organisation.	Help team members to recombine and integrate knowledge that is acquired from past actions (Ulbrich et al., 2009).

4.3 Synthesis: Methodological Approach of the VTB Support System

The methodology that we presented in this chapter 4 is based on a systemic approach. We defined the VTB Support System as a system. We used the functional analysis ((§ 4.1) to identify the functional requirements that characterise the system. Steps of the functional analysis have been pursued to get a most exhaustible vision of the VTB Support System (§§ 4.1.2 - 4.1.5). A list of the entire functions is given in § 4.1.5 that reflects the hierarchical order of the functions.

The house of quality has been used in § 4.2 to deduce substantiated recommendations of the functions that are detected by the functional analysis. The identification of customer requirements has been presented (§ 4.2.1) and quality characteristics have been listed (§ 4.2.2). A catalogue of examples of quality characteristics has been given in table 4-7. The further steps of the approach have been pursued (§§ 4.2.3 - 4.2.4). They enabled us to translate the requirements of the VTB Support System in recommendations and technical solutions that are proposed to satisfy the requirements. By putting the customer requirements in relation to existing recommendations and technical solutions, the results permit an analysis, interpretation and further planning.

The proposed methodology reorganise the requirements of a system that should help to build virtual teams in a clear framework. It stresses the fact that collaboration processes and tools are better appropriated if recommendations and technical solutions in the domain of VPM, CM and VTI are implicated. The methodology of the VTB Support System visualises that it may be used as tool of analysis, communication and planning of virtual team building.

The overview of the methodological approach of the VTB Support System is demonstrated in figure 4-13. Each step and tool of the presented methodology is analysed in terms of modelling, application and result.

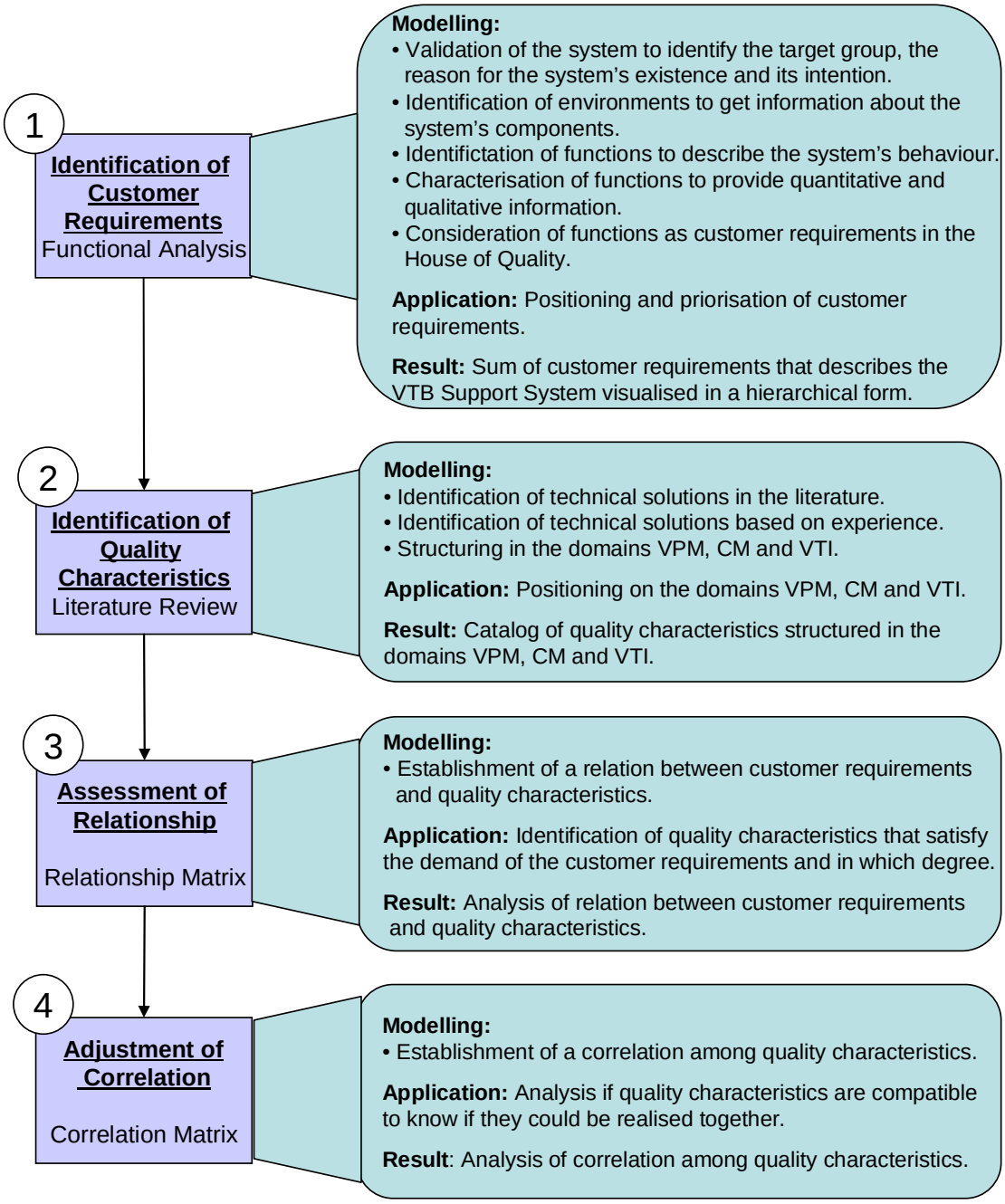


Figure 4-13. Overview of the Methodological Approach to provide a VTB Support System

Part III: Application

5 Examples of the VTB Support System's Application

In this chapter 0 we present three different examples of applying the VTB Support System. Firstly, we focus on a theoretical evaluation with particular emphasis on the domain of human behaviour and interaction in § 5.1. We refer to Tuckman's Team Development Model (Tuckman, 1965). This model is shown in § 5.1.1 and a synthesis based on the state of the art is given. The model is used to evaluate the functions that have been identified by conducting the functional analysis (§ 4.1). At the same time this approach provides a second supporting structure that helps organisations and projects during the constitution of the virtual team a positioning on the hierarchical tree and important functions depending on its specific needs.

The second application in § 5.2 is done with a European funded project, named smE-MPOWER. The project and its industrial needs are introduced in §§ 5.2.1- 5.2.2. Customer requirements are defined and analysed according to an extract of 24 quality characteristics to delineate exemplarily the approach of this kind of application (§ 5.2.3 - 5.1.3).

The third part in § 5.3 is based on the results of the application with smE-MPOWER. We compare the results of the presented application of smE-MPOWER with an enquiry on web 2.0 tools that were organised in form of interviews with 34 marketing managers. An introduction in web 2.0 tools is given in § 5.3.1 and a proposition of a choice of tools and their definition is provided. The presentation of the study, the industrial needs, the application and the analysis and results are shown in §§ 5.3.2- 5.3.5.

We finish this chapter 0 with a synthesis of the VTB Support System's variety of utilisation in § 5.4.

5.1 Theoretical Evaluation of the VTB Support System

In our understanding virtual team building considers beside of the constitution of a virtual team, also its functioning. It contains a technical and a human dimension, which concentrate on working processes, human resource management aspects, and human behaviour and interactions (table 1-1). An example of the VTB Support System's application is given in this § 5.1 that focuses on a theoretical evaluation with particular emphasis on the domain of human behaviour and interaction but also the other aspects of working processes and human resource management are taken into account. Hereby, we use as framework a model of team development based on Tuckman (1965) that is easily adaptable to our system. Even if it stresses mainly aspects of the domain VTI, also VPM and CM are concerned as the system is in interrelation with all its environments (figure 4-7).

The main objective of § 5.1 is to get detailed information about the VTB Support System by providing a hierarchical form of the sum of the functions that describe it. Referring to the team development model of Tuckman (1965) we analyse the structure of the VTB Support System.

According to the systemic approach, Tuckman's Team Development Model builds as an evaluating and positioning framework the fundament of the hierarchical tree. We consider different phases of Tuckman's model to structure the functions that define the VTB Support System.

5.1.1 Tuckman's Model of Virtual Team Development

Tuckman (1965) proposes a model of team development that delineates four stages: forming, storming, norming and performing. In later studies Tuckman and Jensen (1977) added a fifth phase, called adjourning.

The phases are presented in the following list:

- Forming (F): establishes the team. Team members are chosen; the team comes together and gets to know each other. Furthermore the boundaries of the team as well as the boundaries of the project are determined, management support is ensured and the team formation processes take place. This leads to the creation of links between team members and establishs trust.
- Storming (S): is featured by conflict and polarisation around interpersonal issues. Team members test and resist these boundaries that were established in the forming stage. Mutual knowledge is established, ideas are developed, team objectives are clarified and trust is fostered. In this stage communication mechanisms are chosen.
- Norming (N): embosses coherence among the team. Standards regarding the team objectives are developed, standardised working practices and tools are chosen. Communication is regulated.
- Performing (P): helps the developed structure to accomplish the task. Team members work together towards shared objectives. An assessment of needs and deficits is proceeded and trainings according to competence deficits are provided.
- Adjourning (A): takes place when the team has attained its objectives and dissolves. The achievements are recognised. Learning experiences are communicated and shared.

Even if the VTB Support System concentrates primarily on the first phases of the team development: forming, storming and norming, also the other phases must be respected. This conveys the phases of performing and adjourning should also be considered in the VTB Support System. By differing virtual team building in different phases, opportunities and risks that are important for virtual team building are better classified and might be better managed.

We are referring to Hertel et al. (2005) and Stevens et al. (2009) who explore human resource issues according to the phases of virtual project team development and the challenges that virtuality induces. Their research is based on Tuckman's model. We present a **synthesis** of the studies of Tuckman (1965), Hertel et al. (2005) and Stevens et al. (2009) in table 5-1 explaining activities, opportunities and risks of each phase of Tuckman's model of team development.

