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ACTA UNIVERSITATIS OULUENSIS

Raija Suikki

CHANGING BUSINESS ENVIRONMENT—EFFECTS OF CONTINUOUS INNOVATIONS AND DISRUPTIVE TECHNOLOGIES

FACULTY OF TECHNOLOGY,
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Academic dissertation to be presented, with the assent of the Faculty of Technology of the University of Oulu, for public defence in Auditorium IT116, Linnanmaa, on February 23rd, 2007, at 12 noon

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Abstract

Today's turbulent business environment, which is characterised by uncertainty and inability to predict the future, is extremely challenging. Mobile and Internet Protocol (IP) convergence, which brings together technologies and services from the mobile and Internet domains, has been identified as a discontinuity in the mobile telecommunications business. Additionally, new disruptive technologies are introduced together with new, complex products.

This research addresses the approach that, along with introducing disruptive technologies in the mobile and IP convergence era, a new operational mode is needed in the new product development (NPD) process. This study approaches the operational mode from five perspectives: business environment, competence development, process renewal, running technology pilots, and product reliability.

The research on the business environment area proposes two frameworks: one for building and describing and another for evaluating business models. The study on competence development arrives at the conclusion to propose a project management competence development framework. The third research perspective suggests that, when the business environment is changing, and disruptive technologies and continuous innovations create new kinds of products, it is likely that processes need renewal. Running technology pilots to involve customers early enough in new product development is proposed in the fourth research area. Finally, the fifth research topic proposes that it is essential for companies to be able to estimate the reliability of their products during the product development phase.

It is concluded that the new operational mode when introducing disruptive technologies requires reconsidering business models, special attention to competence development, process renewal, customer involvement in new product development, and requires a means to guarantee software reliability.

Keywords: competence development, disruptive technology, mobile and IP convergence, process renewal, product reliability

To my parents

Acknowledgements

It all started in spring 2000, when my daughter Mervi matriculated and started her university studies at Tampere University of Technology. Today, both of us are finalising our studies.

Twenty years had gone from the date when I finalized my Master's thesis. In autumn 2000, I contacted professor Pekka Kess, who gave me my first look at post-graduate studies in general, and then professor Harri Haapasalo promised to supervise my studies. Early in my studies, Harri advised me to form a steering group for them. And so I did. The members of the steering group were Harri from the University of Oulu, professor Pekka Abrahamsson from VTT Electronics, and Senior Program Manager Arto Pussinen from Nokia. We had meetings several times a year. At the meetings I received very valuable and fruitful advice and guidance for my research. Practically all the time Arto, Pekka and Harri were available to answer my questions and support my work. I deeply appreciate the support and encouragement I have received from Arto, my line manager at Nokia, who made it possible to use our working environment as the research environment. Many thanks to Harri, a co-author and an advisor, who tirelessly led me in the work of a researcher and Pekka who gave valuable words of advice and recommendations for my research papers and this thesis. Without you, Harri, Pekka and Arto, this thesis would not have been possible.

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This work took six years, and I appreciate how supportive my family has been – my parents Anna-Liisa and Antti Kuusela, my brother Kari Kuusela and his family, my sister Tuija Kuusela-Korva and her family. With this work I want to encourage my godson Antti in his future studies. Especially, I want to thank my daughter Mervi and her family - Sami and Tuuli - for their support and interest in my work. Finally, I thank my life-companion Matti for his continuous support, endless trust and tireless encouragement during my work.

Oulu, December 2006 Raija Suikki

List of abbreviations

BBN	Bayesian Belief Networks
BPR	Business Process Re-engineering
FMEA	Failure Mode and Effect Analysis
DfSS	Design for Six Sigma
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPC	Internet Protocol Convergence Business Program
ISO	International Organization of Standardization
NIST	National Institute of Standards and Technology
NPD	New product development
ODC	Orthogonal Defect Classification
PMCD	Project Management Competence Development
QFD	Quality Function Deployment
R&D	Research and Development
RQ	Research Question
SRE	Software Reliability Engineering
TQM	Total Quality Management
XP	Extreme Programming

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List of original publications

This thesis is based on the following publications:

I Suikki R, Goman A & Haapasalo H (2006) A framework for creating business models – a challenge in convergence of high clock speed industry. International Journal of Business Environment 1(2): 211-233.

II Suikki R, Tromstedt R & Haapasalo H (2006) Project management competence development framework in turbulent business environment. Technovation 26: 723-738.

III Suikki R (2007) Process Renewal Driven by Disruptive Technologies. International Journal of Business Innovation and Research 1(3): 281-295.

IV Suikki R & Haapasalo H (2006) Business impact of technology piloting – model for analysis in different phases of development cycle. International Journal of Innovation and Technology Management 3(2): 209-235.

V Suikki R (2006) Practical Use of Software Reliability Methods in New Product Development. Proceedings of the 32nd EUROMICRO Conference on Software Engineering and Advanced Applications, EUROMICRO SEAA 2006, Cavtat/Dubrovnik, Croatia, 232-239.

Contents

Introduction

This research was initiated as a response to better understand what kind of operational mode is needed to promote the development and implementation of new disruptive technologies in the telecommunications industry.

The case unit of this research was the Internet Protocol Convergence Business Program (briefly IPC), a temporary Research and Development (R&D) unit that operated in Nokia Mobile Phones and later in the Nokia Multimedia business group. The Nokia Multimedia business group makes advanced telecommunication products such as devices and solutions for imaging, games, media, and businesses. IPC was founded in 2002, and it was discontinued at the end of 2004, when the personnel and ongoing projects were merged with its operational mode and processes in the permanent organisational structures of Nokia Multimedia. IPC consisted of both conventional R&D functions and business development activities and had roughly one hundred employees. IPC was an experimental organisation whose main objective was to find an efficient and fast way to develop new applications, technological enablers, and features for the use of New Product Development (NPD) projects. IPC acted as a pioneer and an adventurist in creating and testing new technologies that would provide new opportunities for customers.

1.1 Background and overview

Today's telecommunications business environment, which is characterised by uncertainty and the inability to predict the future, is challenging: the business environment is changing quickly and the market requires new products with ever shorter product development cycle times. So-called disruptive technologies (Christensen 1997) might cause major changes in a business model and radically alter market positions. Paap & Katz (2004) define disruption as follows: "The disruption in the term 'disruptive technology' is not an attribute of technology. Rather, it describes the effect that some technologies appear to have on markets affected by technology-based innovation and the frequent downturn in the success of major firms that compete in those markets when they fail to adopt the new technology in a timely way. It is a disruption in the business model."

We still live in a time of hyper-competition (D'Aveni 1995), which leads to the situation where cycle-times in product development are ever shorter. We talk about breakthrough products that require radical innovations, i.e. discontinuous improvement. They are riskier than less innovative products, because the product itself is new, the market is unknown, and time to market needs consideration (Deszca *et al*. 1999, Leeman & Winer 1997). According to Moore (1999), products that require us to change our current mode of behaviour or to modify other products and services we rely on are called discontinuous innovations, while continuous innovations refer to the normal upgrading of products. The ability to innovate continuously and faster than competitors is vital to a company's competitive advantage (e.g. Costanzo 2004).

Convergence is a phenomenon in which two or more existing technologies, markets, producers, boundaries, or value chains combine to create a new force that is more powerful and efficient than the sum of its parts (Hartman *et al.* 2000). Mobile and IP (Internet Protocol) convergence brings together technologies and services from the mobile and Internet domains (e.g. Darby 1999, Kari & Kilpeläinen 2001, Sengodan *et al.* 2000). The old and proven ways of doing business are no longer sufficient for success. One of the challenges is to create a profitable business model for the mobile and IP convergence era (e.g. Kari & Kilpeläinen 2001, Kelly *et al.* 2002, Steinbock 2001). The mobile handset manufacturers' proven way of doing business was selling mobile terminals in a highly competitive market. These terminals were embedded systems, incorporating software and hardware. Lately, however, an alternative approach has been introduced: software is nowadays also sold separately from hardware. In the mobile and IP convergence era, the significance of this development will be even more emphasised. This means, that in addition to selling mobile terminals as embedded systems, the consumers can be offered the possibility to buy additional software applications for their devices. As a consequence, the mobile IP software application business is emerging.

Disruptive technological changes in the NPD process require the development of new competences. Companies that are willing to survive in competition must react to the changes quickly. According to Nyhan (1998) competence development is seen as one of the critical strategic factors ensuring companies' competitiveness. Competence is difficult to ensure, because it is distributed in several levels of the company. Examples of these levels are strategic or operative, and technological or business competence. However, winning corporations must acquire these competences. In high clock speed industries, where product life cycles are short, this acquisition process is even more complex, because the content of the competence may not be known long beforehand. These boundary conditions have given rise to much discussion (e.g. Ivergard 2000) about how to gain these competences and create organisational and learning environments, such as learning organisations, which foster employees' skills and sense of initiative and responsibility. The latest management and leadership literature (e.g. Sydänmaanlakka 2003, Ivergard 2000, Laughton & Otteweil 2003) stresses the managers' and leaders' role in this kind of environment i.e., business competence management inside the organisation. Common answers to meet these challenges are the learning organisation, new ways of doing things, teamwork, communications, focus, and self-management. The organisation's role is to provide conditions to ensure this kind of competence development (Senge 1994, White *et al.* 1996, Goldberger 1999). Project management competence consists of knowing the project environment, project management skills, leadership skills, and personal growth. Furthermore, Cavaleri & Fearon (2000) propose that project management structures provide a natural home for organisational learning. Project-oriented business management is one approach to manage turbulent business. For future challenges managers need better knowledge of project management, better understanding of the project orientation in business and the turbulence of the environment they are working in.

When moving from development of continuous improvement products to continuous innovation products, old and fit for use processes might not be appropriate any more; process renewal should be considered along with the new operational mode. Possible approaches to process renewal are total quality management (TQM) (e.g. Dale 1999) and business process reengineering (BPR) (e.g. Hammer & Champy 1993). TQM, a management system that aims at long-term continuous improvement in customer satisfaction and real costs (e.g. Fazel 2003), has been used in countless companies since its launch. BPR, on the other hand, is the rapid and radical redesign of strategic processes to optimise the workflow and productivity in an organisation. It is generally accepted that TQM can generate a sustainable competitive advantage (e.g. Prajogo & Sohal 2001), and the importance of tools and techniques for TQM improvement has been proved (e.g. Tarí & Sabater 2004). Chong & Rundus (2003) claim that the higher the degree of market competition the more positive are the relationships between TQM practices of customer focus and product design and organisational performance. Numerous papers have been published on the relationship of TQM and BPR, and their similarities and differences (e.g. Ahire & Waller 1994, Fazel 2003, Gore 1999, O'Neill & Sohal 1999). Fazel (2003) says that both TQM and BPR embrace the same ideas and goals for organisational improvements and both encourage employee empowerment, teamwork, quality, change, and focus on the customer. Similarly, many studies give proposals on how to use TQM and BPR. Fazel (2003) concludes that TQM and BPR should be used to complement each other; TQM extends a successful BPR program, and BPR is the turning point of a TQM initiative. Also O'Neill & Sohal (1999) summarise other authors' ideas that TQM and BPR should form an integrated strategic management system within organisations. They say that both continuous and discontinuous improvements are needed.

Lately, one more challenge is recognised: to identify customers' requirements when technology platforms are unfolding, products are still in development and customers lack experience with the products (Deszca *et al.* 1999). In addition to moving from continuous improvement to continuous innovation, product and project management has changed substantially in the telecommunications industry. This is partly a consequence of moving from the traditional, so-called waterfall model, to an incremental software development process (see e.g. Haapasalo & Ylihoikka 2004). All this sets new requirements for companies' R&D activities and on reliability and the other quality attributes of their products.

Testing has gained a lot of attention in recent literature (Pol & Veenendaal 1998, Staab 2002, Davis 1997, Black 2004), as well as verification and validation (IEEE (1012-2004), NIST 1996). However, verification and validation focus on testing against specifications rather than validating business needs. ISO 9000-3 defines design verification as an activity that develops procedures that specify how design outputs, at every stage of the product design and development process, should be verified. The idea is that these procedures should verify that outputs satisfy design-input requirements. This is clearly a technical activity which takes place inside a company. Further, ISO 9000-3 defines validation as an activity that develops procedures to validate the assumption that the newly designed products will meet customer needs. Outsiders to the company are connected to the product development process, firstly, when developing design validation procedures that confirm that the new product performs properly under all real-world operating conditions, secondly, confirming that the new product will meet every legitimate customer need and expectation, and thirdly, ensuring that validations are carried out early in the design process whenever this will help guarantee that customer needs will be met. The conventional NPD process is viewed as a multi-phase process starting from idea generation and progressing through to commercial launch (e.g. Lynn *et al.* 1996). However, when facing the challenges described above, the sequential phases of the steps no longer more work optimally even when there is an overflowing volume of tools inside the phases (Ulrich & Eppinger 1995). Instead, the newfound NPD process emphasises probing and learning from the experience gained through sequential probes (Lynn *et al.* 1996).

Until now, as already said, mobile handset manufacturers have sold mobile terminals that are embedded systems, incorporating software and hardware. The current trend is that the proportion of software in the devices is ever-increasing, and further, software is also sold separately from hardware. Consequently, in embedded systems where both hardware and software component reliabilities are combined to get system reliability, demands for software reliability increase. Therefore, software reliability is in the spotlight. The source of failures in software is design faults, whereas the principal source in hardware has generally been physical deterioration (Musa *et al.* 1987, Pressman 2001). Estimating software reliability seems to be difficult. Assessing or predicting software reliability is one of the biggest challenges in the software industry. The first software reliability model was created in 1972 (Lyu & Nikora 1992). So far, more than one hundred software reliability models have been developed (Kan 2003). However, none of them has achieved the status of a de facto standard. Software reliability estimation is important as it provides a means to predict software maturity i.e., when the software is ready for release, and also to manage software risks during the different R&D phases of NPD projects.

Despite changes in the business environment and the introduction of new innovative products, the NPD process is still the solid foundation for product development, even though it requires updating due to the above-mentioned facts. Ulrich & Eppinger (1995) presented the generally known NPD process that includes five phases: concept development, system-level design, detail design, testing and refinement, and production ramp-up. Cooper’s (2001) new product process includes product development, in-house product testing, customer tests of the product, trial sell, trial/pilot production or operation. Cooper’s (2001) Stage-Gate process is a conceptual and operational model for moving a new product project from idea to launch. Stage-Gate breaks the innovation process into a predetermined set of stages, each stage consisting of a set of prescribed, cross-functional, and parallel activities. Generally these kinds of models focus on developers’ interests to verify specifications, not to adjust features to the customers, even undefined needs. Den Ouden (2006) talks about the business creation process. She uses the term “business creation process”, because it has a wider scope than NPD process. It includes the main processes such as strategy, new product development, manufacturing, market introduction, and sales and service. In each of these processes decisions are made that influence the end user experience, and if the product is falling short of the end user's expectation, they are dissatisfied and might complain (Den Ouden 2006).

1.2 Research environment

According to Kostamo (2001), in the 1990's in the mobile telecommunications industry there were only a few players who had a big market share. The distribution channels of mobile phones included telecommunications operators, retail sale chains owned by them, and various distribution enterprises. Today, there are thousands of players in the playground. After switching to the mobile Internet world, the playground became more complex. Digital data transfer, data processing and multimedia technologies are brought to wireless communications with the Internet. All of them are still evolving. In the Internet playground the essential players include terminal manufacturers, software houses, Internet- and data network equipment manufacturers, mainframe-, server- and memory device manufacturers, and telecommunications operators including IP operators, content providers and portals. The relationships between them are complex. Thus, the case company is faced with a wholly new competitive environment.

The market structure is likely to evolve, and the roles of players change and intervene in formerly restricted areas of other players (Kostamo 2001).

Zoller *et al.* (1999) say that numerous groups of players are all willing to take advantage of the new mobile world, which will increase competition. Mobile device manufacturers will face the threat of new players that, in some cases, will have the skills and technology they lack. Powerful industry alliances and joint ventures are trying to define standards. The winners will shape how the market will develop.

Chesbrough & Rosenbloom (2002) argue that the inherent value of a technology remains latent until it is commercialised in some way. If the technology does not fit in the current business, it is essential the companies expand their perspectives to be able to find the right business model in order to capture value from that technology. Even though a technology seems to embody attractive potential value proposition, its commercialisation can fail, if the firm does not discover the proper business model capable of realising that value.

According to Chesbrough & Rosenbloom (2002), it is often difficult for firms to manage innovations that do not fit into their previous experience, when their earlier beliefs and practices do not apply. When attempting to commercialise promising new technological capabilities, current perspectives can pose a constraint. Especially when old models have been successful, they provide both a source of value realisation, and a potential source of cognitive bias. Even if a technology makes little or no business sense in a traditional business model, it may capture great value when brought to market with a different model. A business model integrates earlier perspectives into a coherent framework that takes technological characteristics and potentials as inputs, and converts them through customers and markets into economic outputs. It is thus conceived as a focusing device that mediates between technology development and economic value creation.

1.3 Research objectives and scope

The main research problem arises from the fact that there has only been a little research done on the operational mode, processes, and practices for promoting development and implementation of disruptive technologies. The case unit lacked refined and established methods, processes and operational mode to introduce disruptive technologies. An efficient and effective operational mode is needed to assure profitable breakthrough in the market, to guarantee competitive advantage over rivals, and to react quickly to changes in the business environment and technological development. In particular, a quick response is required when disruptive technologies are introduced by competitors and the case company has to catch up with the leader to remain competitive in the new situation.

The research problem of this study is stated as follows:

What kind of operational mode is needed to introduce disruptive technologies?

This problem is approached from five different perspectives - business environment, competence development, process renewal, running technology pilots, and product reliability - where five research questions (RQ) are formed (table 1) for compiling the research findings as a whole.

Table 1. Research questions.

#	Research question
RQ1	How to build and evaluate business models?
RQ2	How to develop competences?
RQ3	How to renew processes?
RQ4	How to involve customers?
RQ5	How to estimate the reliability of products?

These research questions are related to each other, even though their focus is different. The research questions - from one to five – move from a wider to a narrower subject matter. Fig.1 depicts the scope of the thesis - the individual research areas are illustrated with a cone. The cone depicts the change in the width of the perspective when moving from one research area to another; the deeper one goes into the cone the narrower the perspective becomes. When considering business models one must also keep in view other industries, not just the case company. When competence development is studied, other industries are considered, but the main focus is in the case company. Going further in the cone, process renewal focuses more on the case unit and discusses how the renewal was experienced in the case unit. Finally, the perspective regarding running technology pilots and product reliability studies is on the project level.

The research subjects were chosen in order to understand the nature of the operating area as a whole. Each of these areas is large and would be worth further studies. However, this scope was chosen as an initial move. The first research question (RQ1) considers the business environment to create the basis for selecting an appropriate and profitable business model. The second research question (RQ2) reviews competence development to guarantee the company's ability and capability to succeed in introducing new technologies. The third research question (RQ3) examines processes and practices and their renewal driven by disruptive technologies. The fourth research question (RQ4) goes deeper in the technology and its implementation, and investigates customer involvement in the NPD process; customer satisfaction is one of the primary drivers of most contemporary companies. Finally, the fifth research question (RQ5) discusses the estimation of reliability – especially software reliability as great part of a new technology is implemented through software.

Considering organisational dimensions, the scope of the research on business models (RQ1) is valid on the company level and even beyond the case company. Competence development (RQ2) research is discussed from the overall viewpoint of the case company. When progressing to studies of process renewal (RQ3), running technology pilots (RQ4), and product reliability (RQ5), the scope decreases in the organisational dimension from a business unit to a project level.

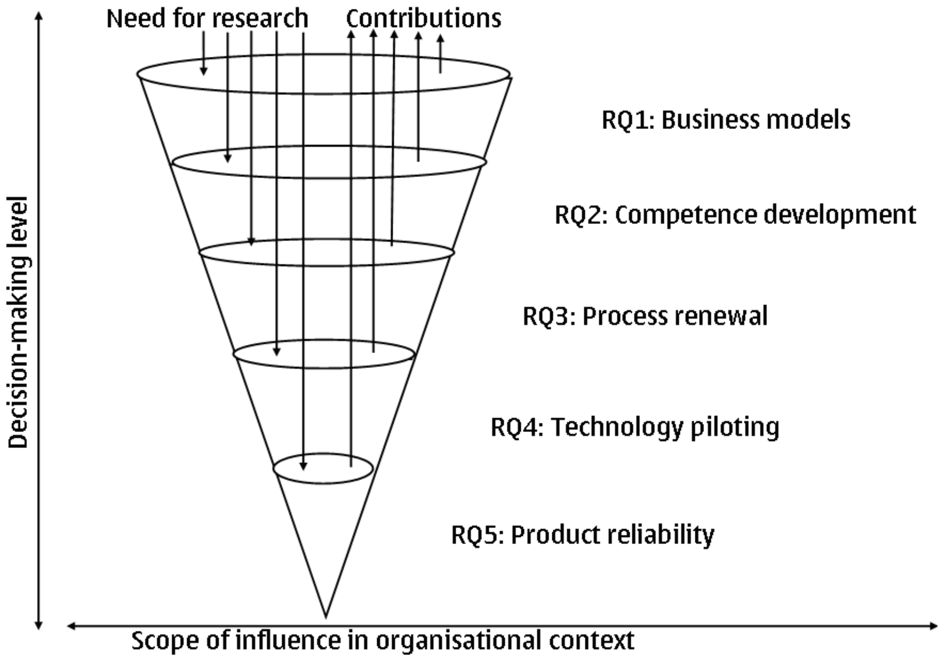

Fig. 1. Research framework.

The five research perspectives were chosen at the very beginning of the research. The focus within the perspectives might have changed a bit, but however, the main research areas remained the same during the whole study.

Inputs to this research were disruptive technologies and mobile and IP convergence. In this study they are taken as given and investigating reasons for identifying them are outside the scope of this research. This research does not cover the implemented technologies themselves or different instances of quality. The reasoning behind the foundation of IPC is out of the scope of this research, too. Agile software development (e.g. Beck *et al.* (2005) and in particular Extreme Programming (XP), a software engineering methodology, which can be considered to be an extreme case of a pilot project where the customer participates in the development directly, are outside the scope of this thesis. However, customer involvement is considered in the fourth research paper discussing pilot projects, when introducing new technologies. Fig. 2 demonstrates the "research path" of this research. The five research questions or research subjects are marked by a circle with the text "RQx". The circles without any text inside depict other possible research subjects that were left out of this research. Fig. 2 illustrates that the highlighted path is just one of many possible paths. The figure shows that this research covers just the chosen research subjects. Of course, there were numerous other subjects to select, but these were topical to the case unit at the time when this research was conducted. The figure shows also that there is room for further study.

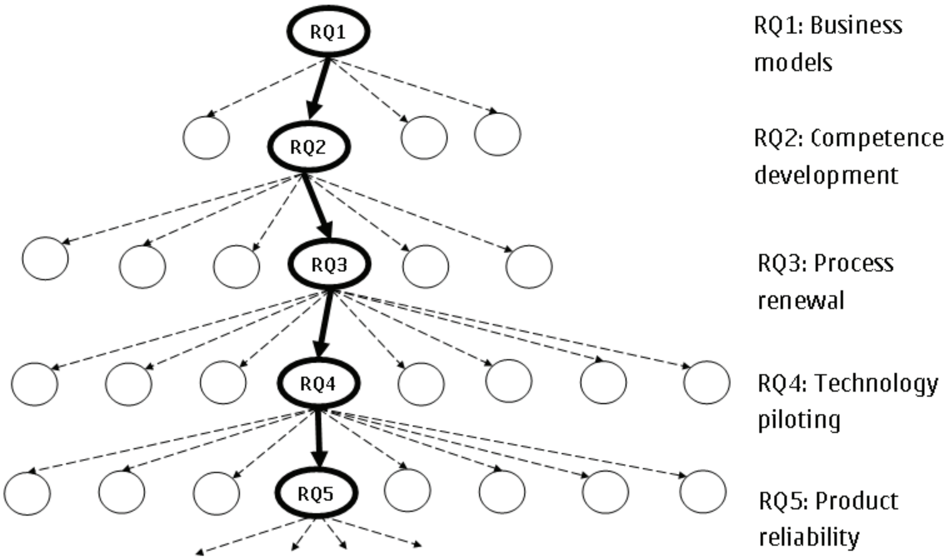

Fig. 2. Research path.

1.4 Research strategy and research papers

In this thesis, the research problem is divided into five research questions, which have different aspects, still related to each other, as described in the previous chapter. Each research question is answered with the help of a published article, a research paper. Each research paper provides a partial solution to the research problem. This thesis combines the contributions of the research papers to give a solution to the original research problem.

Thus, this thesis is a collection of five original publications with this summary. Four of them are journal articles and one article was published in a refereed international conference. I have been the primary author in all of the original publications. In the papers accompanied by other writers I ensured the novelty of the contributions and incorporated them to give additional value to this research as a whole and to the research environment. In the research paper concerning business models, then I condensed the study into a more compact presentation and assessed its relation to the current knowledge. In the research paper concerning competence development, in addition to compression of text, I evaluated the significance of the framework studied in a wider perspective. In the paper discussing technology pilots, I reviewed the literature with the other writer, but the research data was studied and analysed by me. Table 2 lists the articles and combines them with the research questions.

Table 2. Overview of research papers.

#	Title	Authors	Publication	Research question
I	A framework for creating business models – a challenge in convergence of high clock speed industry	Suikki, R., Goman, A., Haapasalo, H.	International Journal of Business Environment, 2006, 1(2): 211-233	RQ1
II	Project management competence development framework in turbulent business environment	Suikki, R., Tromstedt, R., Haapasalo, H.	Technovation, 2006, 26: 723-738	RQ2
III	Process Renewal Driven by Disruptive Technologies	Suikki, R	International Journal of Business Innovation and Research, 2007, 1(3): 281-295	RQ3
IV	Business impact of technology piloting – model for analysis in different phases of development cycle	Suikki, R., Haapasalo, H.	International Journal of Innovation and Technology Management, 2006, 3(2): 209-235	RQ4
V	Practical Use of Software Reliability Methods in New Product Development	Suikki, R.	Proceedings of the 32nd EUROMICRO Conference on Software Engineering and Advanced Applications, EUROMICRO SEAA 2006, Cavtat/Dubrovnik, Croatia, 232-239	RQ5

1.5 Research approach

In the main, this research follows normative and action research approaches. However, other approaches are used as well, as the thesis is composed of five research papers: constructive research, participant observation research, and case study research approaches. Principally the study follows a qualitative research approach. However, a quantitative research approach is also used in some research papers.

There are different methods and paradigms available to support different scientific approaches. The main thing is to choose methods that support the scientific problem by applying thinking and interpretation, which leads to the desired end result. Normative research is looking for results which can be utilised when developing current activities or creating something new. Descriptive research tries to describe the phenomena by creating concepts, describing processes, etc. in order to increase the understanding of the phenomena.

This research aims at understanding the changing environment and, based on the increased understanding, to improve working methods, operations, and practices. A normative research approach supports this target. Additionally, the researcher acted in the case unit studied, and therefore was able to participate in the actions conducted and was also able to change and modify the actions taken. Thus, an action research approach provides the prerequisites for this study.

The target of normative research is to gather facts and also to point out in which respects the object of study can be improved. Normative research includes evaluation of the present state of things and also of the direction of future development. Normative research produces the theory of practice for a professional activity, which can consist of recommendations, rules, standards, algorithms, advice or other tools for improving the object of study (e.g. Olkkonen 1993).

According to Routio (2006), in its simplest layout, the normative process of research and development might consist of a linear series of simple decisions e.g., defining the target, defining which factors in the context can be modified and which not, planning how to reach the target, selecting the best alternative, making a detailed plan of action, submitting practical proposals to the people that can decide on the operations in practice. However, many normative projects deal with complex practical problems, and it is impossible to proceed directly to the synthesis and proposal. Hence, iteration is needed which is illustrated by a spiral (see Fig. 3). The iteration includes steps: (1) evaluative description of the initial state and defining the needed improvements, (2) analysis, (3) synthesis, and (4) evaluation. The steps follow Deming's (1986) Plan-Do-Check-Act cycle.

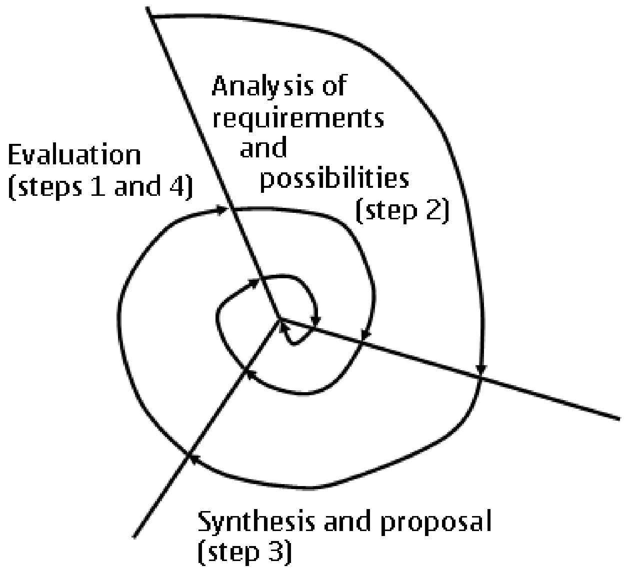

Fig. 3. Iteration in normative research.

By repeating the sequence from 2 to 4, an acceptable result is usually found.

The term "action research" was introduced by Kurt Lewin in 1946 (Susman & Evered 1978). According to Avison *et al.* (1999) action research combines theory and practice through change and reflection in a problematic situation. Action research is an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning. The action research process is illustrated in Fig. 4.

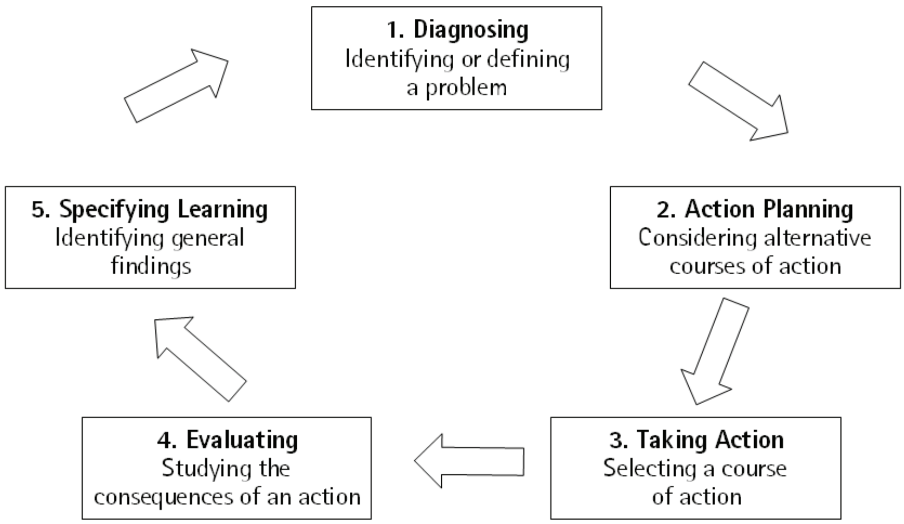

Fig. 4. Action research process modified from Susman & Evered (1978).

Susman & Evered (1978) list six characteristics of action research: (1) Action research is future oriented in dealing with the practical concerns of people. (2) Action research is collaborative; interdependence between the researcher and the client system is essential. (3) Action research implies system development; the aim in action research is to build structures, system, and competences, and to modify the relationships of the system. (4) Action research generates theory grounded in action; theory provides a guide where to concentrate and for generating possible courses of action to solve the problems of members of the organisation. (5) Action research is agnostic; theories and prescriptions for action are the product of previously taken action and are subject to re-examination and reformulation in every new research situation. (6) Action research is situational; many of the relationships between people, events, and things are a function of the situation as relevant actors currently define it.