Table 5-1. Synthesis of Tuckman's Model of Team Development based on the State of the Art

Synthesis of Tuckman's Model of Team Development based on the State of the Art			
Phases	**Activities**	**Opportunities**	**Risks**
1. Forming	Choice of team members. Team comes together and gets to know each other. Determination of boundaries. Securing Management support. Formation of team. Creation of links. Trust development.	Gather the "perfect" virtual team owing to the wide rang of knowledge, competencies, expertise. Increasing creativity by heterogeneous cultural backgrounds of team members. Highly depending on the performance of the team leader in this phase.	Team members feel anxious and spend their time finding out about each other. Lower trust level due to distance. Stereotypes and faulty first impressions may lead to difficulties in creating team coherence. Challenge to define the experts. Individual roles and responsibilities are unclear.
2. Storming	Establishment of mutual knowledge. Idea creation. Clarification of objectives: - task priorities and purposes - roles & responsibilities - processes. Choice of communication mechanisms. Fostering trust.	Able to react quickly to changed customer requirements by assembling the needed resources fast. Higher psychological safety due to the asynchronous processing. Easier conflict resolution through anonymous electronic means.	Misunderstandings or limited understanding owing to cultural barriers could hinder the process of idea creation, information exchange and the decision process and provoke conflicts. Compromises may be required to enable progress.
3. Norming	Featuring of coherence. Development of standards regarding the objectives: - task priorities and purposes - roles & responsibilities - processes - team rules. Choice of working practices and tools. Regulation of communication.	Varied cultural backgrounds oblige to define and share new working processes and to select new technologies supporting them. Reinforce to understand and to learn about different solutions, customer needs, restrictions and opportunities du to the cultural diversity. Cultural diversity may also help to question project objectives to lead to better results. Decision making happens by group agreement.	Conflicts could reduce trust and information exchange. Communication by Web 2.0 tools is time-consuming and slows down the creation of norms. Ensuring common understanding of ideas.

Synthesis of Tuckman's Model of Team Development based on the State of the Art			
Phases	**Activities**	**Opportunities**	**Risks**
4. Perfoming	Team members working together towards shared objectives. Assessment of needs/ deficits. Individual/ team training according to competence deficits.	High creativity. Possibility of regular and frequent interteam communication and feedback that helps to enhance the knowledge creation and team learning. High level of respect enhances communication. Reduction of time to market due to the possibility of reacting fast to changed customer needs. Possibility to enlarge the scope of knowledge, competencies and experiences resulting in enriched vision of NPD opportunities. Transparency. Motivating leadership.	Limited utilisation of the creativity potential of team members due to a too small range or unsuitable Web 2.0 tools for exchanging tacit knowledge, particularly in early NPD process. Maintaining a synergy and information flow or contrarily: information overload. Resolution of complex conflicts is difficult because of limited communication. Lack of standardised processes may provoke difficulty to find old information entries due to duplicates.
5. Adjourning	Team dissolves after project objective achievements. Recognition of achievements. Sharing learning experiences.	Able to organise fast review meeting to avoid "after-project amnesia". Dissemination opportunities.	Cultural differences might affect the readiness to talk about problems and improvement opportunities during and after the project.

The synthesis presented in table 5-1 facilitates to adapt Tuckman's Team Development Model as an evaluating and positioning framework to the hierarchical tree of the VTB Support System. The different phases of Tuckman's model are accounted to structure the functions that define the VTB Support System. By providing a hierarchical form of the sum of the functions that describe it we get detailed information.

5.1.2 Presentation of the Evaluation

Tuckman's team development model is used in the first place to evaluate the functions that have been identified with the help of the functional analysis and that are translated as customer requirements in the approach of the house of quality. In the second place, we aim to propose a second supporting structure that helps organisations and projects during the constitution of the virtual team a positioning on the hierarchical tree and important functions depending on its specific needs.

The evaluation of the VTB Support System's functions is done on the basis of the hierarchical tree (§ 4.1.5). The defined structure of the functions is respected and only the branches of the second level of the hierarchical tree that are characterised by FC functions are allocated (figure 4-10). This evaluation is conducted with regard to the impact of corresponding FT functions of the lower levels of the hierarchical tree. The evaluation results are seen in figure 5-1 that shows the hierarchical tree according to the phases of Tuckman's Team Development Model.

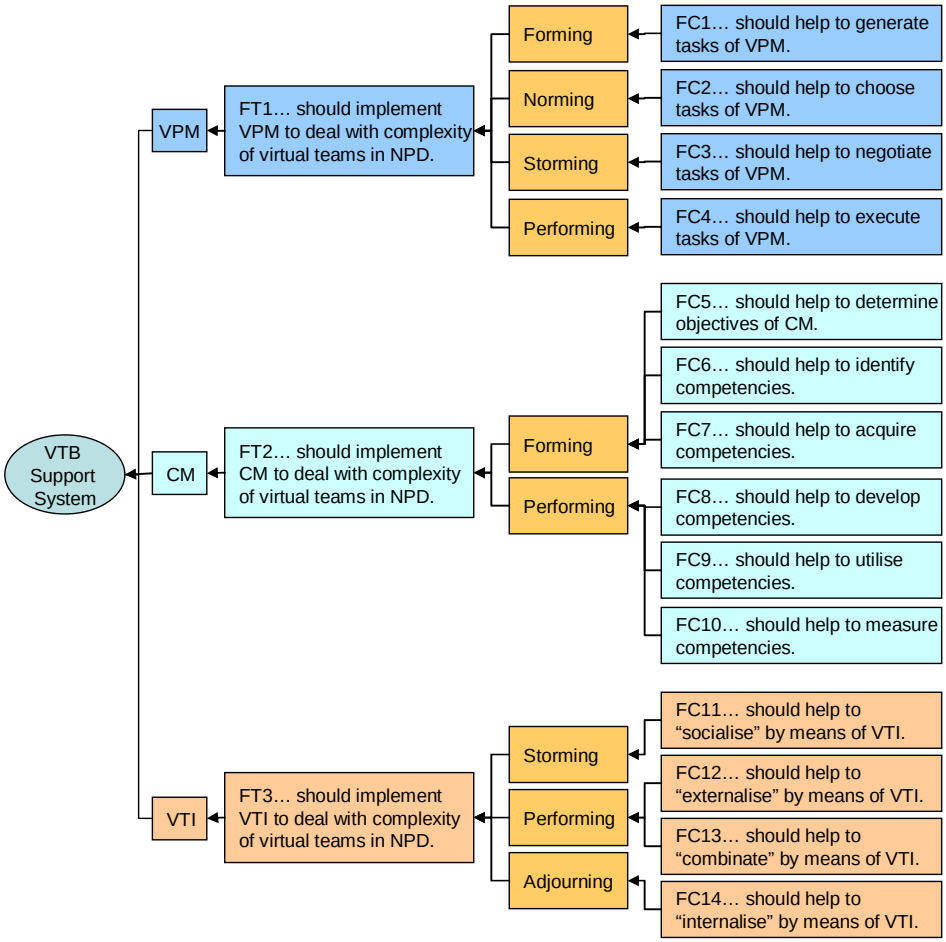


Figure 5-1. Evaluation of the Hierarchical Tree based on Tuckman's Team Development Model: Perspective of the Domains

For reasons of visualisation exclusively the first and the second level of the hierarchical tree are presented. The structure of the third, fourth and fifth level is the same as found in figure 4-10.

The second focus of this approach lays on the structure of the hierarchical tree and the characterisation of the functions. The tree structure provides a clear visibility of the large number of functions constituting the system. It facilitates to measure the importance of the functions in a qualitative way and to represent the system in a hierarchical form. To propose a second supporting structure that helps organisations and projects a positioning on the hierarchical tree. Important functions depend on the specific needs of stakeholders and the focus of the hierarchical tree may be changed according to the phases of Tuckman's Team Development Model. An extract of this way of utilisation is visualised in figure 5-2.