Baskerville (1999) says that the various forms of action research share some agreed characteristics, and they distinguish action research from other approaches for social enquiry. He lists four common characteristics: (1) an action and change orientation; (2) a problem focus; (3) an "organic" process involving systematic and sometimes iterative stages; and (4) collaboration among participants. Different types of action research according to Avison *et al.* (1999) are: (1) action research focusing on change and reflection; (2) action science trying to resolve conflicts between espoused and applied theories; (3) participatory action research emphasising participant collaboration; and (4) action learning for programmed instruction and experiential learning. Dick (2000) characterises action research as cyclic, participative, reflective and qualitative. An important advantage of action research is that it can achieve results without which the research would have been ignored.

Action research also brings problems for the researcher. Representing mostly qualitative approach, Baskerville (1999) claims that the lack of generally agreed criteria for action research complicates the publication review process. Both Avison *et al.* (1999) and Baskerville (1999) insist on exactness from researchers in their research approach, research aim, theory, and method to avoid professional problems. E.g. their work might be described as consulting instead of research. Ethical aspects should also be considered to guarantee the success of the research.

Many authors (e.g. Susman & Evered 1978, Schön 1983, Baskerville 1999) claim that research methods and techniques have become more complicated, situations of practice are more problematic and characterised by uncertainty, disorder, complexity, continuous changes etc., and that human organisations can only be understood as whole entities. Baskerville (1999) says that the fundamental contention of the action researcher is that complex social processes can be best studied by introducing changes into these processes and observing the effects of the changes.

Schön (1983) writes about “reflection-in-action” meaning the professional manager’s thought process. “Reflection-in-action” clarifies the struggle between art and science. According to Schön (1983) research is institutionally separate from practice, connected to it by defined relationships of exchange. Researchers provide the basic and applied science from which to derive techniques for solving the problems of practice. Practitioners furnish researchers with problems of study and with tests of the utility of research results. There is a gap between professional knowledge and the demands of real-world practice. Schön (1983) writes that in the spontaneous, intuitive performance of the actions of everyday life one shows himself or herself to be knowledgeable in a special way, however, not being able to say what he or she knows. One’s knowing is tacit, implicit in the patterns of action.

This research is characterised as normative action research, which seeks models for everyday business-related problems by means of action research. This research, as a whole, follows the characteristics of participatory action research, which combines theory and practice through change and reflection in a problematic situation by the researcher and practitioners. In this study the researcher belonged to the community where the research was done. The researcher had several roles in this research; a planner, leader, facilitator, teacher, observer, and reporter. Action research is an iterative process involving the researcher and practitioners acting together on a particular cycle of activities. Action research addresses complex real-life problems and the immediate concerns of practitioners. All this applies to this research.

Fig. 5 illustrates the research approach of this thesis. Each research question corresponds to one iterative cycle of the action research process. The five research papers form a chain of sequential action research cycles. Iterations in a cycle and each cycle in the chain of cycles add understanding and knowledge to the research environment.

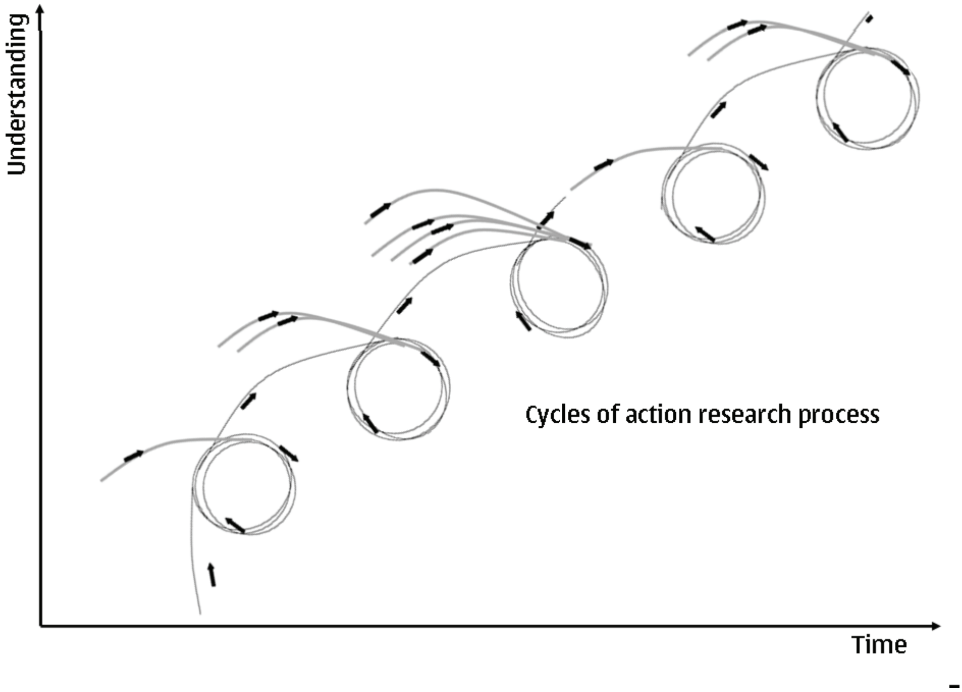

Fig. 5. Research approach.

1.6 Structure of the thesis

The thesis consists of five individually published papers and this summary, which is organised as follows: Chapter 2 presents the theoretical foundation for the research. Chapter 3 summarises the five published papers, which are included at full length in the Appendix. In chapter 4 the overall findings of the study are presented by addressing the research questions based on the research contributions and findings from the individual papers. Finally, chapter 5 summarises the research.

2 Theoretical foundation

2.1 Changes in industries

Many industries are today faced with ever-increasing speed. Moore's law (Moore 1965), which predicts that the transistor density of semiconductor chips would double roughly every 18 months, describes the speed of technology development well. Despite the fact that Moore's law was published more than forty years ago, it is still often referred to. Today, businesses shift their portfolio of products towards more innovative products with higher degrees of uncertainty. At the same time, changes in industries have a much larger impact than before and it is becoming increasingly difficult to achieve product quality targets.

Goldratt (1990) writes about a process of ongoing improvement, which can sustain a company's excellent performance in the long run. He argues that before we can deal with the improvement of any system, we must first define the system's global goal and recognise the role of the system's constraints. A constraint is anything that limits a system from achieving higher performance versus its goal. Goldratt (1990) proposes to rethink the current situation once more and precisely define – verbalise - the problem caused by constraints. He argues that all our inventions, decisions, and convictions are based only on intuition. What is missing is the ability to verbalise our intuition, to provoke it, focus it and cast it precisely into words. As long as proper verbalisation is not used, we ourselves will act in ways that contradict our own intuition.

Moore (1998, 1999) writes about the development of high-tech markets. He advises how to move from an early market dominated by a few visionary customers to a mainstream market dominated by a large group of customers who are pragmatists in orientation. He presents a technology adoption life cycle, a model for understanding the acceptance of new products (see Fig. 6). He proposes that a new technology product is adopted first by a few innovators, who are technologists and pursue new technology products aggressively. The next group buying new technology products are early adopters, who find it easy to understand and appreciate the benefits of a new technology. The early majority are driven by a strong sense of practicality and are ready to wait to see how other people adopt new products before buying. The people in the late majority wait until products have become an established standard before buying them. The last group is laggards, who don't want anything to do with new technology; they buy a technological product when it is buried so deep inside another product that they don't even know it is there. According to the technology adoption life cycle the way to develop a high-tech market is to work the curve left to right (see Fig. 6), focusing first on innovators, early adopters, early majority, late majority, and finally on laggards. In addition to expanding the market, there is another motive, namely keeping ahead of the next emerging technology, the idea of a window of opportunity.

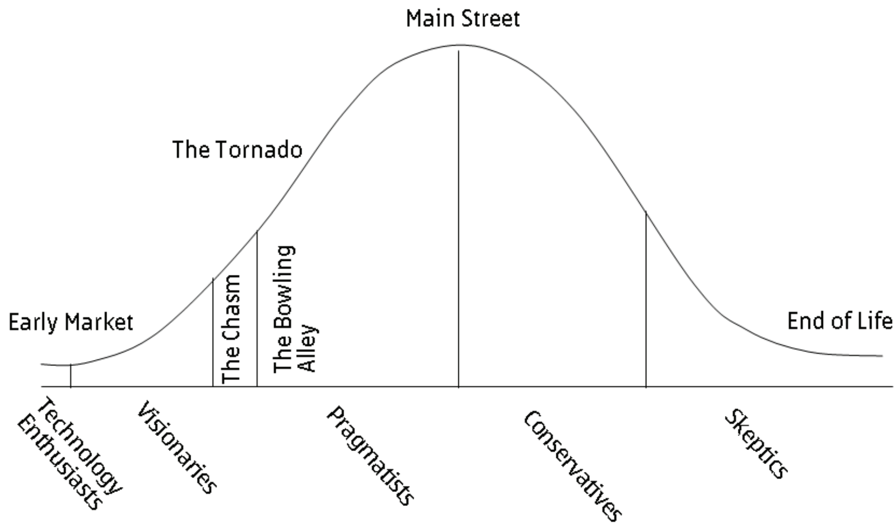

Fig. 6. Technology adoption life cycle (Moore, 1998).

Christensen describes (1997) how new technologies can initiate discontinuities in industries. Disruptive technologies might cause major changes in a business model and radically alter market positions. Only seldom can a market leader keep its position. Typically, in a discontinuity created by disruptive technologies, market dominance is changed to new players and the market share of the previous leader collapses. A newcomer or a previous minor player takes a major part of market share and profits. Christensen (1997) characterises disruptive new technology as a technology that is originally not demanded by the industry's mainstream customers or markets, but by a small niche market or a totally different customer segment. The new technology later also replaces the earlier mainstream technology.

According to Christensen (1997) a market leader is usually very carefully trying to respond to its customers' needs and therefore is tempted to neglect a new market that is not seen important enough to be interesting. A new business opportunity might also be undetected, because the market segment is different from the current one. E.g. customers and delivery channel are different from existing ones, thus remaining undetected. If the market leader is a technology-oriented company, it might even be able to develop the new technology first. Anyhow, this new technology is usually not utilised. A market leading mainstream company will most often not focus its manufacturing or marketing efforts to a new and unknown business segment, because the new market size is too small or customers are not recognised. In a fierce market share fight, all available resources are focused on boosting the currently profitable business, and assets are not directed to new uncertain areas. Technology development effort is directed to the sustaining technologies. This kind of market arrogance leaves a door open for a company that decides to enter the industry through this initially niche market, which might later grow to be the mainstream.

Moore (1998) discusses discontinuous innovations as paradigm shifts. These shifts begin with new category products that incorporate breakthrough technology. At first, the market resists these products and the changes they introduce. But in many cases, finally, there comes a flashpoint of change when the entire marketplace shifts its loyalty from the old technology to the new.

Many authors (e.g. Matthews 1991, Christensen 1997, Moore 1998, Hakkarainen 2006) write about replacing old technologies with new ones. At first, the performance of a new technology is usually rather low, but it improves until the technology reaches the improvement period of its lifecycle, when the improvement becomes rapid. Progress slows down in the mature period and comes to an end when limits of the technology are reached. This is described as S-curves. New disruptive technologies are typically initially not competitive with mature, older technologies. But the S-curve effect typical to a new technology's performance improvement vs. time or development effort might change financial positions. Fig. 7 is based on Christensen's (1997) presentation and is complemented by Moore's (1998) subsequent stages in the life-cycle model i.e., "bowling alley", "tornado", and "main street".

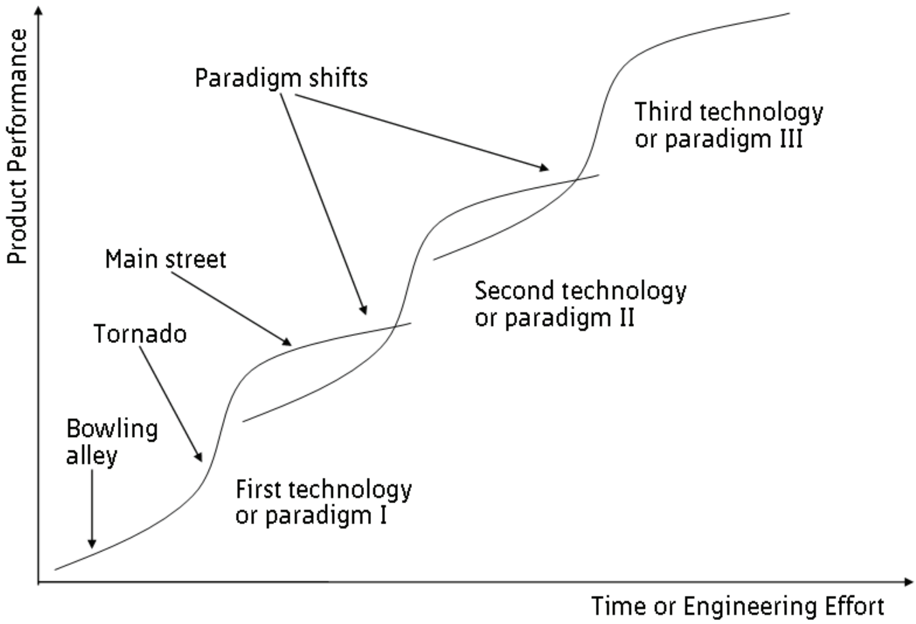

Fig. 7. S curves modified from Christensen (1997) and Moore (1998).

According to Christensen (1997), new technology development teams might be able to develop a new technology to a level where the old technology's capabilities are also exceeded in the mainstream market, and also the mainstream turns to the new technology. New technology performance improves rapidly and with minor efforts in the beginning of the development life cycle, but later on even a minor improvement in technology requires huge effort. Sometimes the new disruptive technology's performance does not exceed the old technology performance. The old technology can maintain its advantage and the new technology remains in its original market segment. A second option is that after a fierce improvement phase (rapidly rising part of S-curve) the new technology exceeds the old technology's performance. In the case of crossing S-curves, the new technology replaces the old one quite rapidly in the mainstream market, thus causing a radical change in product demand. If the new technology also introduces changes in business concept, or changes in how value-added is allocated to the value chain, the impact is even more radical.

Perhaps the clearest case of crossing S-curves in the cellular telecommunication industry history has been the introduction of digital technology. At the starting point, digital mobile terminals were much worse in performance than analogue mobile phones, thus making the analogue phones more preferred by end users. After a few years of technology development, the digital phones' performance clearly exceeded the performance of the analogue ones, thus changing the end-user preference to the digital phones.

Christensen (1997) argues that leadership in sustaining technologies may not be essential, but leadership in disruptive technologies creates enormous value. He suggests that large companies should seek to embed the project in an organisation that is small enough to be motivated by the opportunity offered by a disruptive technology in its early years. Christensen (1997) claims that this can be done either by spinning out an independent organisation or by acquiring an appropriately small company.

Den Ouden's (2006) study deals with introducing new technologies to the consumer electronics industry. The study reveals that the number of customer complaints in consumer electronics industry is ever-increasing and that consumers do not only complain about technical product failures, but also about non-technical product failures. Non-technical failures occur when the product does not satisfy their expectations, but does function technically. Den Ouden (2006) lists four major trends that influence product quality and reliability: (1) increasingly complex products, (2) strong pressure on time-to-market and fast adoption cycles with fewer product generations, (3) increasingly globalised economy, and (4) decreasing tolerance of customers for quality problems; consumers are returning products when they are not satisfied, even when the product is technically functioning according to the specification. Consumer complaints, especially complaints of non-technical failures, are caused by a wide range of decisions taken in the business creation process. In many cases it is no longer feasible to improve on consumer complaints in the current range of products. Improvement will have to be made over product generations. This means that it will not be sufficient to make adaptations in the business creation process as such, but the product innovation cycle will need to be adapted. The product innovation cycle should include learning from complaints with previous products and aim at prevention of consumer complaints in new products.