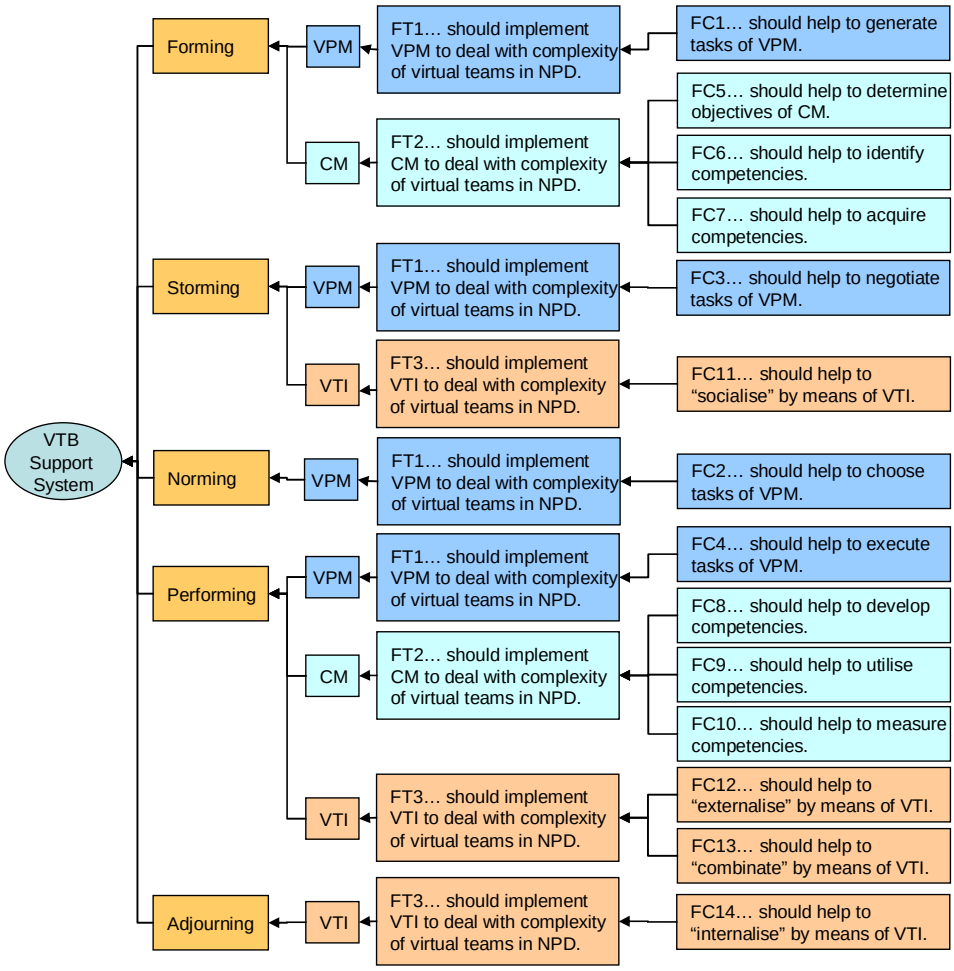


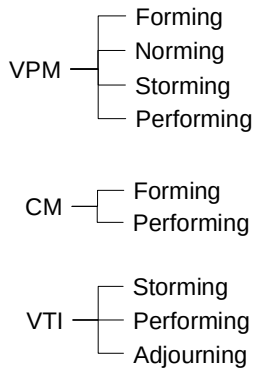
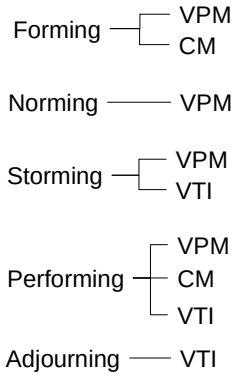
Figure 5-2. Evaluation of the Hierarchical Tree (based on Tuckman's Team Development Model: Perspective of the Phases)

Normally, the functions in figure 5-2 are broken down to several levels in consideration of the hierarchical tree of the VTB Support System (figure 4-10). Exclusively, the first and second level of the hierarchical tree are shown in figure 5-2. They focus on the five phases of Tuckman's Team Development Model.

5.1.3 Analysis and Results

The first part of the approach of the evaluation has delineated that all five phases of Tuckman's Team Development Model are respected by the VTB Support System's functions. Although Tuckman's model focuses mainly on human behaviour and interactions that are in this PhD thesis represented by the domain of VTI, also the domain of VPM and CM are allocated to the team development phases of Tuckman. This is based on the fact that the system's environments are in interrelation and interacting constantly with the others (§§ 4.1.3 - 4.1.4). The results of the evaluation of the hierarchical tree according to Tuckman's Team Development Model are depicted in table 5-2.

Table 5-2. Evaluation of the Hierarchical Tree according to Tuckman's Team Development Model

Evaluation of the Hierarchical Tree according to Tuckman's Team Development Model	
Perspective of the domains	**Perspective of the phases**
	

The second part proposes another perspective on the VTB Support System to provide a further supporting structure that may allow stakeholders to identify easier their required key functions. There might be different priorities concerning the different branches of the hierarchical tree and the respective perspectives.

In this line of thinking, there are two different ways of utilisation of the VTB Support System. The first way focuses on all the domains VPM, CM and VTI of the hierarchical tree as well as on the entire phases of Tuckman's Team Development Model. Priorities are set with the varying percentages of the functions of the hierarchical tree. They are used as fundamental input and permit to translate the key functions in applicable solutions with the help of the house of quality. The hierarchical tree and the quality characteristics of the house of quality are regarded entirely. The different importance within the respective branches that are translated to the planning matrix of the house of quality reflects the needs of the stakeholder. A Stakeholder can be in our case an organisation or a project without a real organisational structure.

The strategy of a stakeholder should be to concentrate on those branches that have been neglected before. This means that the focus would be set on the different branches of the hierarchical tree. The customer's priorities might be determined on this higher level which means that one stakeholder could set the focus on the domains while another one regards Tuckman's phases as the most important perspective of the hierarchical tree. As the VTB Support System should be applicable to a wide range of organisations and projects in the domain of NPD, as well as to various application domains, the focus could vary in consideration of the priorities of the stakeholder.

In this PhD thesis we present different possible scenarios that constitute themselves by crossing the different priorities of stakeholders according to the domains: VPM, CM and VTI or Tuckman's phases: forming, storming, norming, performing and adjourning. With these examples we cope with the two ways of utilisation of the VTB Support System. They are presented in table 5-3.

Table 5-3. Extract of the Generic Model Presented as Potential Scenarios

Extract of the Generic Model Presented as Potential Scenarios							
Focus	**All phases**	**Forming (F)**	**Storming (S)**	**Norming (N)**	**Performing (P)**	**Adjourning (A)**	**Filter a**
All domains	FT1, FT2, FT3, FC1 FT2 […]	FT1, FT3, FC1, FC5 […]	FT1, FC3, FT3, FC11 […]	___	FT1, FT2, FT3, FC4, FC8 […]	___	All-Filter a
VPM	FT1, FT4, FT5, FT6 […]	FC1, FT4, FT5, FT6 […]	FC3, FT17, FT18, […]	FC2, FT13, FT14, FT15, FT16	FC4, FT20, FT21 […]	___	VPM-Filter a
CM	FT2, FT27, FT28 […]	FC5, FC6, FC7, FT27, FT28 […]	___	___	FC8, FC9, FC10 […]	___	CM-Filter a
VTI	FT3, FT48, FT49 […]	___	FC11, FT48, FT49 […]	___	FC12, FC13, FT63 […]	FC14, FT68, FT69 […]	VTI-Filter a
Filter 1	Filter 1 - All	Filter 1 - F	Filter 1 - S	Filter 1 - N	Filter 1 - P	___	Filter 1 - Filter a

Filter 1: Selected functions of VPM, CM and/ or VTI Filter a: Selected functions of F, S, N, P and/ or A

The ability of the VTB Support System to adapt its point of view on the needs of the stakeholder constitutes the generic aspect of the model.

The focus of scenario "All - All" is set on the entire hierarchical tree that includes all the branches of the different domains VPM, CM and VTI and keeps the whole Team Development Model of Tuckman in mind. Priorities of the stakeholders are set by percentages.

The other scenarios centre on specific branches either with priority on different branches following the domains VPM, CM and VTI of the original hierarchical tree (figure 4-10) or with priority on Tuckman's phases on different branches of the hierarchical tree that have been visualised in figure 5-2. It takes into account that there might be different priorities concerning the different branches of the hierarchical tree in matters of the degree of respective requirements of the stakeholders. There might be a stakeholder who stresses two branches - branch "VTI –All" and "VPM - All" - or another one that focus exclusively on one branch – branch "CM - P". In this case the stakeholder sets the focus on functions in the domain of CM that describe the performing process of Tuckman's Team Development Model.

"Filter 1" and "filter a" designate the possibility of taking exclusively some selected functions of different domains. The variations of using the VTB Support System are flexible and depend on the need of the respective organisation or project and its positioning on the hierarchical tree.

5.2 Project Application: smE-MPOWER

The flexibility of utilisation of the VTB Support System allows us to provide a generic model that is adaptable to each context. By being able to point out different specific aspects the VTB Support System, it is applicable to the needs of different stakeholder.

5.2.1 Industrial Context: Presentation of the Project

smE-MPOWER is an European funded project for SME support and was financed through the Economic and Technological Intelligence project scheme within the European 6th Research Framework Programme (FP6). It ran from 2005 to 2007 and was formed of a committed community of coaches from ten European countries. It provided regional policy recommendations in order to stimulate improvement of the framework conditions for SME driven research in these countries. The geographically balanced consortium included Ireland, Cyprus, Slovakia, Lithuania, Romania, Switzerland, Israel, Germany, France and the United Kingdom. The coordination has been executed by the experienced leadership of the Fraunhofer Institute for Factory Operation and Automation (IFF), in Magdeburg/ Germany.

The aim of smE-MPOWER was to enhance the number of SME driven innovation projects in the context of European Research through the creation of a Learning Community. It pursued effective dissemination, purposeful networking for synergies with complementary initiatives, conferences targeting decision makers and SME Intermediaries interested in joining the Coaching Community. SmE-MPOWER lead to more SME driven proposals in European Research based on the European 7th Research Framework Programme (FP7) by facilitating and coaching SME driven innovation projects. One of the strongest points of smE-MPOWER was that it started with real industry needs in the targeted SMEs and provided a new approach of empowering them for ownership in self-defined Research and Technology Development (RTD).

The main project objectives of smE-MPOWER are presented in the following list. They are extracted from the project proposal (see Project Reference: 23401, Cordis, FP6):

(1) Increased SME Participation in European Research: The primary objective is to empower innovative high-tech SMEs for self-defined research activities. This is realised through widespread awareness measures, the creation of trans-national SME groupings with similar innovation needs and their purposeful coaching towards innovation project implementation. This contributes directly to the much desired outcome of mobilised SMEs and SME-driven research proposals in emerging and future European RTD activities, especially the FP7.

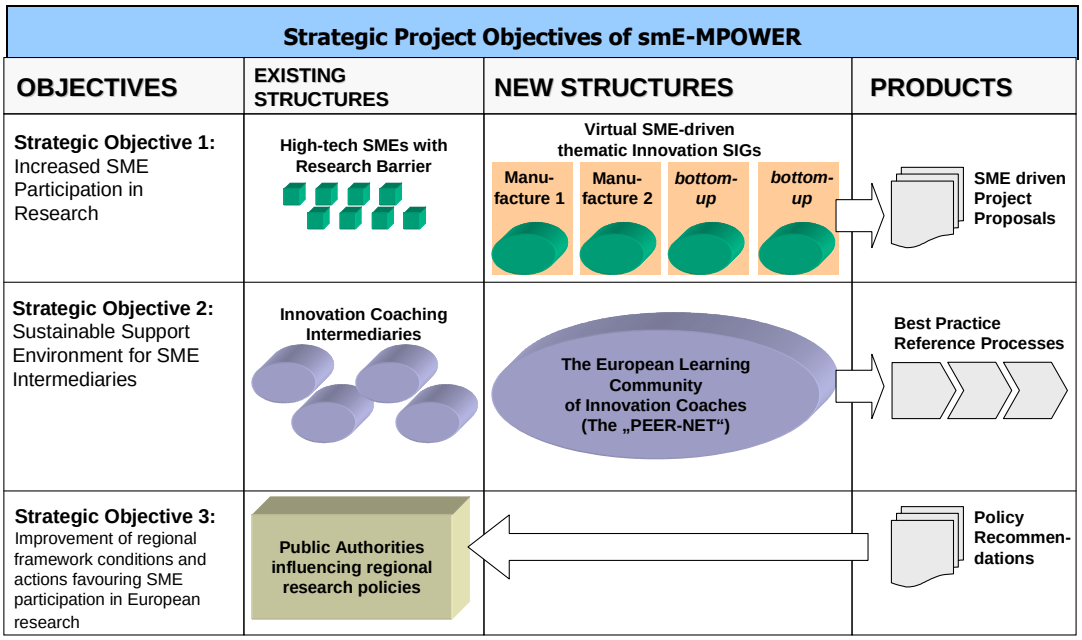
(2) Sustainable Support Environment for SME Intermediaries: The secondary objective is to empower innovation coaches of established SME Intermediaries - like SME National Contact Points, Innovation Relay Centres, industrial incubators and professional associations - for a continual improvement of their innovation support services. This is realised through a newly initiated, uniquely resourced and well-positioned pan-European Learning Community for Innovation Coaches starting with the experts of the project consortium. This community (called "PEER-NET") is a growing network of industrial incubators for the trans-national transfer of best practices and the provision of peer-to-

peer mentoring. It is the target to achieve the project's primary mission in the long-run and therefore a central focus of the project.

(3) Improvement of regional framework conditions and actions favouring SME participation in European research: The tertiary objective is to provide a contribution to the empowering of regional and national administrations for new policy actions favouring the involvement of SMEs in European research. Policy recommendations result from the collective experience of the participating regions with regard to their specific hurdles hampering the participation of project involved SMEs in European research. This provides an additional leverage point for further regional policy actions beyond the scope of this project.

These three strategic objectives are visualised in table 5-4 that is extracted from the project proposal (see Project Reference: 23401, Cordis, FP6).

Table 5-4. Strategic Project Objectives of smE-MPOWER (based on the project proposal)



As depicted in table 5-4 the development of new products is focused on the three strategic objectives. The smE-MPOWER consortium worked as a virtual team to develop in the NPD project: SME driven project proposals, best practice reference processes and policy recommendations.

SmE-MPOWER was very successful and personally congratulated by the European Commission's Head of Unit SME for its achievements. About 10.000 SMEs have been addressed during the project in 50 regional awareness workshops and involvement and in about 10 international conferences. More than 1.000 SMEs have been mobilised towards collaboration within FP7 and 300 SMEs were coached by smE-MPOWER. Half of them participated in nearly 50 submitted proposals.

5.2.2 Industrial Needs

The application has been done with one of the coordinators of smE-MPOWER, Ms. Katrin Reschwamm from Fraunhofer Institute for Factory Operation and Automation (IFF) in Magdeburg, Germany. The IFF is an autonomous institute of the Fraunhofer-Gesellschaft that was founded in 1992. Its focus is set on applied research and development in the fields of Automation, Information Logistics, Logistics Systems and Networks, Production and Plant Management and Virtual Development and Training. It works in close cooperation with industry, the scientific community and government. Its typical industry-close profile helps the IFF to consult and to coach many regional SMEs on their innovation needs towards a successful research proposal under FP7.

Our expert, Ms. Reschwamm has worked for more than 10 years as Research and Project Manager at IFF before she has been appointed as Managing Director at EUrelations AG, Switzerland in January 2011. She has received numerous certifications in Project Management from the Fraunhofer-Gesellschaft, Otto von Guericke University Magdeburg and the German Society for Project Management. Since 2002 she has been actively involved in the German Society for Project Management and has headed their regional chapter in Magdeburg for the last 4 years.

As the coordinator of the smE-MPOWER project, Ms. Reschwamm and her IFF team were responsible for the overall project coordination and carried out the project management. This implicated the following activities that are important for virtual team building, especially for the domain of VPM:

- Preparation of project documents such as activity, management and progress reports,
- Organisation and moderation of virtual team meetings,
- Communication with all project partner through collaboration tools,
- Information of all partners about planning, work in progress and problems,
- Supervision of project objectives and timeliness of the work plan,
- Monitoring of resources and milestones,
- Anticipation of any major deviation to the work foreseen and if needed, proposing corrective/ alternative actions,
- Decision on documentation standards, quality control and acceptance procedures,
- Coverage that decisions taken in the full meeting are in line with the project objectives and future developments.

As the project was already finished when the application has been done, our expert took a retrospective point of view to get recommendations that could be taken as lessons learned from the project. The importance of the costumer requirements could vary from customer to customer, from organisation to organisation and from NPD project to NPD project in matters of the respective needs. In this case, a positioning on 12 different functions has been done.

5.2.3 Presentation of the Application

The purpose is to demonstrate an extract of the functioning of the VTB Support System that stresses the main functions chosen by our expert that are handled as quality characteristics in the house of quality. Regarding to the different possibilities of a positioning on the hierarchical tree that have been presented in § 5.1.2, our expert aimed to take all three domains VPM, CM and VTI into account as well as all five phases of Tuckman's Team Development Model: forming, storming, norming, performing and adjourning. To give consideration to the most important functions of smE-MPOWER the presented scenario "Filter 1 – Filter a" has been chosen (table 5-3). This means that exclusively selected functions in the domains VPM, CM and VTI and Tuckman's phases are taken into account. Tuckman's Team Development Model is exclusively used as a second positioning framework to identify the key functions. In the later analysis the focus is set on the domains VPM, CM and VTI.

Our expert identified twelve key functions of the hierarchical tree's third level that are presented as customer requirements in table 5-5.

Table 5-5. Customer Requirements according to the Application with smE-MPOWER

Customer Requirements according to the Application with smE-MPOWER				
1st level	**2nd level**	**3rd level**	**Domain**	**Phase**
FT1	FC2	FT13 The system should help to choose resources to satisfy the requirements of stakeholders. FT14 The system should help to choose the right technology to insure effective Virtual Project Management.	VPM	Norming
FT1	FC4	FT21 The system should provide that Virtual Project Management is based on agility. FT23 The system should help that leadership enhances Virtual Project Management.	VPM	Performing
FT2	FC6	FT30 The system should help to identify required resources of organisations and projects. FT34 The system should help to staff team members in projects with the support of Competence Management.	CM	Forming
FT2	FC8	FT40 The system should help to generate new competencies to implement new resources in the NPD process. FT41 The system should help team members to adopt their competencies in the NDP process.	CM	Performing
FT3	FC11	FT50 The system should help to establish sustainable relationships in-between team members and stakeholders. FT57 The system should provide a continuous support of communication to increase team member satisfaction.	VTI	Storming
FT3	FC14	FT68 The system should help to embed virtual teams in the organisation. FT70 The system should foster Virtual Team Interaction to enhance knowledge of the organisation.	VTI	Adjourning

In a broader application the input of importance of the whole hierarchical tree should be kept clearly in mind. As in our case exclusively twelve functions have been defined as customer re-

quirements, they are handled as equal. Priorities in form of percentages of importance should be made if several levels of the hierarchical tree are taken into account. In this case the results of the hierarchical tree are implicated in form of the determined percentages in the planning matrix of the house of quality. It demonstrates the weighted importance of each requirement that the VTB Support System is attempting to fulfil. This permits to concentrate on these functions and their corresponding recommendations and technical solutions that seem to be the most important ones for the customer.

While customer requirements describe what should be implemented, quality characteristics are focused on the way how those requirements should be implemented and give precise recommendations. The recommendations are structured in the domains VPM, CM and VTI. They were found in the scientific literature or are based on our personal experience in European projects and industry as well as national and international exchanges with experts. They are incorporated in the house of quality as quality characteristics ("Hows"). For reasons of visualisation exclusively an extract of 24 quality characteristics, eight on the basis of each domain, is shown in table 5-6.