Currently many businesses are facing an increasing number of consumer complaints, despite the application of quality tools that were proved to be very powerful in the past. The traditional quality and reliability field monitoring systems are set up for technical failures only. They check if the product is functioning according to the technical specification. Problems of a non-technical nature are classified as "Failure Not Found" and causes of these problems are still unknown. Den Ouden (2006) claims that the available approaches/tools to fulfil product quality and reliability are not sufficient any more, even they were applicable earlier with continuous improvement products; the approaches studied were: project management, quality management, customer/user centred design, learning in and across projects, Quality Function Deployment (QFD), consumer involvement in idea generation, evaluating and testing with consumers, risk management and Failure Mode and Effect Analysis (FMEA), Design for Six Sigma (DfSS) and robust design, and quality and reliability testing. Instead of choosing one preferred approach, Den Ouden proposes an adaptable approach, which, however, still needs further study.

To understand the challenges industries have today, one must realise the changing environment of the businesses. A comparison of the mid-nineties and present-day situation reveals major differences in the business context. Table 3 shows the main characteristics.

Table 3. Characteristics in the business context of new product development (Den Ouden 2006).

	Until mid-nineties	Nowadays
Business strategy	Maintaining market share through production of high volumes and selling at competitive prices	Growth of turnover and profit through attractive, innovative products at higher price points
Product portfolio	Incremental innovations; existing technologies to existing markets (Garcia & Calantone 2002)	Really new products; new technologies to existing markets or existing technologies to new markets (Garcia & Calantone 2002)
Number of product generations to reach commodity	> 10: enough time to learn consumer expectations and improve technical product quality and reliability	~3: no time to learn over product generations
Main uncertainty	Technology, in relation to cost effective mass production	Market, in relation to attractiveness of product and expectations of consumers on the product functions
Product complexity	Low: limited functions and connectivity options	High: multiple-functions and connectivity options
Consumer expectations	Known, due to stable markets and incremental innovations	Unknown, due to dynamics in market and decision to introduce really new products
Role of specification	Fixed and complete at start, stable through the project	Evolving over time

The present-day telecommunications industry is changing continuously; existing technologies are replaced by newer ones, moving from sustaining technologies to disruptive technologies is happening, products are becoming ever more complex, the business environment is changing, etc. Telecommunication devices have evolved from “just” mobile phones to advanced devices including sophisticated features and services, e.g. imaging, music, videos, games, multimedia messaging. Den Ouden (2006) deals with introducing new technologies in the form of innovative products in consumer electronics industry. Her studies are very relevant, as the same phenomena are also happening in the telecommunications industry. The ideas presented by Christensen (1997) and Moore (1998, 1999) deal with the macro level of the business environment in general, not any specific industry. It gives a firm standpoint for further studies. This research tries to solve problematic situations on the case company level: what kind of business model is appropriate, which new competences are needed and how to acquire them, are current processes suitable for implementing disruptive technologies, how to involve customers in new product development, and how to ensure reliability of software during the R&D phase. The next chapters (2.2 – 2.6) cover theories on these topics and chapter 2.7 describes the utilisation of these theories.

2.2 Business environment

The telecommunications industry is in the middle of convergence, which means networks and terminals dedicated to a given purpose will gradually disappear or merge. (Teleware 2001). Mobile and IP convergence brings together technologies and services from the mobile and Internet domains. This will open up many new opportunities. (See e.g. Darby 1999, Kari & Kilpeläinen 2001, Sengodan *et al.* 2000.) A lot is expected from the convergence of the two most successful innovations of the telecommunications industry, the Internet and mobile communications (Kelly *et al.* 2002).

In other words, according to many authors (e.g. Kari & Kilpeläinen 2001, Kelly *et al.* 2002, Steinbock 2001), the rapidly evolving mobile telecommunications business is experiencing a discontinuity on the brink of a new era, caused by mobile and IP convergence. This discontinuity opens up opportunities, but it also brings a considerable amount of uncertainty to the business. The old and proven ways of doing business are no longer sufficient for success. The difficulty is in finding the right ways to take advantage of the opportunities and profiting from them. One of the challenges is to create a profitable business model for the mobile and IP convergence era.

Several writers (Kostamo 2001, Kari & Kilpeläinen 2001, Zoller *et al.* 1999, Barret & Ahonen 2002) propose that the mobile handset manufacturers' proven way of doing business is selling mobile terminals in the highly competitive market. These terminals are embedded systems, incorporating software and the hardware. Lately, however, an alternative way has been introduced: software is nowadays also sold separately from hardware. New services and applications will be created and offered by numbers of service developers, even by end users. User-generated content will also drive the development, but naturally also network operators and third party service providers will create services. It is still unclear as to with which devices the combining of Internet and mobility will be achieved. It is only certain, that there will be no single terminal type, but multiple solutions.

The product could also be software, which is an example of information goods. The cost structure of producing information differs from the usual: the fixed cost is high but marginal cost is low. Furthermore, with advances in technology, the cost of distributing information is falling considerably (Shapiro & Varian 1999). Digital products can be transmitted over the Internet instantly and at almost no measurable marginal cost (De *et al.* 2001). Kostamo (2001) writes that in the mobile and IP convergence era there are a lot more players in the game than before and at the same time technologies are evolving rapidly and business models are transforming. The market structure is likely to evolve, and the roles of players change and intervene in formerly restricted areas of other players.

2.2.1 Business models

Timmers (1998), Magretta (2002), and Hamel (2000) note that literature has not been consistent in using the business model concept. A variety of terms are used to mean roughly the same, including business model, business design (e.g. Bovet & Martha 2000a, Kalakota & Robinson 1999, Slywotzky 1996), and business concept (e.g. Hamel

2000). In this research, a business model describes (1) the offering, (2) the value chain or network, and (3) the revenue model of the enterprise. The chosen elements are those that are of most interest in this study.

As Normann & Ramírez (1994) discuss, a clear distinction between products and services can no longer be drawn. Offering is a concept that is comprised of them both: it is used to refer to any output of a value creation system (the producer or supplier) that is an input to another (the customer). Offerings consist of three components: physical goods, services, and ideas or information. The goal of any offering is to create value for the customer. (Band 1991, Kotler 1997, Normann & Ramírez 1994.) Kotler (1997) has presented five levels of an offering – core benefit, basic product, expected product, augmented product, and potential product - each of which adds more customer value.

Activity to create value is the basic building block of business (Normann & Ramírez 1994). The concept of value chain was originally developed by Porter (1985). He refers to a company's internal value chain. Later the concept has also been used to denote an industry-wide value chain, which Porter names value system (see also Kotler 1997, Hoover *et al.* 2001). Lately this has been widely replaced by the term value network, as the nature of business has evolved towards networked environments (Allee 1999). In value constellations, co-production of value is an essential term; it refers to supplier and customer working together in the joint value creation process, and thus helping each other to create value (Normann & Ramírez 1994). Wikström *et al.* (1994) describe the same model as value star. The company needs to define its strategic position in relation to the customer's value creation process, around which the value star is composed. The modern networks that are emerging with e-business, generally share the characteristics of the traditional networks, but differentiate themselves through digitality (Sweet 2001, Bovet & Martha 2000b, Tapscott *et al.* 2000). Amit & Zott (2001) have created a model of the sources of value creation in e-business: they are efficiency, complementarities (that are present whenever having a bundle of goods together), lock-in (manifested as switching costs), and novelty.

Revenue model is an inherent part of a business model. It describes how the company finances its operations, i.e. how and from whom the revenue is generated (Rajala *et al.* 2001). The company should define its revenue model in conjunction with identifying the market in which the company will compete (Chesbrough & Rosenbloom 2002).

Shapiro & Varian (1999) and Shy (2001) discuss ICT (Information and Communication Technologies) industries. They claim that ICT industries belong to so-called network markets that include e.g. the telephone, email, the Internet, computer hardware, and computer software. The cost structure of ICT goods differs from the usual: the fixed cost is high but marginal cost is low, practically negligible. This kind of cost structure implies that the average cost function declines sharply with the number of copies sold. Thus a competitive equilibrium does not exist, and markets of this type will often be characterised by dominant leaders that capture most of the market.

2.2.2 Building business models

Porter (2001) questions the value of business models. He argues that simply having a business model is an extremely weak foundation for building a company, and that no business model can be evaluated independently of industry structure. Moreover, according to him, the business model approach to management leads to faulty thinking and self-deception.

Nevertheless, contrary views do exist. As Magretta (2002) argues, a good business model is essential for an organisation to succeed, yet this does not mean that a business model alone would be enough – a company still needs a competitive strategy. It is clear, that a business model alone is no magic solution, nor can it be evaluated without putting it into the right context. However, used in the right way, business modelling is an efficient management tool. When used correctly, a business model forces managers to think closely about their businesses. A model can by itself create a strong competitive advantage, and it can be used to get the whole organisation aligned around the kind of value the company wants to create. A good business model can become a powerful tool for improving execution.

In addition, companies have to consciously and continuously improve their business models. Slywotzky (1996) says that value migrates from outmoded, economically obsolete business designs to new ones that more effectively create utility for the customer and capture value for the producer. Sooner or later, every business model reaches the point of diminishing returns: traditional business models just do not keep on bringing ever growing revenues forever. Therefore, business model innovation is obligatory to be able to create new wealth (Hamel 2000). The business design dimension is no longer an optional part, but it is elementary for a company intending to stay in business (Kalakota & Robinson 1999).

Constructing a business design requires making a number of critical choices. If the business design is to succeed, its elements must be aligned with customers' most important priorities, and the elements must be tested for consistency with each other to ensure that the business design functions as a coherent, mutually reinforcing whole. Building a powerful business model is challenging. Therefore, a set of questions can be used to help in selecting the most powerful elements as Slywotzky (1996) proposes. The foundation of a business design is a set of basic assumptions about customers and economics. These assumptions profoundly influence the design's overall strength and viability, and therefore must be examined carefully and made explicit. The next task is defining those elements that match customers' most important priorities. Having established the core of the offering that will create utility for the chosen customers, the task is to define how the organisation delivers that utility and the degree to which it can earn a profit while doing so.

Hamel & Prahalad (1996) propose a somewhat similar approach, which is also based on answering some key questions about the concept of served market, revenue and market structure, configuration of skills and assets, and flexibility and adaptability.

The third approach, based on question lists, is that of Hamel (2000). His framework for unpacking the business model consists of four major components: core strategy, strategic resources, customer interface, and value network. Each of these has several subcomponents. The four major components are linked together by three bridge components: configuration of activities, customer benefits, and company boundaries. Underpinning the business model are four factors that determine its profit potential: efficiency, uniqueness, fit, and profit boosters.

Timmers (1998) approaches the question of building a business model with a different method. He presents a systematic approach for identifying business model architectures, which is based on company internal value chain deconstruction and reconstruction, i.e. identifying the elements of the value chain and possible ways of integrating information along the chain. The framework thus consists of three elements (Timmers 1998):

- Value chain deconstruction, which means identifying the elements of the value chain.
- Interaction patterns, which can be one-to-one, one-to-many, many-to-one, many-to-many.
- Value chain reconstruction, that is integration of information processing across a number of steps of the value chain.

The possible business model architectures are then constructed by combining interaction patterns with value chain integration.

The last approach presented has characteristics from the two different types of approaches discussed above. To create an innovative business design, first some questions need to be answered. Kalakota & Robinson (1999) suggest that after answering the questions, there are three steps in business design. The first step is self-diagnosis. Before beginning to create an e-business design, the company must be diagnosed. There are three categories of companies: market leaders, early adopters or visionaries, and the silent majority. One has to see where in the picture one's company is, and if the position is not desirable, make a path to get where one would rather be. The second step is reversing the value chain. Success depends on creating new product offerings in which customers see value. Successful companies no longer just add value; they invent it. To achieve this, the traditional value-chain thinking must be revised. In contrast to the traditional inside-out models, by which businesses define themselves in terms of the products they produce, the business design has to be outside in, and the strategy has to revolve around the customer. Customer needs must be the starting point for creating new offerings. Business designs are an outcome of the reconfiguration and integration of competences, channels, application infrastructure, and employee talent. The creation of a business design is inseparably linked to the management of change. Change is not an uncontrolled activity; choosing a narrow focus sets the boundaries of change. Thus, this is the third step. As there are few organisations that can do many things well, a narrow focus is often more powerful than a much broader one.

2.2.3 Evaluating business models

As Magretta's (2002) definition of business model has two components: a story that describes how an enterprise works, and modelling the behaviour of business numerically, so does the way she evaluates business models. There are two tests that a successful business model must pass: the story must make sense, and the calculations must show ability to make profit. Just as in a good story, elements of a good business model include precisely delineated characters, plausible motivations, and a plot that turns on an insight about value. When it comes to numerical modelling, a spreadsheet is only as good as the assumptions that go into it, and these assumptions about economics and motivations of a model are really tested only in the marketplace. Magretta (2002) continues that in order for a business model to be successful, it has to represent a better way than the existing alternatives, either by offering more value to a group of customers or by completely replacing the old way of doing things. The really powerful business models do not just shift existing revenues among companies, but they create new, incremental demand.

Assessing a business design's value creating power requires a detailed understanding of how well that design meets customers' most important priorities, both today and in the future. An equally important task is evaluating the ability of the business design to capture profit. Business design evaluation requires answering the following questions (Slywotzky 1996):

- What are the basic customer and economic assumptions on which the business design is built? Are the assumptions valid? What could change them?
- What are customers' most important priorities? Are they changing?
- What elements of the business design match the customers' most important priorities? How well are they served? Are there priorities that are not well served?
- What differentiates the business design from competitors' designs? Do the customers care about that differentiation?
- Are competitors' business designs based on the same basic assumptions?
- Is the business design internally consistent? Are there elements that do not support the meeting of customer priorities?
- How cost effective is the business design?
- Can the business design recapture value? How sustainable and defensible is that mechanism?
- How long will the business design be sustainable? Will some changes in customer priorities require changes in it?
- Are alternative designs already being employed that meet the next cycle of customer priorities better?

According to Hamel (2000) there are four factors to consider in determining the wealth potential of any business concept: its efficiency, uniqueness, internal consistency or fit, and exploitation of profit boosters. The extent to which the business concept is an efficient way of delivering customer benefits is elementary to create wealth. A business model must be efficient in the sense that the value customers place on the benefits delivered exceeds the cost of producing those benefits. A business concept also needs to be unique: the greater the convergence among business models, the less the chance for above-average profits. The goal is not uniqueness for its own sake, but to create a business model that is unique in its conception and execution. To produce profits, a business model must be unique in ways that are valued by customers. A business concept generates profits when all its elements are mutually reinforcing, i.e. the degree of fit among the elements of the business concept is high. A business concept has to be internally consistent – all its parts must work together for the same goal. The last factor is the extent to which the business concept exploits profit boosters that have the potential to generate above-average returns. There are a dozen profit boosters that can help to generate high profits: one or two of these should be built into the business model. The profit boosters can be grouped under four categories: increasing returns (network effects, positive feedback effects, learning effects), competitor lock-out (pre-emption, choke points, customer lock-in), strategic economies (scale, focus, scope), and strategic flexibility (portfolio breadth, operating agility, low breakeven point).

Magretta (2002) says that even though some considerations of a business model's potential can be found, the business model can only be properly tested in the market. Profits will tell, whether the model is working or not. When managers operate consciously from a model of how the entire business system will work, every decision, initiative, and measurement provides feedback. Business modelling can thus be seen as the managerial equivalent of the scientific method – starting with a hypothesis, which is then tested in action and revised when necessary. Also Chesbrough & Rosenbloom (2002) argue that the best measure of the worth of a given business model is the success of the enterprise. However, one cannot simply infer that good business models lead to success. It seems that the process of reshaping an initial business model creates learning opportunities that may contribute importantly to success.

2.3 Organisational learning

Goldberger (1999) argues that healthy individuals and organisations share the same three characteristics: productivity, innovativeness and resilience. When systems become excessively regular, there is an increase in predictability and a loss of resiliency, and this periodicity is bad for organisational health. Healthy behaviour can be described with words like plasticity, variability, resilience, and productivity. To keep the organisations healthy, managers should think of themselves more as choreographers, composers and conductors.