Table 5-6. Extract of Quality Characteristics according to the domains VPM, CM and VTI

Extract of Quality Characteristics according to the domains VPM, CM and VTI	
Virtual Product Management (VPM)	
VPM1	Provide a common architecture and shared platform elements (Marion and Schumacher, 2009).
VPM2	Support and guide team members about task (Greenberg et al., 2007; Picard, 2009).
VPM3	Provide task-related evaluation of the data.
VPM4	Procure positive confirmation of decisions (Rice et al., 2007).
VPM5	Update the technology over time.
VPM6	Establish a help-desk to provide assistance.
VPM7	Boost animation by virtual team leader or members.
VPM8	Facilitate rapid adaptation of the virtual team to new conditions by agility (Picard, 2009).
[…]	
Competence Management (CM)	
CM1	Emphasise compatibility and similarity of team members to facilitate the successful combination of complementary assets (Heimericks and Schreiner, 2002).
CM2	Propose an integrating architecture for CM based on a unified and shared model of competencies (competence ontology).
CM3	Identify quantitative and qualitative requirements for competencies (Duarte and Snyder, 2006).
CM4	Identify competencies in relation to the project-related recording of the activities.
CM5	Encourage lesson learned: During their engagement in the project, the team members increase their own capabilities and pass them along to the other team members (Kjiellberg, 1999).
CM6	Develop appropriate team training concepts to prepare and support the team members for the specific challenges of virtual teamwork (Hertel et al., 2005).
CM7	Provide inexperienced virtual team members with an experienced coach.
CM8	Help virtual team members to offer voluntarily their competencies to take new tasks as occasion that helps to develop their performance.
[…]	

Extract of Quality Characteristics according to the domains VPM, CM and VTI	
Virtual Team Interaction (VTI)	
VTI1	Express flexibility and empathy towards virtual team members (Kayworth and Leidner, 2000).
VTI2	Reduce the sense of physical and psychological distance (Kanawattanachai and Yoo, 2002).
VTI3	Ensure that team leaders enact and maintain a sufficient level of socio-emotional interactions among their team members (Kanawattanachai and Yoo, 2002).
VTI4	Encourage participation in organising (Greenberg et al., 2007).
[…]	
Virtual Team Interaction (VTI)	
VTI5	Help virtual team members to learn from virtual collaboration experiences to adapt their behaviour accordingly (Ulbrich et al., 2009).
VTI6	Help team members to recombine and integrate knowledge that is acquired from past actions (Ulbrich et al., 2009).
VTI7	Communicate about experiences and lessons learned in the whole organisation.
VTI8	Present milestones and final results of the project in the whole organisation.
[…]	

General recommendations that support virtual team building are provided in table 5-6. Those recommendations have to be translated into precise technical solutions that give examples how the recommendations may be realised. Nothing can be produced, serviced or maintained without detailed specifications or some set of given standards. This is the reason why the analysis of the given examples should lead to precise HOWs.

5.2.4 Analysis and Results

Before going into detail of the results we present with figure 5-3 the house of quality according to the selected functions. It builds the basis of our analysis.

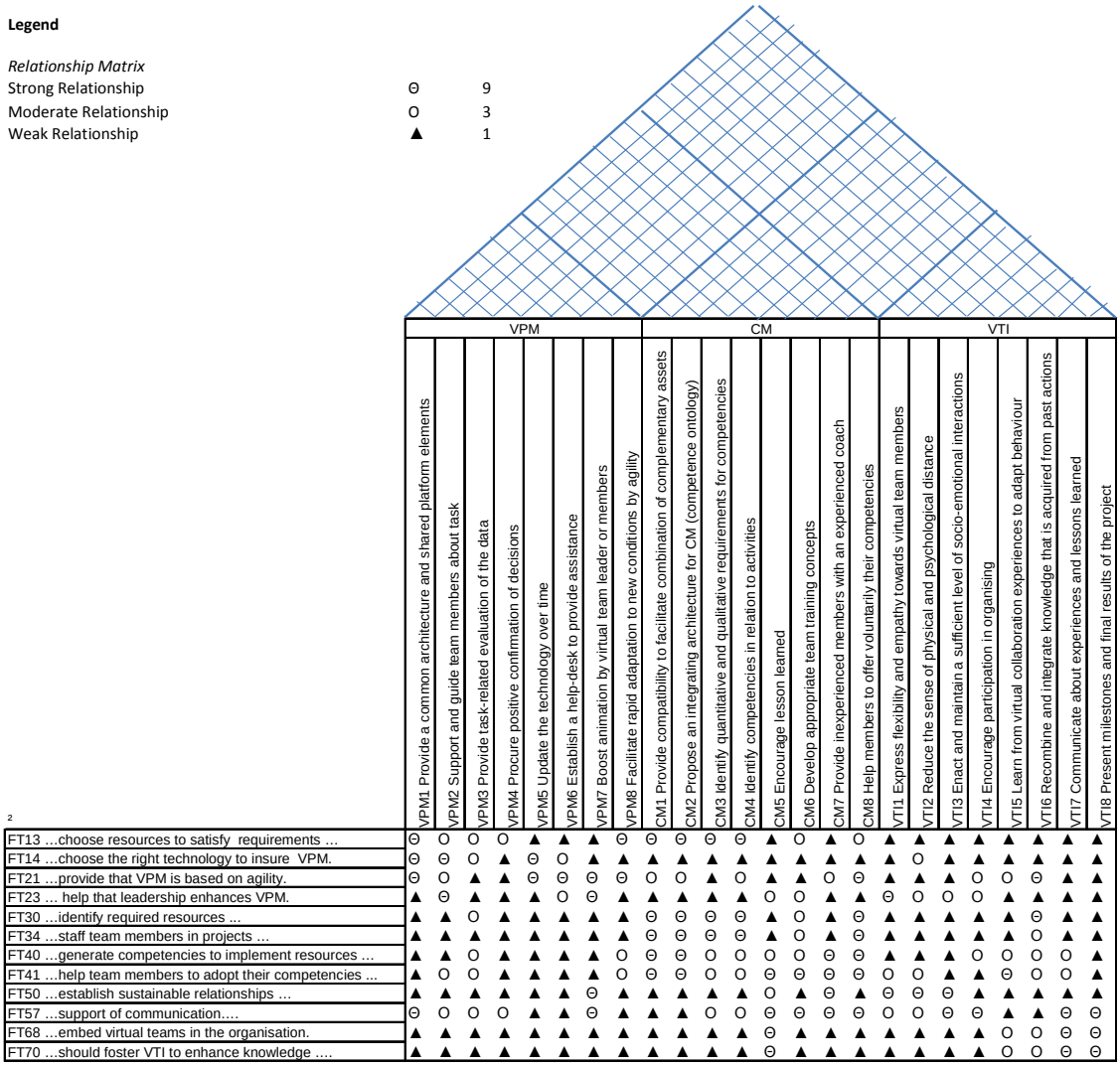


Figure 5-3. House of Quality according the Application with smE-MPOWER

The results of the house of quality are extremely rich and there is much potential of interpretation depending on the respective point of view of the work. In this work we concentrate on two aspects. Our first purpose is set on the customer requirements that have been defined by our expert of smE-MPOWER. This analysis represents how well they are satisfied by the extract of 24 quality characteristics. The second focus is set on the extract of quality characteristics in each domain VPM, CM and VTI and analyses which quality characteristics satisfy the best the requirements.

We are not examining the correlation matrix in this example as we give exclusively an extract of quality characteristics. Objective is to assess the relationship matrix which helps us to analyse if

the extract of quality characteristics is effectual to satisfy the customer requirements in a first step.

By establishing a relation between the customer requirements and the quality characteristics we get to know whether or not quality characteristics match the demand of the requirements and up to which degree. The quality characteristics are abbreviated with QC in the table 5-7. The foci concentrate on the horizontal addition of the relations given in the relationship matrix of the house of quality. The results of the analysis are demonstrated in table 5-7.

Table 5-7. Analysis of Relationship Matrix according to the example of the VTB Support System

Analysis of Relationship Matrix according to the example								
Customer Requirements	**QC: all**		**QC: VPM**		**QC: CM**		**QC: VTI**	
The system should …	**Total**	**Index**	**Total**	**Index**	**Total**	**Index**	**Total**	**Index**
FT13 … help to choose resources to satisfy the requirements of stakeholders.	82	1.1	30	1.45	44	1.31	8	0.37
FT14 … help to choose the right technology to insure effective VPM.	54	0.75	36	1.74	8	0.24	12	0.55
FT21 … provide that VPM is based on agility.	94	1.26	50	2.41	24	0.72	20	0.92
FT23 … help that leadership enhances VPM.	60	0.8	26	1.26	12	0.36	22	1.01
FT30 … help to identify required resources of organisations and projects.	76	1.02	10	0.48	50	1.49	16	0.74
FT34 … help to staff team members in projects with the support of CM.	68	0.91	8	0.39	50	1.49	10	0.46
FT40 … help to generate new competencies to implement new resources in the NPD process.	76	1.02	12	0.58	48	1.43	16	0.74
FT41 … help team members to adopt their competencies in the NDP process.	98	1.31	14	0.68	60	1.79	24	1.11
FT50 … help to establish sustainable relationships in-between team members and stakeholders.	66	0.88	16	0.77	18	0.54	32	1.47
FT57 … provide a continuous support of communication to increase team member satisfaction.	118	1.58	30	1.45	44	1.31	44	2.03
FT68 … help to embed virtual teams in the organisation.	52	0.7	8	0.39	16	0.48	28	1.29
FT70 … foster VTI to enhance knowledge of the organisation.	52	0.7	8	0.39	16	0.48	28	1.29
Ø	74.7	1	20.7	1	33.5	1	21.7	1

We refer to table 5-7 to find out strengths and weaknesses of the existing quality characteristics in view of the demand of the requirements. Furthermore, through this approach these requirements whose demands are not achieved by the presented existing quality characteristics can be easily identified. The indexes allow additional comparison by division with the mean values. Regarding all quality characteristics of the three different domains (QC:all) the level of satisfaction of function *"FT57 The system should provide a continuous support of communication to increase team member satisfaction"* by the quality characteristics of all domains is 118, which is an index of 1.58, whereas the function *"FT68 The system should help to embed virtual teams in the organisation."* is satisfied at a level of 52, which represent only an index of 0.7.

Concentrating on how the respective quality characteristics of the different domains respond to the demand shows for FT57 a high index in each domain (QC:VPM = 1.45; QC:CM = 1.31; QC:VTI = 2.03). As function FT57 is allocated to the domain of VTI (figure 4-10) it is normal that QC:VTI responds the best on the demand. Interestingly, also the QC:VPM and QC:CM satisfy its demand significantly which seems to be based on the fact that the aspect of communication is also important in the other domains. In contrast, FT68 is exclusively well satisfied by QC:VTI (index: 1.29) but less by the others (QC:VPM = 0.39; QC:CM = 0.48). Regarding the index of QC:all (0.7) highlights that QC:VTI responds the best to this requirement. This counts for the most of the presented customer requirements in this work. They are the best satisfied by quality characteristics that are assigned to their domains VPM, CM, or VTI. Those functions that have a generic impact like FT68 are also well responded by quality characteristics of other domains. To summarise, it is to say that it might be useful to make a first assignment of quality requirements to the respective domains as it have been done in table 4-7 with the catalogue of examples of recommendations and technical solutions. Depending on which focus is taken, it might make sense to consider the different domains individually. The analysis of QC:All may falsify the results.

The second focus of concentrating on the quality characteristics allows getting an understanding about the relationship matrix from a different point of view. In this way, the vertical addition of relations measures the contribution of quality characteristics to the customer requirements. The results are visualised in table 5-8.

Table 5-8. Analysis of the Quality Characteristics according to the example of the VTB Support System

Analysis of the Quality Characteristics according to the example

	VPM1	VPM2	VPM3	VPM4	VPM5	VPM6	VPM7	VPM8
Total	44	36	24	16	28	24	44	32
Index	1,18	0,97	0,64	0,43	0,75	0,64	1,18	0,86

	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8
Total	53	53	42	44	50	38	46	62
Index	1,42	1,42	1,13	1,18	1,34	1,02	1,23	1,66

	VTI1	VTI2	VTI3	VTI4	VTI5	VTI6	VTI7	VTI8
Total	32	28	30	26	28	38	40	36
Index	0,86	0,75	0,8	0,7	0,75	1,02	1,07	0,97

After determining a hierarchy of the different customer requirements the quality characteristics must be translated into precise specifications. As we are exclusively given an example of the approach and the quality characteristics have been chosen stochastically, we present specifications of the quality characteristics of the different domains that satisfy the best the entire customer requirements. In this example these are: VPM1 (1,18) and VPM7 (1,18), CM8 (1,66) and VTI6 (1,02).

Detailed recommendations for the specific quality characteristics are given in the following list. They are determined as technical solutions:

- VPM1 Provide a common architecture and shared platform elements (Marion and Schumacher, 2009).
    - Implement Web 2.0 applications (Marion and Schumacher, 2009).
    - Provide structure for virtual team work with formal procedures and structured processes (Lurey and Raisinghani, 2001; Rice et al., 2007).
- VPM7 Boost animation by virtual team leader or team members.
    - Use various numbers of different technologies and collaboration to be more efficient (Kayworth and Leidner, 2000).
    - Support virtual team leaders to use advanced forms of communication technology.
- CM8 Help virtual team members to offer voluntarily their competencies to take new tasks as occasion that helps to develop their performance.
    - Make people aware of the effects of their actions and helping them to apply meaningful and intentional purposes to each action.
    - Foster transparency of project mission and individual team assignments.
    - Foster transparency of project values/expectations - quality, quantity of work, communication, teamwork, etc.
    - Foster transparency of project status, issues, problems and changes to all project team members.
- VTI6 Help virtual team members to learn from virtual collaboration experiences to adapt their behaviour accordingly (Ulbrich et al., 2009).
    - Conduct regular periodic face-to-face meetings: Activities before and after collaboration meeting are higher (Kayworth and Leidner, 2000; Hameri and Nihtilä, 1997).
    - Identify which plans and strategies were not successful in the past and why, and aim to improve them.

A catalogue of recommendations and technical solutions is provided in table 4-7. The quality characteristics are noted as examples. In a further step the technical solutions should be translated to indicators. For instance, the technical solution "establish a help-desk to provide assistance" could be concreted with the indicator of "a minimum of 4 h response time".

Based on our results of the application with smE-MPOWER the following § 5.3 focuses on web 2.0 tools.

5.3 Zooming in on Web 2.0 tools

Many organisations and projects use web 2.0 tools without structure, objectives and measurement if the tools are adapted and able to obtain objectives by their use (Prinz et al. 2010). Organisations and projects should understand the implication of web 2.0 tools and develop strategies to use them effectively (§ 2.1).

We focus on two parts in this § 5.3. Firstly, a brief state of the art of web 2.0 tools to present the tools we are dealing with in this PhD thesis (§ 5.3.1). Secondly, an enquiry is presented in § 5.3.2 that focuses on web 2.0 tools in relation to the VTB Support System. With the help of this enquiry based on interviews with 34 participants we aim to provide propositions according to the VTB Support System.

5.3.1 Web 2.0 tools

To maintain the complex relationship between employees, customers or stakeholders, organisations and projects need to use collaborative applications and approaches that help to disrupt inter-organisational or intra-organisational boundaries. Web 2.0 tools offer mechanisms to bring geographically dispersed project members together, to enhance organisational communication, collaboration and productivity. Web 2.0 applications can play an important role in the NPD process by offering effective media for communication and disseminating information. They have reached a state of maturity that makes them easily useful to simplify the communication and the exchange of all kinds of data and knowledge.

Hameri and Nihtilä (1997) distinguish that web-based systems provide to "(…) team members easy access to engineering drawings, 3D models, parameter lists, prototype test results and other engineering information" as well as information "(…) about project structure and schedules, (…) meeting notes, newsgroups and electronic bulletin boards." These ICT applications are rather used for sharing and disseminating information than for fostering collaboration and team building. As this PhD thesis focusses on the aspect of virtual team building we concentrate primarily on the communication part of ICT applications, as web 2.0 tools do.

Referring to Stevens et al. (2009) especially in early phases of distributed NPD virtual teams need a well designed selection of web 2.0 tools. They should efficiently support knowledge creation, learning processes and creativity. Structured information and explicit knowledge may be exchanged in later phases of the NPD process with other tools.

If applications are not used properly, the collaboration does not guarantee success (Prinz et al., 2010). Even if technology enables the collaboration process, the key success factor for efficient collaboration is the willingness of the team members to participate and to contribute (Walker, 2006). People are needed who wish to collaborate, have an openness of change as well as a high level of trust.

The presented web 2.0 tools present either asynchronous or synchronous communication, but rarely both. It may be difficult for virtual team members to switch between tools and move fluidly across the asynchronous or synchronous barriers. In general, synchronous communication's support is complemented by asynchronous systems and the other way around. Normally,

virtual teams use a mix of various different web 2.0 tools (DeLuca et al., 2006). The choice of specific tools may be made on the basis of the level of familiarity to team members, social norms, minimisation of disruption of daily business etc. We propose a rational choice of web 2.0 tools in table 5-9.

Table 5-9. Proposition of Web 2.0 Tools and their Definitions

Proposition of Web 2.0 Tools and their Definitions	
Tools	**Synthesis of Definitions**
Instant messaging chat (Chat)	Instant written conversation area, where the real-time dialog appears line by line as in a book's dialog.
Forum (Fm)	Area opened by a moderator who suggests specific topics and invites members to post messages and comments. Previously called newsgroups.
Web conferencing (Conf)	Live meeting combining voice on the phone and onscreen presentations by a speaker. Guests see the screen of the leader, who can give the lead to anyone. The white board, where every participant can write on the screen, chat and pool are common additional tools. Also called webinars.
Blog	Personal web site where the owner posts messages and invites people to post comments. The site looks like a chronological list of messages and their comments.
Wiki	Web site which pages can be created and modified by visitors. A specific writing rule, e.g. a capital letter in the middle of a word, allows to create a new page with this word as its title.
Posting	Ability given to visitors to upload documents in a web site area.
Sharing	Ability given to a group of individuals to modify a unique document located in a web site place.
Commenting	Ability given to web site visitors to add a written remark below a document, a video, a photograph, a product description, etc.
Polling	Surveying internauts' opinion with online questionnaires.
Rating	Evaluation by web visitors of content in a web site. It can be a document, an article, a product or service, a proposed project, a person, etc. The evaluation is made on a scale and the average mark is published close to the rated content.
Social networking (S.N.)	A website where community members post in a personal area their profile, photo, interest and links with other persons. It allows authorised visitors creating groups and provides interaction tools as chat, forums, document posting, email, IP voice or web conferencing and commenting. Information about members is linked with their activities.
Tagging	Ability to add and share favorite keywords linked to a document, photo, video, etc. Also called bookmarking, they share links of websites. Associated with RSS they allow to be kept posted.
Really simple syndication (RSS)	Ability to get a message when specific tagged pages or documents are new. The new content can be automatically published into another web site.

Proposition of Web 2.0 Tools and their Definitions	
Mobile messaging	Ability to send short messages (tweets) to groups on their mobile devices and get their feedback.
Remote control	Ability to use the PC of a person remotely. The mouse and keyboards of both persons become active on one of the two PCs.
Pod cast and video casting	Ability on specific viral-based web sites to post rich media documents, tag them, comment them and send their link to groups. Used for videos, audio documents.
Learning Management System (LMS)	Dedicated to tracking learner's online activities. Many include forums, blogs and web conferencing.

These web 2.0 tools are evolving fast with the evaluation of technology and should be regularly updated. The eleven most popular of the these tools were selected with the help of the enquiry and organised into eight following groups of tools for this study: instant messaging chat (Chat), forum (Fm), web conferencing (Conf), blog, and wiki, document posting with document sharing (P.S.), commenting with polling and rating (C.P.R.), social networking (S.N.).

5.3.2 Industrial Context: Presentation of the Study

We compare the results of the presented application with smE-MPOWER (§ 5.2) with another study that was done during a collaboration with M. Marc Diviné of A2Z-Innovation, IAE-Paris, University Paris1 Panthéon-Sorbonne (Diviné et al., 2010).