White *et al.* (1996) offer new organisational perspectives and skills to managers when guiding managers throughout the turbulence of today's corporate environment. They argue that change and uncertainty are the new touchstones of leadership excellence. The business world of today and tomorrow can be seen as a series of fast flowing rapids full of excitement, challenge, adventure and uncertainty, where risks will be higher and rewards greater. They identify leadership skills necessary to ride the corporate rapids: learning from difficult situations or mistakes, maximising one's energy and using it for new learning opportunities, understanding simplicity as the means to clear and effective communication, bringing the focus on teams' various agendas, and being open to new ideas for learning and growth.

2.3.1 Competence development

Hamel & Prahalad (1994) have defined competence as a bundle of skills and technologies that enables a company to provide benefits for customers, rather than a single skill or technology (see also Ivergard 2000, Sydänmaanlakka 2003). Therefore, core competence is a source of competitive advantage. Westera (2001) has given two perspectives to competence: theoretical and operative. The theoretical perspective means that competence is conceived as a cognitive structure that facilitates specified behaviour. The operational perspective covers a broad range of higher-order skills and behaviours that represent the ability to cope with complex, unpredictable situations; this definition includes knowledge, skills, attitudes, metacognition, and strategic thinking and presupposes conscious and intentional decision-making. (See also Nordhaug 1991.)

Argyris & Schön (1978) distinguish between individual and organisational learning in that individual learning in an organisation may not represent organisational learning unless members of the organisation act as learning agents for the organisation. When an organisation learns, the total amount of competences differs from the sum of individuals' competences in the organisation (Saeed 1998). However, there have to be individuals in the organisation to develop its competences. In other words, competence is formed from the results of learning, either the individuals' or the organisation's (e.g. Westera 2001).

2.3.2 Learning organisation and organisational learning

Sociotechnical systems conception of a learning organisation, according to Argyris & Schön (1978), focuses on the idea of collective participation by teams of individuals in developing new patterns of work, career paths, and arrangements for combining family and working life. According to this view, individuals can and must learn to redesign their work, and upper-level managers must learn to create the contexts within which they can do so.

Senge (1994) writes about ”the art and practice of organisational learning”. His treatment of the subject unites system thinking with organisational adaptation and with the realisation of human potential in a mixture that has a distinctly utopian flavour. Senge's (1994) prescriptive approach combines the methodology of systems dynamics with certain ideas adapted from the Argyris & Schön (1978) theory-of-action perspective, notably an awareness of the importance of the "mental models" held by organisational practitioners, including those that constrain to facilitate reliable inquiry into organisational processes.

According to Argyris & Schön (1978), an organisation is a collective made up by people. Collectivities become organisational when they meet three constitutional capabilities: to make collective decisions, to delegate authority for action to an individual in the name of the collectivity, and to say who is and who is not a member of the collectivity. Under these conditions, it makes sense to say that individuals can act on behalf of an organisation and to say that on behalf of an organisation individuals can undertake learning processes that can yield learning outcomes.

Senge (1994) argues that a deep learning cycle constitutes the essence of a learning organisation – the development not just of new capacities, but also of fundamental shifts of mind, individually and collectively. The five basic learning disciplines that Senge (1994) presents are the means by which this deep learning cycle is activated: personal mastery, mental models, shared vision, team learning, and systems thinking. The disciplines are vital, but they do not in themselves provide much guidance on how to begin the journey of building a learning organisation. The work of building a learning organisation takes place within the architecture of guiding ideas, innovations in infrastructure, and theory, methods, and tools. Guiding ideas shed light on what the organisation stands for and helps people stay committed. Innovations in infrastructure are the means through which an organisation makes available resources to support people in their work. Through developing practical tools and methods, theories are brought to practical tests, which in turn lead to the improvement of theories. There are many tools and methods vital in developing a learning organisation. They all help people enhance the capabilities that characterise learning organisations: aspiration, reflection and conversation, conceptualisation.

Cavaleri & Fearon (2000) summarise that organisational learning is being adopted at an increasing rate as part of an integrated package with other synergistic approaches, such as quality improvement, innovation, and knowledge management. Many leaders see organisational learning as representing one of the best strategies for increasing an organisation's capacity for creating breakthrough innovations.

2.3.3 Organisational culture

Schein (1992) defines organisational culture as the result of team learning. The basic situation for building a culture arises when a group of people faces a problematic situation and they have to work together to solve the problem. The process includes a definition of the problem and a shared perception about the confidence that the solution works now and later as well. The ability to share includes learning and understanding the culture, and the new, shared experience starts building a new culture that later becomes the group's special characteristic.

Schein (1992) links organisational culture to the idea of a learning organisation. He argues that in a world of turbulent change, organisations have to learn ever faster, which calls for a learning culture that functions as a perpetual learning system. The primary task of a leader in a contemporary organisation is to create and sustain such a culture, which then, especially in mature organisations, feeds back to shape the leader's own assumptions. Schein (1992) defines leadership as the attitude and motivation to examine and manage culture. He regards the organisation as a group and analyses organisational culture as a pattern of basic assumptions shared by the group, acquired by solving problems of adaptation and integration, working well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems. In organisational learning, basic assumptions shift in the heads of the group members. Schein (1992) continues that the job of a learning leader is to promote such shifts by helping the organisation's members to achieve some degree of insight and develop motivation to change. Leaders can foster a learning culture by envisioning it and communicating the vision.

Cavaleri & Fearon (2000) see that organisational learning can never survive as a viable entity in organisations, as a stand-alone overlay framework on other business processes, because managers perceive it as an unmanageable process. There is a need to integrate organisational learning into existing business processes. The adoption of organisational learning can only happen when managers see it as manageable.

2.3.4 Knowledge management

According to new economic theory the most important competitive advantage is the company's ability for continuous innovation (e.g. Saeed 1998). Intellectual capital consists of data, information, and the ability to use information and competence to constantly create new ideas and innovations. Ståhle & Grönroos (1999) define knowledge management meaning the methods which are aimed to direct and manage the company's human capital and intangible assets. The company's ability to innovate depends on the whole organisation and its resources, and on how it works. The more the company has connections and relations the more there are possibilities to exchange information. The intellectual capital is both intangible and dynamic. Ståhle & Grönroos (1999) claim that the competence, interactions and information flow are the base of an organisation's system, but intellectual capital is not only content but also events and action. The process, which results in the outcome, is as important as the result itself. The company has to manage its intellectual capital: it has to get the answer how to manage the competence, relations and information flow.

According to Nonaka & Takeuchi (1995), human knowledge is developed and spread throughout the organisation as a social interaction between tacit and explicit knowledge. Organisational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge – the SECI model (Socialisation, Externalisation, Combination, Internalisation). Socialisation is a process of sharing experiences and thereby creating tacit knowledge such as mental models and technical skills. An individual can acquire tacit knowledge directly from others without using language. The key to acquiring tacit knowledge is experience. Externalisation is about transferring tacit knowledge to explicit knowledge. Combination converts explicit knowledge to explicit knowledge. Reconfiguration of existing information through sorting, adding, combining, and categorising of explicit knowledge can lead to new knowledge. Internalisation converts explicit knowledge to tacit knowledge. It is closely related to "learning by doing". When experience through socialisation, externalisation, and combination is internalised into individuals' tacit knowledge bases in the form of shared mental models or technical know-how, they become valuable assets.

Johannessen & Olsen (2003) argue that competitive advantages based on explicit knowledge will, to an increasing extent, only provide a short-term advantage. Tacit knowledge is intimately related to the task-related part of a company's competence. Thus, tacit knowledge is wholly embodied in the individual, rooted in practice and experience, expressed through skilful execution, and transmitted by apprenticeship and training through watching and doing forms of learning. Tacit knowledge is the most important proprietary and difficult-to-replicate knowledge that the organisation holds, as it is invisible, and difficult to imitate.

Organisations are renewed through processes of inductive organisational learning (i.e., from the concrete to conceptual level) (Mintzberg & Westley 1992). Several authors (Savolainen 1999, Yukl 1989, Argyris & Schön 1978) write that implanting new ideas and ideologies involves innovative behaviour, and learning is the means through which managerial ideological change occurs. Therefore, learning is an essential aspect in examining organisational change processes. Change and learning reinforce each other.

The increasing pace of change tends to invalidate known answers, demanding continuous learning. New knowledge is attained through learning, learning generates change, which can lead to change and can again lead to learning, etc. Learning functions as a mechanism through which new ideas and ideologies are implanted. Applied to a real-world process of organisational quality implementation learning occurs through the stages of materialising ideas, internalising ideas and concepts, gaining support for the idea, preparing a plan of action and, finally, activity.

Artto *et al.* (1998) define a project company as a company that delivers products and solutions to its customers through projects, and its business as project business or project-oriented business. Project management is a universal concept containing planning and managing the project-oriented activities. It has evolved in order to plan, coordinate, and control the complex and diverse activities of modern industrial and commercial projects (Artto *et al.* 1998, Lock 2000). Lock (2000) says that the purpose of project management is to foresee or predict dangers and problems as far as possible to plan, organise and control activities so that the project can be completed as successfully as possible in spite of the risks; it starts before any resources are committed, and must continue until all work is finished. Project business or project-oriented business refers to a company, or rather a project company, where activities generally are aimed to deliver and implement projects for its customers (Artto *et al.* 1998).

Project management is an application of knowledge, skills, tools, and techniques to project activities to meet project requirements. The project team manages the work of the projects. The Project Management Institute (PMI) (2000) organises project management competences into nine basic project management knowledge areas (project integration management, project scope management, project time management, project cost management, project quality management, project human resource management, project communications management, project risk management, project procurement management) (PMI 2000).

2.4 Quality management and process renewal

Traditional quality management approaches introduced by Deming (1986), Juran (1980), and Crosby (1979) are widely used in many businesses, but mainly for incremental innovations. For products requiring continuous innovation these approaches do not seem to work (Den Ouden 2006). Also Deszca *et al.* (1999) argue that quality tools that applied to product development, when the business environment was stable and competition between companies was not as fierce as today, are not fit for use any more. Additionally, hard competition requires shifting the portfolio of products towards more innovative products, which increases the degree of uncertainty. Brombacher (2005) lists four major trends in the reliability of technical systems:

– Increasingly complex products
– Strong pressure on time-to-market and fast adoption cycles
– Increasingly global economy
– Decreasing tolerance of consumers in quality problems.

When moving from the development of continuous improvement products to continuous innovation products, old and fit for use processes might not be appropriate any more; process renewal should be considered. Possible approaches to process renewal are TQM (e.g. Dale 1999) and BPR (e.g. Hammer & Champy 1993). TQM is a management system aiming at long-term continuous improvements (e.g. Fazel 2003). TQM has been used in countless companies since its launch. It is generally accepted that TQM can generate a sustainable competitive advantage (e.g. Prajogo & Sohal 2001, Reed *et al.* 2000), and the importance of tools and techniques for TQM improvement has been proved (e.g. Tarí & Sabater 2004). Chong & Rundus (2003) claim that the higher the degree of market competition the more positive are the relationships between TQM practices of customer focus and product design and organisational performance. BPR is the rapid and radical redesign of strategic processes to optimise the workflow and productivity in an organisation (e.g. Fazel 2003). Numerous papers have been published on the relationship of TQM and BPR, and their similarities and differences (e.g. Ahire & Waller 1994, Fazel 2003, Gore 1999, O'Neill & Sohal 1999). Fazel (2003) says that both TQM and BPR embrace the same ideas and goals for organisational improvements and both encourage employee empowerment, teamwork, quality, change, and focus on the customer. Similarly, many studies give proposals on how to use TQM and BPR. Fazel (2003) concludes that TQM and BPR should be used to complement each other; TQM extends a successful BPR program, and BPR is the turning point of a TQM initiative. Also O'Neill & Sohal (1999) summarise other authors' ideas that TQM and BPR should form an integrated strategic management system within organisations. They say that both continuous and discontinuous improvements are needed.

Huffman (1997) argues that organisations should use different improvement strategies in concert when re-engineering their processes. He proposes the use of four improvement strategies - "Four Re's" - in organisational improvement i.e., repair, refinement, renovation, and reinvention. The first level of repair involves quick fixes, and the second level of repair removes the root causes of the problem to prevent its return. Refinement is an approach for making an adequate product, system, process, or activity even better; it involves continuous improvement. Renovation is an approach taken to achieve major improvement. A critical aspect of renovation is that the result is transformation, not replacement. Reinvention is the most demanding improvement strategy. It is initiated with the belief that improving the current product, system, process, or activity will not be enough to completely satisfy customer needs. The first action is to imagine that the current product, system, process, or activity does not exist, and a new one is invented. Huffman's (1997) "Four Re's" have ideas of both TQM and BPR i.e., repair and refinement can be categorised to TQM including continuous improvement actions, and renovation and reinvention to BPR, including more radical changes in processes.

2.5 Pilot projects

2.5.1 Conventional product development

Ulrich & Eppinger (1995) present the widely known NPD process that includes five phases: concept development, system-level design, detail design, testing and refinement, and production ramp-up. Additionally, they present five variants of generic development process applicable to a firm's unique context: generic (i.e. market pull), technology-push, platform products, process-intensive, and customised. Cooper (2001) is in line with Ulrich & Eppinger (1995). Cooper's (2001) new product process includes product development, in-house product testing, customer tests of the product, trial sell, trial/pilot production or operation. Cooper's (2001) Stage-Gate process is a conceptual and operational model for moving a new product project from idea to launch. Stage-Gate breaks the innovation process into a predetermined set of stages, each stage consisting of a set of prescribed, cross-functional, and parallel activities. Generally these kinds of models focus on developers' interests to verify specifications, not to adjust features to the customers' even undefined needs. Fig. 8 compares Ulrich's & Eppinger's (1995) NPD process to Cooper's (2001) Stage-Gate model.

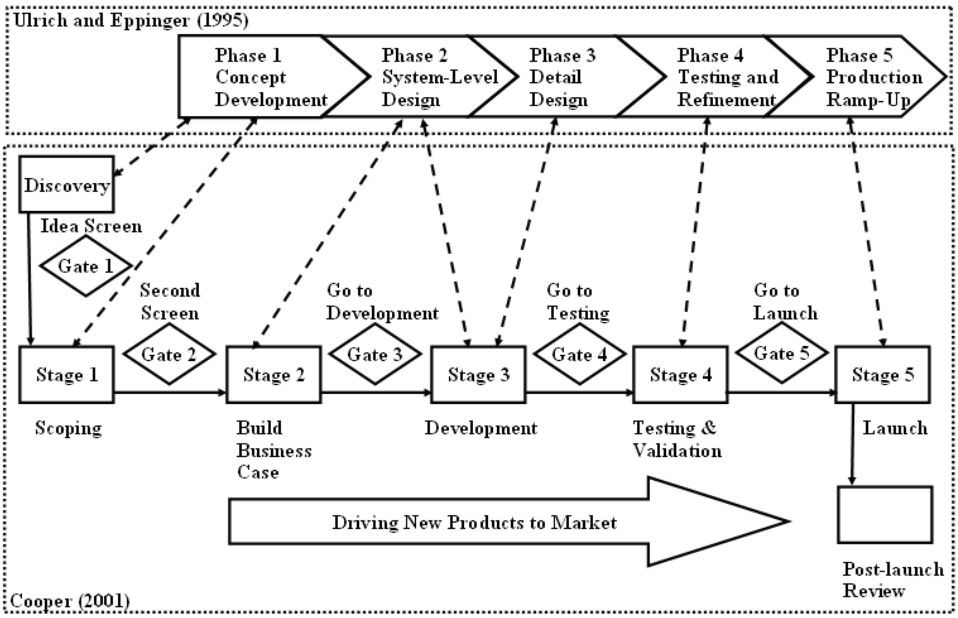

Fig. 8. Ulrich's & Eppinger's (1995) generic new product development process compared to the Stage-Gate model introduced by Cooper (2001).