Interviews were organised with 34 marketing managers. With the help of this enquiry we aim to provide propositions based on the VTB Support System. The choice of the interviewees of the enquiry is based on following criteria:

- Employees of organisations that employ over 5000 employees worldwide,
- Team leaders working in marketing department as manager,
- Employees who are involved in virtual teams as team leaders in mid or long term interdisciplinary NPD projects,
- Employees based in France in order to limit cultural differences.

34 employees with this profile who work in different organisations accepted to participate at interviews for the enquiry. Those 34 organisations present 41% of organisations with over 5000 employees in France that is in total about 82. 16, 4%, of the 34 organisations represented in this study belong to the Stock French Index CAC40.

5.3.3 Industrial Needs

The results of the enquiry are put in trlation with the customer requiremùents according to the application wtih smE-MPOWER (table 5.5). They are compared with the extract of results of the relationship matrix (figure 5-3). They present the interrelation of each web 2.0 tool. These val-

ues have been calculated by the extract of the VTB Support System, according to the application with smE-MPOWER. The customer requirements are based on the functional analysis and the fulfilment of their demand by recommendations and technical solutions. The enquiry helps to compare the theoretical results with the actual use of the tools in the industrial practice. We verify whether the selection of tools deducted from the requirements of the VTB Support System and the recommendations and technical solutions is the same as the tools in use or the tools best rated in interest.

5.3.4 Presentation of the Application

The interview took about an hour face to face or via phone. It was structured in three parts. It started with an introduction part on the definitions of 20 existing web 2.0 tools in order to have to a common understanding (table 5-9). The second part explored which tools were used by the virtual teams in that the participants were involved. We also investigated whether other tools were used apart from the 20 listed. In the third part of the interview, the interviewee was asked to evaluate her/ his interest in the use of the tool within the virtual teams, on a scale from 1 to 10. The interest was demanded also for tools which were actually not used in the organisation or in projects. This was understood as the probability of team use within the organisation if they had been available. Half of the interviewees had to consult other persons and come back with their answers.

5.3.5 Analysis and Results

We aim to compare the theoretical results of the house of quality with the industrial reality. Therefore our focus is set on the eight chosen quality characteristics of the web 2.0 tools: instant messaging chat (Chat), forum (Fm), web conferencing (Conf), blog, and wiki, document posting with document sharing (P.S.), commenting with polling and rating (C.P.R.), social networking (S.N.). The results of the relationship matrix in consideration of the web 2.0 tools and the selected quality characteristics by smE-MPOWER (table 5.5) are illustrated in table 5-10.

Table 5-10. Results of the Relationship Matrix according to the Web 2.0 Tools

Results of the Relationship Matrix according to the Web 2.0 Tools

	WEB								
	WEB1 Chat	WEB2 Forum (Fm)	WEB3 Web Conferencing	WEB4 Blog	WEB5 Wiki	WEB6 Posting & Sharing (P.S.)	WEB7 Commenting, Rating, Pooling (C.P.R.)	WEB8 Social Networking (S.N.)	
FT13 … choose resources to satisfy requirements …	O	O	Θ	▲	▲	Θ	Θ	O	38
FT14 … choose the right technology to insure effective VPM.	O	O	Θ	▲	O	O	Θ	▲	32
FT21 … provide that VPM is based on agility.	Θ	Θ	Θ	O	O	Θ	Θ	Θ	60
FT23 … help that leadership enhances VPM.	▲	▲	Θ	▲	O	Θ	Θ	O	36
FT30 … identify required resources of organisations and projects.	▲	O	▲	O	▲	O	O	O	18
FT34 … staff team members in projects with the support of CM.	▲	▲	▲	▲	▲	▲	▲	O	10
FT40 … generate competencies to implement new resources in NPD…	▲	▲	▲	O	▲	▲	▲	▲	10
FT41 … help team members to adopt their competencies in NDP…	▲	O	▲	▲	▲	▲	▲	O	12
FT50 … establish sustainable relationships …	Θ	O	O	O	▲	▲	▲	Θ	30
FT57 … support of communication to increase team member satisfaction.	Θ	Θ	Θ	O	O	Θ	Θ	Θ	60
FT68 … embed virtual teams in the organisation.	▲	▲	▲	O	Θ	▲	▲	O	20
FT70 … should foster VTI to enhance knowledge of the organisation.	O	O	O	Θ	Θ	O	O	O	36
	42	40	56	32	36	50	56	50	

Legend: Θ Strong Relationship (9); O Moderate Relationship (3); ▲ Weak Relationship (1)

The focus of interpretation distinguishes the interrelation between three types of value for each web 2.0 tool: 1) the value provided by their relation to the customer requirements of the VTB Support System based on the house of quality, 2) the actual use of each tool based on the enquiry and 3) the interest rated by the interviewees in the tool also based on the enquiry. The results of valuing the web 2.0 tools in three kinds are depicted in table 5-11.

Table 5-11. Results of Valuing Web 2.0 Tools

Results of Valuing Web 2.0 Tools									
House of Quality	**Chat**	**Fm**	**Conf**	**Blog**	**Wiki**	**P.S.**	**C.P.R.**	**S.N.**	**Ø**
Relation to customer requirements	42	40	56	32	36	50	56	50	45.25
Index	0.93	0.88	1.24	0.7	0.8	1.1	1.24	1.1	1.00
Enquiry									
% of use in the enquiry	1.38	0.83	1.20	0.53	0.43	1.49	0.88	1.26	1.00
Interest rate in the enquiry	1.01	0.95	1.32	0.82	0.78	1.29	0.93	0.89	1.00

Table 5-11 shows the three kinds of valuing the web 2.0 tools, resulting from the relationship matrix, the actual use and the interest in the enquiry. The size of the enquiry with 34 answers

is such that the 95% confidence interval is maximum (1.96 x the standard deviation), i.e. 18% each side of the measured value. In the other way, the vertical addition of relations measures the contribution of the web 2.0 tools to the functions. The indexes allow additional comparison by division with the mean values and a comparison with the data of the enquiry. The index highlights how the web 2.0 tools answer to the need of the customer requirements.

The first analysis of the enquiry is extricated from the differences between "actual use" and "interest rating". The web 2.0 tools instant messaging chat (Chat = 1.38 and 1.01) and social network (S.N. = 1.26 and 0.89) are overused compared to their interest estimation. The tools forum (Fm = 0.83 and 0.95), web conferencing (Conf = 1.20 and 1.32) and commenting, polling and rating (C.P.R = 0.88 and 0.93) represent close values. On the opposite, the tools blog (blog = 0.53 and 0.82) and wiki (wiki = 0.43 and 0.78) show an interest at a higher level than their actual use.

The focus on the quality characteristics shows that blog is valued with an index of 0.7 whereas wiki is valued 0.8. Both have a low use in the industrial day life of our interviewees (blog = 0.53; wiki = 0.43), what relative this result. Web 2.0 tools include the ability to build on project partners' distributed contribution to capture tacit knowledge. Blogs and wikis are predestined to share unstructured information based on projects or processes that are not strictly pre-defined but help to collaborate in an adaptive way to find innovative solutions. Structured information must be furnished in another way.

The web 2.0 tools web conferencing (Conf = 1.24) and commenting, polling and rating (C.P.R. = 1.24) satisfy the best the demand of the extract of the customer requirements of smE-MPOWER. But in the actual use of C.P.R. the enquiry shows that C.P.R. is unfortunately under-represented (C.P.R. = 0.88). A virtual team should be in this case encouraged to use more this tool even if the interest rate seems to be very high (C.P.R. = 0.93). Interestingly, instant messaging chat is "overused" (% use of Chat = 1.38) and "over evaluated" (interest rate: Chat = 1.01) by the interviewees in the industrial day life, but responds only "correctly" to the customer requirements (Chat = 0.93).

The application delineates that 2.0 tools include rich internet applications that may be used in different ways for different needs. Software is provided as service and the web is used as a general platform. Web 2.0 offers by open standard and user-friendly tools for creating content, the ease of use featured in virtual team environments. The fast development of web 2.0 tools and the regular arrival of new tools make it necessary to revaluate the use and the perceptions. The list of these tools increases quickly, so that the understanding and the choice of them becomes a managerial issue. This is where the VTB Support System should be established.

5.4 Synthesis: Variety of Utilisation

Three different kinds of application have been presented in this chapter 0, one that considers the theoretical evaluation, one project application with smE-MPOWER, and one with the focus on an enquiry on web 2.0 tools. They give insights on the large variety of possibilities that the VTB Support System offers.

The first application serves as an evaluation framework (§ 5.1). We refer to Tuckman's Team Development Model (Tuckman, 1965). At the same time, this application provides a second supporting structure that facilitates a positioning on the hierarchical tree and important functions of organisations and projects during the constitution of the virtual team depending on its specific needs. This allows coping with the complexity of the house of a VTB Support System by dividing the customer requirements in different categories. The complexity may be easier handled separately in several smaller matrixes. This may help organisations and projects during the constitution of the virtual team to position on the hierarchical tree and identify the most important functions depending on their specific needs. The variations of using the VTB Support System are flexible. They depend on the need of the respective organisation or project and its positioning on the hierarchical tree. We have provided in table 5-3 an extract of VTB Support System's generic aspect.

The second application in § 5.2 is conducted with a European funded project, named smE-MPOWER. Carnevalli's and Miguel's (2008) postulate in their literature review focussing on QFD that it seems to be difficult to identify the most important customer requirements. In our case exclusively twelve functions have been chosen by our expert. These take all three domains VPM, CM and VTI into account as well as all five phases of Tuckman's Team Development Model: forming, storming, norming, performing and adjourning. In this case we referred to the first application that allowed our expert to choose key functions. It was easily adaptable for this second case of application. Customer requirements are defined and analysed on the basis of an extract of 24 quality characteristics to demonstrate exemplarily the approach of this kind of application. Recommendations have been exemplarily translated to technical solutions that concentrate more in detail on the behalf of the customer requirements' adaptation to the industrial practice than the general recommendations. It is advised to set measurable indicators to be sure that the technical solutions are employed.