Meyer & Lehnerd (1997) define product platform as “a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced” and product family as “a set of individual products that share common technology and address a related set of market applications”. They say that product portfolios of prosperous firms change through periodic enhancements to basic product and manufacturing technologies. Some of the changes are breakthroughs, while others are incremental. Meyer & Lehnerd (1997) talk about “power tower” meaning an integrative model for managing innovation. The power tower is needed for effectively managing the evolution of a product family. The power tower includes market applications, product platforms, and common building blocks. The common building blocks are: consumer insights, product technologies, manufacturing processes, and organisational capabilities. Meyer & Lehnerd (1997) also apply the product family concept to software – the underlying platform, modular add-ins, and robust, common interfaces linking them together and to the user.

2.5.2 Discontinuous product development

In today’s dynamic telecommunications industry we talk about breakthrough products, which create or expand a new category, which are new to customers, which often require customer learning (e.g. Internet), which raise issues related to channels of distribution and organisational responsibility, and which create the potential for new infrastructure and add-ons (e.g. multimedia products) (Deszca *et al.* 1999, Leeman & Winer 1997). Breakthrough products represent products that require radical innovations.

The conventional NPD process (Cooper 2001, Ulrich & Eppinger 1995, Lynn *et al.* 1996) presented above is analysis-driven. According to Lynn *et al.* (1996), with different techniques companies try to find the right market, the right product, the right price, the right promotion, and the right channel. However, this process does not apply to products based on discontinuous innovations in process and product technology. The discontinuous NPD process places much less emphasis on analysis and much more on probing and learning from the experience gained through sequential probes. The logic is experimental. The difference between the conventional and the discontinuous NPD processes results from identified uncertainties; the market is ill-defined and evolving, the technology is ill-defined and evolving, and the two interact. Lynn *et al.* (1996) concludes that it is virtually impossible to predict what product will eventually be offered, at what price, to whom, when, and where.

According to Lynn *et al.* (1996), in the probe and learn process, companies run a series of market experiments; companies develop their products by probing potential markets with early versions of their products, by learning from the probes, and probing again. The initial products are not final versions of the product, and are more like prototypes. The probe and learn process starts with introducing an early version of the product to a probable initial market. Probing with immature versions of the product serves as a means for learning about the technology and the market. Probing and learning is an iterative process.

Cole (2002) agrees with Lynn *et al.* (1996) that companies can develop products by probing potential markets with early versions of products, learning from mistakes, modifying the product, and probing again. Product development is seen as a non-linear process with backward and forward movements. Probing markets with immature versions of the products makes sense if they serve as a vehicle for learning. However, this process may cause decrease in market trust and satisfaction. Also this process may be too time-consuming. Cole (2002) claims that the probe and learn process lies at the heart of continuous innovation, and captures the essence of continuous improvement. He even extends probe and learn to Probe-Test-Evaluate-Learn, and says that it is an accelerated Plan-Do-Check-Act cycle. Finally, he argues that probe and learn is about organisational renewal, and it is associated with quick learning and the acceleration of the product development process.

2.5.3 Prototypes and early trials

Deszca *et al.* (1999) propose the identification and inclusion of customer opinions when breakthrough products are in question. The success of a new product depends on anticipating future requirements. This makes the work even harder, because customers have no historical experience with similar products and are unable to articulate needs into new product ideas. Therefore, education about the new products and the usage contexts are required. Prototype market testing is a means to answer the questions: who is the customer, what should the product contain, how should it function, and what infrastructure is needed to support it. However, prototype market testing might cause confusion, as early prototypes may substantially differ from finalised products. Another alternative is to wait until the product is fully designed, which again increases development time. Lynn *et al.* (1996) propose that prototypes and early trials are used in an iterative and sequential fashion to enhance learning.

Ulrich & Eppinger (1995) define a prototype as “an approximation of the product along one or more dimensions of interest”. Under this definition, any entity that exhibits some aspect of the product that is of interest to the development team can be viewed as a prototype. Prototypes can be usually classified along two dimensions. The first dimension is the degree to which a prototype is physical as opposed to analytical. Physical prototypes are tangible artefacts created to approximate the product. Analytical prototypes represent the product in a non-tangible, usually mathematical, manner. The second dimension is the degree to which a prototype is comprehensive as opposed to focused. A comprehensive prototype corresponds closely to the everyday use of the word prototype, in that it is a full-scale, fully operational version of the product. Focused prototypes implement one, or a few, of the attributes of a product. Within a product development project, prototypes are used as learning tools, they enrich communication, they are used to ensure successful integration, and prototypes are used to demonstrate that the product has achieved a desired level of functionality. In addition to the advantages prototyping provides for product development, Cole (2002) highlights the benefits of prototyping for quality improvement. Prototyping enables early error detection and thereby reduces engineering changes, thus reducing design iterations.

Den Ouden (2006) argues that a new class of non-technical problems contributes in a large part to the ever increasing number of customer complaints on innovative new products. She says that current analyses of customer feedback mainly focus on checking if the product meets technical specifications. These analyses show a rising volume of customer feedback where no failure could be established. Den Ouden's (2006) study reveals that customers complain not only about technical failures but also when the product does not satisfy their expectations. Running pilots might be one way to involve customers in product development to get the first ideas of customers' expectations.

2.6 Product reliability

Reputation is integral in quality, reliability, delivery, and price. Quality, which is simply meeting the customer requirements, is the most important of these competitive weapons. Part of the acceptability of a product or service will depend on its ability to function satisfactorily over a period of time; this aspect of performance is called reliability (e.g., Musa 1999, Musa *et al.* 1987, Oakland 1995, O'Connor 1995). According to Jones (1996), quality and reliability logically belong together, and good quality guarantees reliable products. ISO/IEC 9126 (ISO 1991) provides a framework for the evaluation of software quality. It defines six software quality attributes:

- Functionality: are the required functions available, including interoperability and security
- Reliability: maturity, fault tolerance and recoverability
- Usability: how easy it is to understand, learn, operate the software system
- Efficiency: performance and resource behaviour
- Maintainability: how easy is it to modify the software
- Portability: can the software easily be transferred to another environment, including installability

Testing is a means to find out the level of reliability. Musa (1999) defines two types of software reliability engineering testing i.e., reliability growth testing, which aims at finding and removing faults, and certification testing, with which a binary decision will be made: accept or reject the software. Testing has gained a lot of attention in the recent literature (Pol & Veenendaal 1998, Staab 2002, Davis 1997, Black 2004). Also the combination of verification and validation seems to be known in standards such as 1012-2004 IEEE and NIST (1996). ISO 9000-3 defines design verification as an activity that develops procedures that specify how design outputs, at every stage of the product design and development process, should be verified. The idea is that these procedures should verify that outputs satisfy design-input requirements. The same standard (ISO 9000-3) defines validation as an activity that develops procedures to validate the assumption that the newly designed products will meet customer needs.

Jones (1996) argues that planning and estimation are the reflections of measuring, and that metrics are increasingly used to estimate the future. Neil & Fenton (1996) affirm that the most important requirement of software metrics is to provide information to support quantitative managerial decision-making during the software lifecycle. They say that the main motivators for using metrics are the desire to assess or predict effort/cost of development processes and the desire to assess or predict the quality of software products.

The field of hardware reliability has been established for some time, but the field of software reliability is a newer one. When embedded systems are considered, both hardware and software are incorporated, and consequently, hardware and software component reliabilities are combined to get system reliability. The source of failures in software is design faults, whereas the principal source in hardware has generally been physical deterioration (Musa *et al.* 1987, Pressman 2001). Estimating software reliability seems to be difficult. When software has been released, users give feedback about software reliability, which is too late. Fenton & Neil (1999) argue that organisations are still asking how they can predict the quality of their software before it is used despite the substantial research effort spent attempting to find an answer to this question over the last 30 years. According to Kan (2003) this research area has been one of the most active in the software industry. He says that more than one hundred reliability models have been published in scientific journals and conferences. However, not so many models have been tested in a real environment with real data, he says. Problems in the use of reliability models appear because data collection is expensive, models are difficult to understand, and simply, because they do not work in practice.

Wood (1996) argues that the number of defects remaining in software helps decide if the product is ready for delivery or if more testing is needed and for how long. This information provides an estimate of failures customers are going to meet when using the software and it helps define the appropriate maintenance level. There are lots of papers advocating statistical model, metrics, and solutions trying to answer the question "Can we predict the quality of our software before we use it?" Generally, efforts have tended to concentrate solely on one of the following problem perspectives (Neil & Fenton 1996):

- Predicting the number of defects in the system using software size and complexity metrics.
- Inferring the number of defects from testing information.
- Assessing the impact of design or process maturity on defect count.

Fenton & Neil (1999), Fenton & Neil (2000), Neil & Fenton (1996) argue that, despite statistical methods, – as discussed above - also other approaches for software reliability estimation exist. For example Bayesian Belief Networks (BBN) stands for causal analysis. A BBN is a graphical network combined with an associated set of probability tables. The nodes of the network represent uncertain variables and the arcs represent the causal/relevance relationships between the variables. BBN enables reasoning under uncertainty and combines the advantages of an intuitive visual representation with a sound mathematical basis in Bayesian probability. With BBN, it is possible to articulate expert beliefs about the dependencies between different variables and to consistently propagate the impact of evidence on the probabilities of uncertain outcomes.

Chillarege (1994) claims that Orthogonal Defect Classification (ODC) is a technique that bridges the gap between statistical and causal models. Analysis of ODC data provides a valuable diagnostics method for evaluating the various phases of the software life cycle and the maturity of the product. ODC provides a means to understand the dynamics of software development by using classification of defects, so that they provide measurements (e.g. Chillarege 1994, IBM 2002). ODC means that a defect is categorised into classes that collectively point to the part of the process which needs attention.

2.7 Exploitation of the theoretical foundation

Previously, the general theoretical background (in chapter 2.1) and theoretical foundation for each research paper (in chapters 2.2 – 2.6) was reviewed. Next, the exploitation of the theoretical foundation will be presented for each research paper i.e., for each research question.

Business models. There are different definitions for business models. This research builds business models from three elements: offering, value creation systems, and revenue modes (e.g., Normann & Ramírez 1994, Kotler 1997, Porter 1985, Hoover *et al.* 2001, Shapiro & Varian 1999). Based on - above all - Slywotzky (1996), Hamel & Prahaland (1996), Hamel (2000), Timmers (1998), and Kalakota & Robinson (1999), a framework for describing and building business models was created. Additionally, the business model evaluation framework introduced in this research is founded on the evaluation criteria presented by Slywotzky (1996) and Hamel (2000).

Competence development. The theoretical foundation for competence development lies on learning organisation, organisational learning, knowledge management and project orientation (e.g., Argyris & Schön 1978, Senge 1994, Nonaka & Takeuchi 1995, Artto *et al.* 1998), which are enabled by organisational culture (Shein 1992). These, above all, are utilised in building a framework for project management competence development. Project management competences are categorised to project management knowledge areas according to PMI (2000).

Process renewal. TQM and BPR form the theoretical foundation for the research on process renewal. In the literature TQM and BPR are seen as complementing each other or as a continuation of each other (e.g., Fazel 2003, O'Neill & Sohal 1999). Huffman's (1997) "Four Re's" model combines ideas of TQM and BPR. The model is utilised in the research paper on process renewal, where experiences of praxis are preferential.

Technology piloting. NPD process (Ulrich & Eppinger 1995, Cooper 2001) and product platforms (Meyer & Lehnerd 1997) form the basis for new product development. However, continuous innovation and disruptive technologies change the situation (Deszca *et al.* 1999, Cole 2002, Costanzo 2004) and lead to new approaches in new product development; the probe and learn process (Lynn at al. 1996) increases its importance. The research paper on running technology pilots validates the probe and learn process.

Product reliability. The theoretical background in the fifth research paper deals with quality and reliability and views the estimation of software reliability. Despite more than one hundred reliability models (Kan 2003), published studies still raise a problem: can the reliability of software be predicted before it is in use? (e.g. Neil & Fenton 1996, Wood 1996, Kan 2003). The research on software reliability estimation exploits the theoretical foundation in practice; Musa (1999) gives a firm standpoint for software reliability estimation.

3 Models for management in a disruptive business environment

This chapter presents the individual research contributions of the research papers.

3.1 A framework for creating business models – a challenge in convergence a of high clock speed industry

The research paper discusses business models that could prevail and succeed in the mobile IP software application business. The paper presents two frameworks: one for describing and building, the other for evaluating business models. Additionally, based on four existing business models, six alternative scenarios of business models for mobile and IP convergence were created. The scenarios were named to reflect the model they represent. “Old and proven” effectively follows the proven model of the case company in selling mobile devices as embedded systems. “Configure-to-order” adds mass-customisation to this paradigm: it allows end users to select which additional applications they wish to incorporate in the product they are purchasing. “Software house” concentrates on selling software applications independently of hardware: it aims at building a massive volume of sales and a dominant position in the mobile IP software application market. “Internet store” aims at making the whole purchasing process easy and enjoyable. It utilises the Internet as the sole sales and distribution channel for the applications, and builds a community around its online store. In the “Content-driven” scenario the application is bundled in a third party’s service offering, and does not have a separate price for the end user. The third parties receive the applications free of charge, but are required to pay a commission from the revenues gained from the service usage. “Open software” frees the software and source code for downloading from the Internet, thus being a loss leader model: the software is provided free with the hope that it boosts the hardware sales. Finally, this paper presents a proposal on how to evaluate the business models using the defined evaluation framework.

A framework for describing and building business models (table 4) was created in order to form a commensurable way to describe business models. It ensures that multiple aspects are considered when designing business models, and it also provides formalism for building business models. The business model evaluation framework created (table 5) provides a set of diverse dimensions for the assessment of business models. The framework offers a sound basis for business model evaluation and it enables comparability of estimations.

Table 4. Framework for describing and building business models.

Dimension	Component	Description
Offering	Composition	What is the offering: what physical, information and service aspects are included?
	Customer	Who is the customer? (If relevant, identify both end and direct customer.)
	Sales approach	Sales channel, distribution, billing (how do customers pay)?
Value creation system	Structure	Networked or chain? Position of the firm?
	Network players	Who are the players? What are their roles? The relationships between players and the firm?
	Network size	The amount of the players, i.e. how many customers, suppliers etc.?
Revenue model	Basic logic	How and from whom is the revenue generated, i.e. where in the business system the firm takes profit?
	Cost and pricing structure	What kind of cost structure in producing the offering (fixed and marginal costs)? Value-based or cost-based pricing? For what do customers pay: bundling or unbundling?
	Market	Which market is served? Size of the market? Market structure (dominant player, diversified)?
	Share of total value	How big a portion of the total value created in the network can the firm capture with the revenue model?

Table 5. Business model evaluation framework (adapted from Slywotzky (1996) and Hamel (2000)).

Dimension	Questions to consider
Suitability	How well does the model meet customers' most important priorities? Are there priorities that are not served? Is it likely, that the priorities will change and thus make the model obsolete?
Internal consistency	How internally consistent is the model? Do all the parts work together for the same goal? Do the elements positively reinforce each other? Are there conflicting elements or elements that do not support the meeting of customer priorities?
Uniqueness	Does the model differ from those of competitors, or the "average" within the industry in conception and execution? Is it unique in ways that are valued by customers and benefit them?
Efficiency	What value do customers derive from the offering? What costs does the firm incur in providing that value? Does the value customers place on the benefits exceed the cost of producing them, i.e. is the model an efficient way of delivering customer benefits?
Ability to capture value	Can the model recapture value? Does it capture a sufficiently large portion of the total value created in the network? Are these mechanisms sustainable and defensible?
Economic considerations	Is the revenue model sound? Are the cost and pricing structures reasonable? Is the market large enough? How cost effective is the model?
Future potential	Does the model represent a better way than the existing alternatives? Will the model meet the customers' priorities also in the future? How long will the model be sustainable? Are alternative models being employed that meet the next cycle of customer priorities better?
Feasibility	Is the model realistic? How easy is it to implement? Is it possible to "sell the idea" to other network players? How probable is it that the model would work in practice?

This paper points out the possibility and practicality of business model designing and evaluation to be utilised in a revolution phase of an industry. It is reasonable to have frameworks to analyse the changes in industry rapidly, because the sooner changes in the industry or need for business model re-development are realised the more competitive the changes are in the new environment.