The third part § 5.3 is based on the results of the application with smE-MPOWER. We compare the results of the presented application with smE-MPOWER with an enquiry on web 2.0 tools that were organised in form of interviews with 34 marketing managers. This application highlights the flexibility of the VTB Support System that can be easily adapted on another focus. Web 2.0 tools are not conform to the general understanding of quality characteristics as they represent software applications and not recommendations or technical solutions. Nevertheless, the model is adaptable to this specific application. The enquiry helped to compare the theoretical results with the actual use of the tools in the industrial practice and helped us to draw recommendations and suggestions for further research to implement a system like ours in industry and, more precise, to virtual team leaders concerning the choice and use of web 2.0 tools. Care

must be taken in generalising our results, however given our small enquiry size. The size of the enquiry and the extract of the VTB Support System trigger an uncertainty level which has to be taken into account in our results.

More than to generalise the results of the second and third application, we intended to represent our approach of the VTB Support System to make future choices of quality characteristics or web 2.0 tools based on a robust basis. However, the small extract that we have given as example is not significant enough, but it gives sophisticated insights of how the VTB Support System may function in future.

6 Conclusion

In this PhD Thesis we provide an approach that helps to propose a tool of support, the VTB Support System, which facilitates to build virtual teams by giving recommendations and adaptable technical solutions.

The process of virtual team building is not just limited to the traditional understanding of "building" a team, but takes three aspects into consideration: its organisation, its staffing and its development. Therefore our understanding of virtual team building contemplates a technical and a human dimension. They are reflected in the three domains VPM, CM and VTI. The recommendations of the VTB Support System are identified in consideration of those three domains.

In order to build the VTB Support System, we use the approach of the functional analysis combined with the house of quality of QFD, as basic framework. This allows us to identify all the functions of the VTB Support System that describe its requirements and to deduce substantiated recommendations and technical solutions through the house of quality. The house of quality allows representing the recommendations and the functions in a matrix. It helps to evaluate the relationship between recommendations and functions and represents if a recommendation satisfies the demand of one or multiple functions.

The system is situated in the context of NPD. An extremely interesting attribute of NPD projects is the uniqueness of the NPD process and the products themselves. NPD is implemented in the functional analysis as environment and as this reflected in the functions. The VTB Support System is applied in three different cases, which underlines the generic aspect of the model and the fact that it is not only adaptable in organisations but also in projects without a real organisational structure.

The VTB Support System may be used in different kinds and on different levels. It serves as communication and planning tool and is considered as support to build virtual teams in the beginning of a project, in the middle or in the end. In the early project phase it might help to define requirements and to decide about technical solution on a robust basis. In a running project those requirements might have changed and the focus might be set on different main functions. In the end of the project the system could help to evaluate the virtual team building process and to identify lessons learned for future virtual teams.

In most cases, requirements are defined during the constitution of the virtual team, and they depend on its particular needs. In a traditional face-to-face team, decisions concerning the constitution of the project team are either already taken by the steering committee before the projects starts, or discussed between the project leader and the steering committee at the very start of the project. In the case of virtual team building decisions concerning the constitution of the virtual team are taken by the team members. The importance of the main functions is derived while building the project team and translated into percentages. When working in a project, either face-to-face or virtually two different kinds of population co-exist: individuals who work (the project team) and individuals who decide (the steering committee). In both cases, decisions have to be made in terms of the project, either at a strategic level or at an opera-

tional level. The system may also be applied by project managers, or the management at the organisation level.

6.1 Contributions

With regard to the main objective of this work to answer the research question: "How to support the building of a virtual team in the domain of VPM, CM and VTI?" we have treated several sub-objectives.

We presented the context of this PhD work that is set on CSCW, particularly on virtual teams in the domain of NPD, called Virtual Project/ Product Development Teams (§ 2). We defined three life cycles regarding the project, the product and the team and defined the according domains VPM, CM and VTI. Definitions have been given to describe the manner in which virtual teams collaborate. Furthermore, a synthesis highlighted concepts of the domains VPM, CM and VTI that are excerpted from the state of the art to provide a holistic view of virtual team building.

In order to satisfy the research objectives to describe the manner in which virtual teams collaborate (objective: 1) and to provide a holistic view of virtual team building (objective: 2) we identified main recurrent themes of virtual team building based on the state of the art, on our personal experience in European projects and industry as well as national and international exchanges with experts (§ 3). A survey of those themes has been provided regarding opportunities and risks for virtual team building. The main recurrent themes have been incorporated in the VTB Support System in form of environments while conducting the functional analysis (§ 4). They are reflected in the functions that describe the customer requirements of the VTB Support System. We cope with the objective to define the requirements of the VTB Support System (objective: 3) by providing a complete list of the identified functions. Recommendations and technical solutions have been analysed and developed (objective: 4) to improve virtual team building and a catalogue of recommendations and technical solutions has been provided to obtain the objective to translate the requirements into recommendations and technical solutions that are adaptable to industrial reality (objective: 5) (table 4-7). A part of them have been applied in the industrial reality (§ 5) which helped us (objective: 6) to proof the VTB Support System as tool of analysis, communication and planning. The VTB Support System has been introduced and used and recommendations (objective: 7) to the specific needs of the stakeholder have been given.

The main research question of this work: "How to support the building of a virtual team in the domains of VPM, CM and VTI?" has thus been answered in a very inclusive way. With the developed tool of the VTB Support System virtual team building might be facilitated in the domains of VPM, CM and VTI.

6.2 Limits

The VTB Support System is a generic model that claims to be adaptable to each context. This is the reason why its focus is very large and it is difficult to take all quality characteristics into account. According to Carnevalli and Miguel (2008) one of the most frequent challenges during

their literature review dealing with QFD was the difficulty in matters of the large size of the matrixes. Carnevalli and Miguel (2008) refer to Lowe and Ridgway (2000) who propose a maximum number of eight customer requirements and eight quality characteristics. Even if we think that an 8 x 8 matrix does not meet the demand of the complexity of the QFD we present an extract of the VTB Support System that is close to the 8 x 8 matrix. Working with smaller matrixes may comprise to work with a higher number of them. The house of quality may implicate the building of other matrixes that help to give more detailed recommendations throughout the virtual team building process as we have done in our example with the technical solutions (§ 5.2.4). The defined most important recommendations will be handled in a further matrix of the house of quality as requirements. In this second matrix technical solutions have to be suggested. This results in a chain of houses of quality, the deployment, which are more and more detailed in their specifications and adapted to different requirements due to the process of the implementation of the VTB Support System and the needs of each specific organisation or NPD project. Recommendations have in our case exemplarily been translated to technical solutions that concentrate more in detail on the behalf of the customer requirements' adaptation to the industrial practice than the general recommendations. It is necessary to set measurable indicators to be sure that the technical solutions are employed. In a final matrix the focus might be on indicators that describe exactly the technical solutions. Nevertheless, the maintenance of the measurement of those indicators seems to be difficult and in practice they are unfortunately rarely used.

Care must be taken in generalising the results of the application examples in view of the small size of the extract. More than to generalise the results, we aim to represent the approach of the VTB Support System. Even if the small extract that we give as example is not significant enough, it gives sophisticated insights of how the VTB Support System may function in future. It should also be considered that the analysis of the relationship and correlation matrix is not based on an algorithm but have to be conducted within a team of experts. As in this case a source of errors can not be totally excluded. This gives room for future research work, aiming at advancing the model by identifying and using algorithms. Further perspectives are presented in § 6.3.

6.3 Perspectives

In future, we aim to find out if the sum of the essential functions is satisfied by already existing techniques and concepts or if there are still recommendations and technical solutions missing in the literature or based on our personal experience in European projects and industry as well as national and international exchanges with experts to satisfy the functions. We will focus on the still missing technical solutions to cope the demand of those functions. Firstly, we use concepts defined in different well-developed methodologies, secondly we aim to consult concepts that we find in the practical field. Additionally, we intend to provide an interrogation platform in form of the house of quality where recommendations and technical solutions of well-developed methodologies could be consolidated. This permits us to be as inclusive as possible also in the three domains of VPM, CM and VTI.

Another step will be to include the percentages of importance of the hierarchical tree to figure out the significance of each function. They may be included in the house of quality as planning matrix that shows the weighted importance of each customer requirement. In our application cases we handle the functions as equal as we have focussed exclusively on an extract of twelve. Even if virtual team members of a cross-functional NPD project are members of the same organisation, but from different functional areas within this organisation, there might be cultural differences. Employees with a background as Engineer use for instance a different set of working processes than employees from marketing. They might easily agree about a standard NPD process but however disagree about the importance of the different stages of the process. Marketing-oriented stages could be much more important to members from the marketing than they are to engineers. Specific virtual teams should confirm the customer requirements of the VTB Support System as well as the technical solutions. They could add weights to them in compliance with their evaluation of importance. This will lead to different scenarios that depend on the specific needs of the stakeholder.

In future application also the correlation matrix will be taken into account to see if quality characteristics have a specific rapport among each other and whether they could be realised together. Technical solutions should be compatible and coherent among themselves to be sure that can be applied together. Future research will concentrate on the validation of those technical solutions. This copes with the demand of the V-diagram (figure 4-1) that is used as model for future research to ameliorate the VTB Support System.

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Publications

The research work exposed in this PhD thesis has been object of several publications:

Journals:

Schumacher, M., Diviné, M., Stal- Le Cardinal, J., Bocquet, J.C. (2012). Virtual teams challenging human and technical web 2.0 dimensions. *International Journal of Networking and Virtual Organisations*, Vol. 10 (2), pp. 210-228.

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