3.2 Project management competence development framework in a turbulent business environment

The research paper introduces the Project Management Competence Development (PMCD) framework, which is based on the learning organisation, organisational learning, organisational culture, knowledge management, and project management. The PMCD framework was created to develop project management competences in a systematic and sustainable way. It includes a long term competence development activity (Project Academia), and short-term activities (N1Race, Project Coaching Principles -workshops, Case Coach Leadership simulation, and Coffee Room Culture and Visual Management). All these activities represent continuous learning and improvement, knowledge sharing and experiential learning.

The PMCD framework is illustrated in Fig. 9.

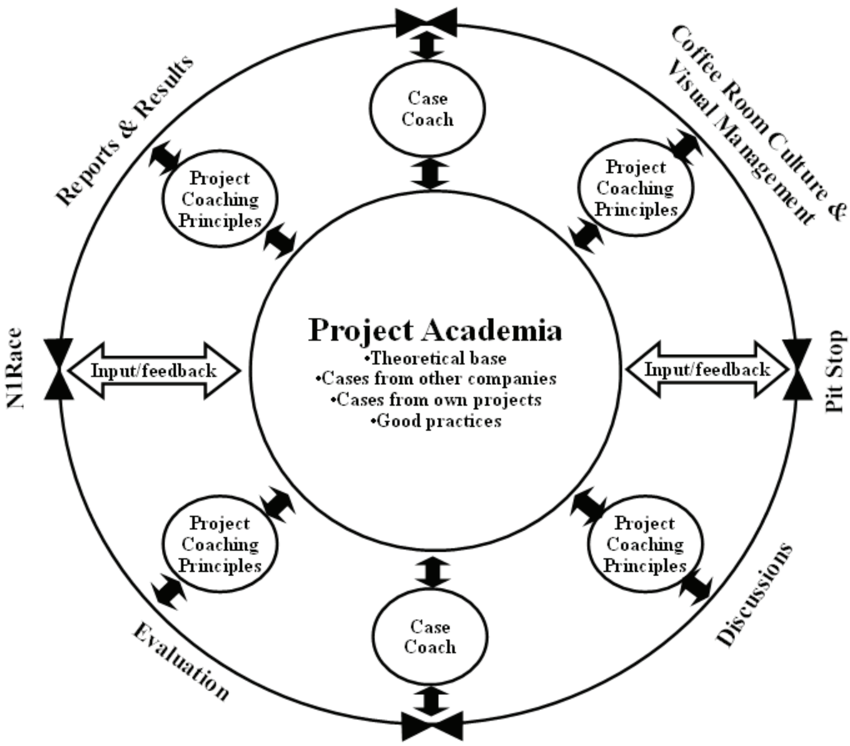

Fig. 9. Project management competence development framework.

Uncertainty and inability to predict the future characterise today’s business environment. Use of information and control systems and their compliance with pre-defined goals, objectives, and best practices may not necessarily lead to long-term organisational capabilities. Disruptive technologies also impact. This is the current world, which challenges the underlying assumptions i.e., ”accepted way of doing things.” This world needs the capability to understand the problems given by the changing conditions afresh. The focus is not only on finding the right answers but also on finding the right questions. Competence management focuses on ”doing the right thing” instead of ”doing things right”. To remain aligned with the dynamically changing needs of the business environment, organisations need to continuously assess their internal theories of business for ongoing effectiveness. This is the only viable means for ensuring that today's ”core competences” do not become the ”core rigidities” of tomorrow.

Project orientation gives a flexible standpoint for the deliveries, which means that the environment is understood beforehand as being dynamic. If we look at this from the competence point of view, it gives us a valid basis, because competence is also seen as dynamic in nature and the acquisition process has to be kept continuously ongoing. This paper describes a framework for competence development appropriate for dynamic, project-oriented business.

3.3 Process renewal driven by disruptive technologies

The research paper presents experiences of process renewal driven by disruptive technologies in the case unit. The paper presents strategies used in process renewal and what are the findings when disruptive technologies drive the change. New technologies, continuous innovation, and changes in today's business environment cause chaos in the prevailing circumstances; the old and proven way of doing business requires changes in the operational mode. This research proves several authors' (e.g. Ahire & Waller 1994, Fazel 2003, Gore 1999) ideas of combining the approaches of TQM and BPR.

This paper proposes that the prerequisites for successful process renewal are top management commitment and confidence in the selected strategy, focusing on customers, taking their requirements into account and involving them in the development work, persistency in transferring new ideas, flexible processes, satisfactory quality management, and competence development. This study addresses the reality that when technologies change, products are new and innovative, the environment is turbulent, and product development cycle times are short and then also the way of doing things has to be reconsidered. A different operational mode, renewed processes, persistence, high commitment, strong confidence and boldness to do things differently are required when convincing co-operators, management, and customers.

Table 6 summarises the case unit's process renewal procedure that is adapted from Huffman's (1997) approach – the "Four Re's", which are repair, refinement, renovation, and reinvention. The procedure starts with step 'Zero', which gives the initiatives for the renewal, and moves from the analysis phase up to launching the processes and finally to capturing the lessons learnt.

Table 6. Process renewal procedure in the case unit.

Step	Description	Responsible	Method
Zero	New operational mode, disruptive technologies, breakthrough products are the drivers of the renewal	-	-
1	Clarify the target of process improvement: flexibility, practicality, simplicity	Management team	
2	Customer requirements are unknown	-	-
3	Analyse the available process descriptions, identify needs for modification, identify missing process descriptions. Which of the Four Re strategies is best suited to the nature and extent of each initiative: - problem – repair or - could be better – refine or - wide gap – renovate or - huge gap or not existing - reinvent	Quality manager	
4	Repair – conduct root-cause analysis, refine – brainstorm improvement ideas, renovate – break down paradigms and apply innovation, reinvent – forget current approach and start with clean slate	Teams, quality manager as facilitator	Workshops
5	Repair – develop alternative corrective actions and choose optimum action, refine – develop and select appropriate improvements, renovate – match innovation possibilities to process requirements, reinvent – invent new approaches, processes.	Teams, quality manager as facilitator	Workshops
	Introduce process descriptions to test and get immediate feedback.	Quality manager	
6	Launch process descriptions	Quality manager	
7	Capture lessons learnt	Teams, quality manager as facilitator	Workshops

Process renewal driven by disruptive technologies deviates from management-driven process renewal in the first place in the primary target: what will the processes be like and what do customers want. The future is unknown; nobody knows what kind of processes would be most practical, efficient, and productive, and customers do not know what to expect. Additionally, in order to come out on top the company has to be agile and fast. Management-driven process renewal is done more controllably, renewal is well planned, specifications are created, and resources allocated which is different from process renewal driven by disruptive technologies. The way of process renewal presented gave many advantages: (1) renewed or adaptable processes could be tested right away and feedback was received and possible corrections were made rapidly, (2) common sense fostered practicality and decreased bureaucracy, (3) compatibility of processes was considered and tested in practice immediately, (4) customer requirements were considered, as the operational mode involved customers from the very beginning of the product/service development, and (5) involvement of all employees was guaranteed because they were the best experts to say how to work and thus provided the contents of the processes.

The starting point, before the process renewal, was that all process descriptions - except for piloting processes - were available, even though not practicable as such in the case unit environment. In the end, a workable set of process descriptions was achieved. In short, the process renewal embraced adaptation of existing processes to the changed environment, some of the processes needed a longer time period to assure their functioning, however.

The case unit served as a learning field, where new competences were acquired. People had to learn the new technologies, how the technologies could be utilised in future products, what is required from the technological environment, and infrastructure. Above all, people had to learn and probe new ways of doing things and also transfer the knowledge to other people.

3.4 Business impact of technology piloting – model for analysis in different phases of the development cycle

The research paper presents experience from running pilots for the introduction of disruptive technologies in the telecommunications industry and proposes pilots as a means to introduce new products and applications. This study opens running pilots up to a process embedded in the NPD process. The study validates the probe and learn process (Lynn *et al.* 1996) and shows the importance of customer involvement in providing new innovations and enhancement ideas in a technologically advanced environment. This paper presents and facilitates the actual process of running pilots in order to manage it.

The study was started with a rough model for running pilots for the end product or part of it in different finalising phases of the NPD process. This idea proved to be good one, since running pilots is basically a simple operation, even when the detailed operationalisation is complex. If the requirement specification is completely fixed by the customer, running pilots means only verification. In cases where the requirements are unclear validation comes into the picture and the real benefits of running pilots will be realised on a full scale. This is equally important for both the supplier and the customer. In validation the most important benefit is in confirming the common understanding of the requirements. The proposed piloting process is especially applicable when disruptive technologies are in question. In this case, the future is still unknown, it is not known if the new technology exceeds the old technology performance, and customers are unable to formulate what they want. When sustaining technologies are concerned, verification and validation processes (ISO 9000-3) are more applicable.

Fig. 10 illustrates the case unit's piloting process, which is embedded in the product development process. The process contains a chain of sequential trials (shown with the box with the dashed line in the figure), and thus executes the probe and learn process. The phases inside the piloting process are sequential, but running pilots is concurrent with other activities in the product development process. The principles of Cooper's (2001) Stage-Gate process were applied in the case unit's NPD projects.

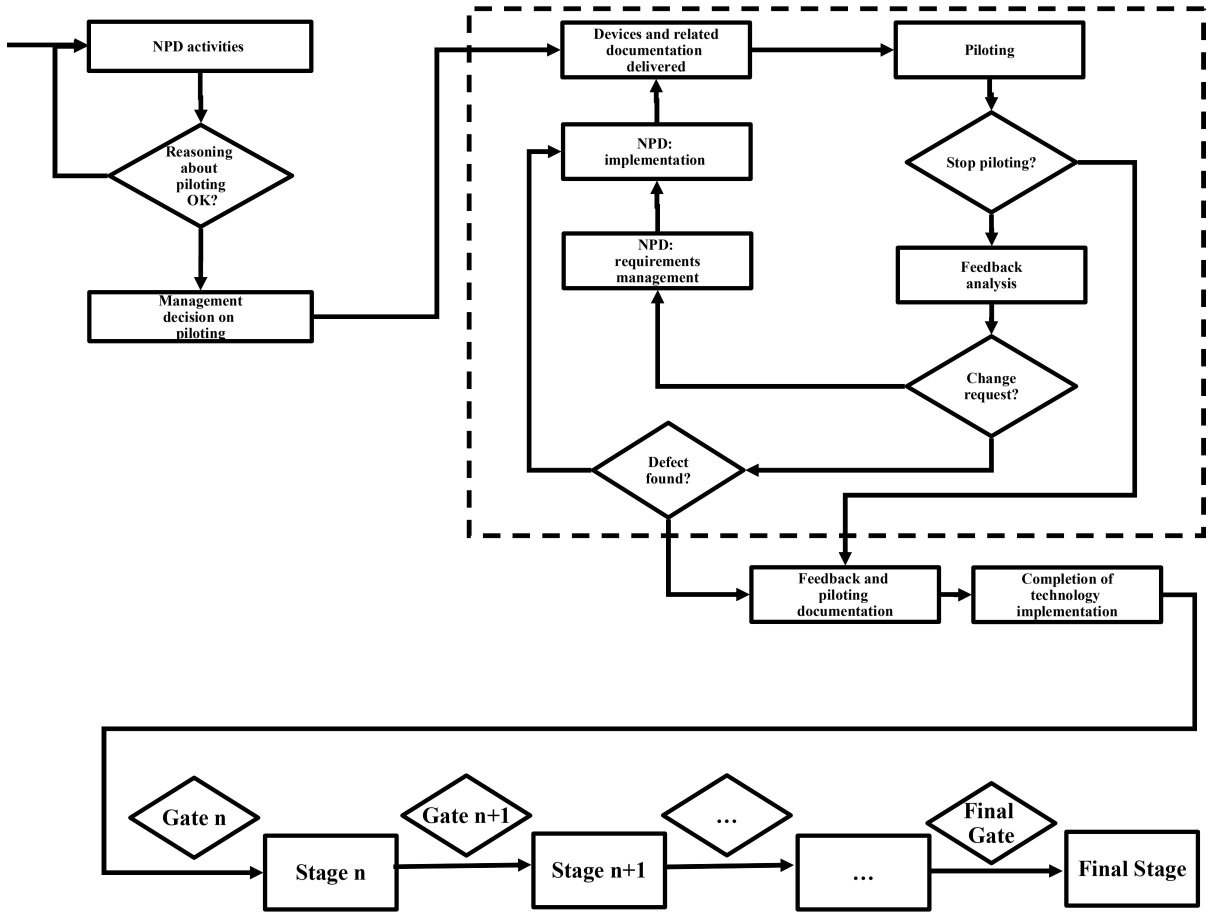

Fig. 10. The Stage-Gate (Cooper 2001) analogy in relation to the piloting process in the case unit.

In a high speed industry the importance of running pilots is even greater, because the requirements change in relation to time – so the content of the delivery evolves. The need for a project model for running pilots comes from the fact that operations should not only be managed, but also analyzed and compared. Comparison and development are only possible when utilising a systematic approach. From the efficiency point of view it is clear that every pilot should be managed as a project – with a clear target, specific start and end phases and with defined resources.

The idea of Lynn's *et al.* (1996) probe and learn process included in the discontinuous NPD process was proved to be applicable for the purposes of the case unit in introducing new technologies. Highlighting that the discontinuous NPD process places more emphasis on probing and learning from the experience gained through sequential probes; less emphasis is placed on analyses, even though analyses are essential to avoid incorrect conclusions and to find the root causes of failures. Prevention of errors is important, but learning from errors seemed to be vital in the environment of the case unit. The logic in the probe and learn process is experimental, iterative, and incremental. Also the well-known idea of Stage-Gate (Cooper 2001) was noted to be effective in iterative development, as it breaks the innovation process into a predetermined set of stages. The process ensures that all sub-areas of a product development process are considered, and the process enables progress visibility for top management, thus providing the preconditions for decision making.

3.5 Practical use of software reliability methods in new product development

The research paper presents seven software reliability estimation methods studied in the case company. Despite tens of software reliability models developed since the beginning of 1970's, few – if any - of them have worked optimally across projects (Kan 2003). This paper focuses on investigating the practical use of the methods in real-life complex development situations and demonstrates how the methods could be applied to the NPD process in the case unit. The results show that none of the methods operate alone but need to be combined with each other. The paper focuses on the practicalities of software reliability estimation and embeds it into the case company's process framework.

There are both similarities and differences between the methods studied, and also advantages and disadvantages in each of the methods. Fig. 11 illustrates when each method could be used in relation to the NPD process stages in the case company. Some of the methods discussed can be used from the very beginning of the product development project i.e., before the software is executable, and some methods just after the software is executable. The figure suggests that it is useful to combine methods to complement each other.

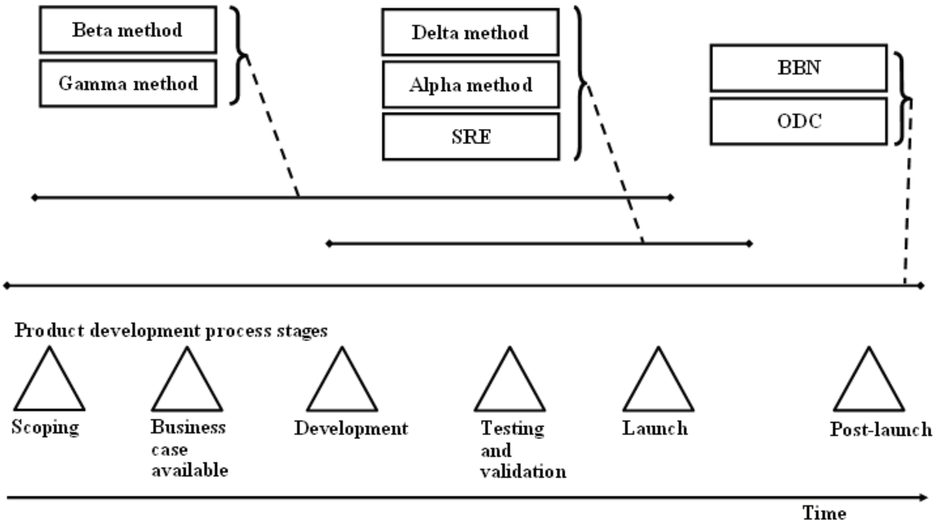

Fig. 11. Software reliability estimation methods in relation to stages of the NPD process in the case unit.

According to Fenton & Neil (1999, 2000), statistical models have dominated software metrics, though they often lead to misunderstanding about cause and effect. Therefore, they propose to use holistic models for software defect prediction, using causal models, like BBN, as alternative approaches to the single-use models. Software reliability engineering (SRE) is an approved method (e.g. Musa 1999) for software reliability estimation, as proved also by this research. In this study, SRE and one of the case unit's tailored methods (using the principles of SRE) have emerged as preferred methods – yet, not totally forgetting other methods.

The study reveals that the biggest obstacle when introducing the software reliability estimation methods to NPD projects in the case company has been missing enablers i.e., automated testing tools, scarce resources, and lacking competences. This study brings out the importance of data collection and more importantly the analysis of data during the whole life cycle of the NPD process.

4 Evaluation and discussion

In the previous section individual research papers and their contributions are presented. In this chapter, the logical deduction to link the papers together is presented, theoretical and managerial implications of the contributions are discussed, reliability and validity of the research results are considered, and exploitation of the research results is proposed.

4.1 Logical chain of inferences

Magretta (2002) defines the difference between strategy and a business model as follows: a business model describes the ensemble where building blocks of business are connected to each other; competition is not included in a business model, but is part of strategy. Mobile and IP convergence and disruptive technologies require reconsidering both for an appropriate business model and strategy. When a business model changes, it is necessary to rethink competition and competitive advantages as well. Competence development is a source of competitive advantage and it is essential for a company to acquire new competences faster and earlier than its competitors. At the same time, when the business environment is changing, new competences are needed, and disruptive technologies and continuous innovation create new kinds of products, it is likely that processes need renewal, and a new operational mode in a company must be introduced to tackle the new challenges. Furthermore, despite changes in the business environment and despite the means by which companies try to manage in the ever-changing circumstances, customer satisfaction is still the driving force for the success of companies. To involve customers early enough in new product development, running pilots gives means for this. Additionally, as the proportion of software is ever larger in products and customers are ever more demanding, the reliability of software, technologies, and products has to be guaranteed. For companies it is essential to be able to estimate the reliability of their products during the product development process and not to wait for customer feedback.

The above-mentioned chain of inferences describes how one moves from a wider perspective to a narrower one (see Fig. 1). Fig. 12 illustrates the connections of the five perspectives or research papers in another way: the new operational mode is the rallying point of the individual studies. Despite the straightforward transition from one perspective to another, there are also linkages between all of the perspectives. Next some examples are given to show how the aspects are intertwined with each other.

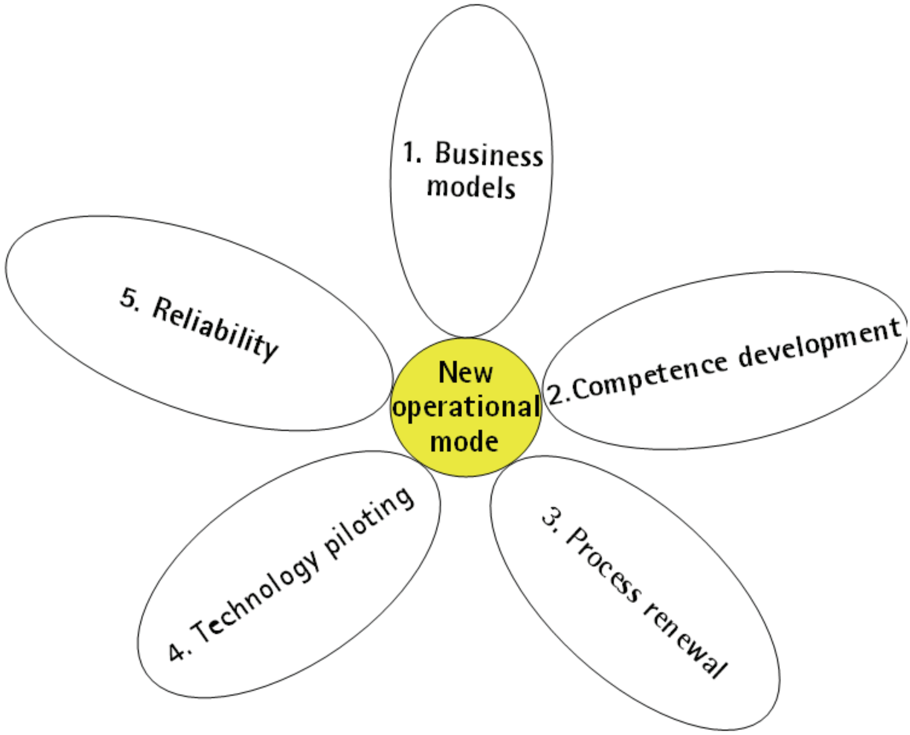

Fig. 12. Connection of the research papers to the new operational mode.

When introducing disruptive technologies new business models are required, which requires acquiring new competences. As the business model is new, learning is essential and distributing the lessons learnt is vital for the case unit and company. The case unit acts as a learning field and a learning organisation. Introducing disruptive technologies and new business models also triggers the need for a new operational mode and process renewal, as the old and proven practices are not necessarily beneficial any more. Further, when dealing with new technologies and new products, customer requirements and expectations must be considered carefully. Running pilots with customers is one means to involve customers in the NPD process. Finally, despite a novel business model, despite probably still insufficient new competences, despite new operating practices, and despite unknown customer expectations, better profitability, productivity and reliability of the new products must be guaranteed.

From the competence development point of view, refined and practical processes help to accumulate skills and competences and also help to create a good foundation for a learning organisation. Additionally, running pilots is an excellent way to develop competences; quick feedback through pilot projects strengthens learning, as learning from errors is still a firm cornerstone. When competences are in place, it obviously reduces errors and increases product reliability.

Process renewal is essential when the operational mode changes. Process descriptions help to align sub-areas and expertise areas as well. The piloting process is a novel process and with the help of the overall process renewal, the piloting process is also aligned with the NPD process. Well-defined processes guide concentration on the essential, prevent overlapping work, help to prevent generating errors and, in this way, minimise rework. Thus, processes support increased reliability.

Running pilots is a way to detect errors early enough and thus increase product reliability, and running pilots is a means to test the maturity and reliability of standards and de factos. Above all, pilot projects help in ascertaining customers' expectations for new technologies and new products.

The previous logical deduction leads to the research problem, which was formulated as: What kind of operational mode is needed to introduce disruptive technologies? The above-mentioned logical deduction anticipates that an operational mode consists of different elements, different aspects, and thus, a very simple and short answer is not possible. As a conclusion, the operational mode when introducing disruptive technologies requires reconsidering business models; the old and proven way of doing business is not adequate any more. The new operational mode requires special attention to competence development; especially tacit knowledge is highlighted in project-oriented business. A framework for competence development gives a solid basis for development of competences and knowledge management. Further, the old and proven processes and quality tools used in development of continuous improvement products are no longer appropriate; process renewal is required to move to the adaptable, flexible processes. The new operational mode requires more intensive customer involvement in product development; with highly innovative products customers are often unable to give specific requirements as the technology is new and customers lack the experience in such products. Technology pilots offer an efficient and effective way to involve customers in product development in the R&D phase. The customer point of view is also in the spotlight in reliability estimation; reliable estimates of software reliability support managerial decision-making as to when to launch the software.

4.2 Implications

In chapter 2 the theoretical foundation for the research papers was given, and the research papers were presented in chapter 3. In this chapter both theoretical and managerial implications are discussed.

4.2.1 Theoretical implications

Table 7 summarises the theoretical contributions of the five research papers and then, implications of the research papers are discussed.

Table 7. Summary of research contributions.

#	Title of the paper	Contribution	Research questions
I	A framework for creating business models – a challenge in convergence of high clock speed industry	- Framework for creating and building business models - Framework for evaluating business models - Business model scenarios and a proposal for evaluating them	RQ1
II	Project management competence development framework in turbulent business environment	- Framework for project management competence development	RQ2
III	Process Renewal Driven by Disruptive Technologies	- Process renewal procedure - Experiences on process renewal driven by disruptive technologies compared with management-driven process renewal	RQ3
IV	Business impact of technology piloting – model for analysis in different phases of development cycle	- Introducing technology pilots concept in product development framework - Experiences on customer involvement in pilot projects	RQ4
V	Practical Use of Software Reliability Methods in New Product Development	- Integration of software reliability estimation methods to product development framework - Evaluation of software reliability estimation methods in the case unit	RQ5

Business models: The research paper proposes practical tools for building and evaluating business models and creates business model scenarios. The paper discusses a very topical issue and is solidly based on existing knowledge. However, when a new business model is chosen, further studies are still required to analyse how the model works in practice. The model needs further reconsideration based on the analysis.

Competence development: The paper confirms the importance of the concepts of learning organisation, organisational learning, knowledge management and organisational culture. It proposes a practical framework for competence development. The proposed framework has been used in the case company and the results are promising so far. Still, as the environment is ever-changing, also the framework needs modifications. There are future development challenges: how to evaluate the impacts of the framework, how to create and follow-up career/competence development path, what are the working methods, etc.

Process renewal: This paper strengthens the idea of existing literature of combining both TQM and BPR approaches in process development. Experience with the operational mode and renewed processes of the case unit has been encouraging. However, they still need further research to find out if they also prove to be favourable in long-term use.

Technology piloting: The research paper is based on existing knowledge of the NPD process, which is complemented with a piloting process that involves customers in development work. The paper proposes the piloting process applied in the NPD process. Additionally, the research verifies the probe and learn process. The study proved the applicability of the presented model for running pilots, but also the utility of the whole piloting activity. However, piloting activities (process development and analysis) need continuous evaluation of and reflection on the ever-changing environment. Ultimately, processes should be defined to reflect the best practices and especially help product development projects to fulfil their business targets.

Product reliability: This research gives a practical point of view for software reliability estimation based on existing knowledge of software reliability models. It proposes a praxis for coping with a very challenging task. However, the studied and, especially, the preferred methods need continuous evaluation due to the changing environment. In addition to currently presented methods there are future development challenges: how to further develop the methods to better respond to the daily practices of NPD projects.

This research as a whole provides one solution for how to investigate and evaluate the current situation of a company in today's business environment. One has to keep in mind that the approach presented is only one possibility of many as to how this can be done. There are certainly many other ways and aspects to evaluate a company's possibilities to cope with the dynamic business environment.

4.2.2 Managerial implications

Fig.1 depicts the scope of the thesis composed of the five individual research papers. The scope is illustrated with a cone; the deeper one goes into the cone the narrower the management perspective becomes. The research paper 1 ("A framework for creating business models – a challenge in convergence of high clock speed industry") focuses on business models and discusses the prevailing business environment from the point of view of the case company, but of course it is relevant also beyond the case company. The focus area – competence development - of the research paper 2 ("Project management competence development framework in turbulent business environment") is more concise compared to the previous one, and covers the case company; the paper introduces a framework that is built especially for the case company but is applicable to other companies and other industries as well. Further, the research paper 3 ("Process renewal driven by disruptive technologies") concentrates on experiences from the process renewal of the case unit as part of the case company; the paper tells experiences of the process renewal conducted in the case unit. The research paper 4 ("Business impact of technology piloting – model for analysis in different phases of development cycle") deals with technology pilot projects in relation to the NPD process in the case unit; it goes deeper into the technology development in the case unit. Finally, the research paper 5 ("Practical use of software reliability methods in new product development") focuses on software as part of technology products, and covers the project level in the case unit.

In respect of the different research perspectives, the time frame for these implications is also different. The implications for new business models will be visible during the long term period. However, today it is known that the business model is different but its impact in the quantitative meaning is not yet concrete. Practices and tools for competence development are changing all the time. The proposed competence development framework introduced in the second research paper has been in use since 2001; data from it is already presented in the paper. The renewed processes have been in use in the case unit for about three years. Their impact on daily work is seen as flexibility. However, quantitative data of the use of the processes is not yet sufficient. With respect to technology pilot projects, the first trials have been conducted and the lessons learned have been distributed to later pilot projects. The impact of technology pilot projects is also visible as quantitative data as can be seen in the fourth research paper. Special attention is drawn to feedback data collection and analysis in current projects. The technology piloting process is in use in the case unit. Software reliability estimation methods introduced in the fifth research paper have the most concrete impact. The proposed methods are introduced in NPD projects in the case company. Quantitative data analyses have been done, and a more systematic way to collect and analyse data taken into use. Commercial modelling tools have been introduced and significant savings in resources is expected.

The five perspectives represent different fields: business models deal with economics, competence development concerns human resources and personnel management, process renewal relates to quality management, running pilot projects goes deeper in technology management, and software reliability applies to software engineering. The purpose of this "cone approach" is to help understand the wholeness of the situation. However, these perspectives are not the only ones, just some of them. The aspects chosen were the most important and topical to the case unit.

The research environment changes quickly and research results focusing on changes in different sub-areas have given valuable input for managerial decisions. The case unit, IPC, consisted of both R&D functions and business development activities. It was an experimental and temporary organisation, whose main objective was to find an efficient and fast way to develop new applications, technological enablers, and features for the use of NPD projects utilising new, disruptive technologies. IPC acted as a pioneer and an adventurist in creating and testing new technologies that provide new opportunities for customers. IPC was established in 2002 and today it does not exist as such, but is merged with its operational mode and processes in permanent organisational structures of the case company. IPC worked in its way for new technologies. Success factors were – above all – top-management commitment and confidence in the case unit's work, focusing on customers, taking their requirements into account and involving them in the development work, persistency in transferring new ideas, flexible processes, satisfactory quality management, and competence development. This study addresses the viewpoint that, when technologies change, products are new and innovative, the environment is turbulent, and product development cycle times are short, then also the way of doing things has to be reconsidered. A different operational mode, renewed processes, persistence, high commitment, strong confidence, and boldness to do things differently are required when convincing co-operators, management, and customers.

When contemplating this research today as a whole it confirms the managerial decisions made during the existence of the case unit. The work gives confidence to managers that their decisions have been fair guesses. From time to time, some decisions have been made based on intuition (according to one manager of IPC). However, one can say that this intuition is evidence of the tacit knowledge that the people of the case unit have. Goldratt (1990) writes about intuition and says that all our inventions, decisions, and convictions are based only on intuition. What is missing is the ability to verbalise our intuition, to provoke it, focus it and cast it precisely into words. As long as proper verbalisation is not used, we ourselves will act in ways that contradict our own intuition. This study can be considered as verbalising the intuition of the key managers.

A summary of contributions to the case company is presented in table 8.

Table 8. Research contributions to the case company.

#	Title of the paper	Contribution	Research Question
I	A framework for creating business models – a challenge in convergence of high clock speed industry	Today it is known that the old and proven way of doing business is not sufficient any more. Theoretical foundation for building business models and their evaluation is provided.	RQ1
II	Project management competence development framework in turbulent business environment	Business environment is changing and new competences are needed. Project management competence development framework provides a firm standpoint for competence development.	RQ2
III	Process Renewal Driven by Disruptive Technologies	Mobile and IP convergence, disruptive technologies and business agility push to process renewal. The case unit's renewed processes give a basis for further process development.	RQ3
IV	Business impact of technology piloting – model for analysis in different phases of development cycle	Customer satisfaction and user experience urge to customer involvement. Technology pilot projects involve customers in new product development.	RQ4
V	Practical Use of Software Reliability Methods in New Product Development	Despite new technologies and changing business environment the reliability of products is still vital for success. Methods for software reliability estimation are introduced to estimate reliability during R&D phase.	RQ5

Next, an extract from the message of the director of IPC is presented. The message was sent to IPC personnel on December 27, 2004 – at the time when it was discontinued as an independent unit and was merged in the current organisational structure of Nokia Multimedia (Huotari 2004):

> "IPC started approximately three years ago and after a short start-up phase we concentrated to do architecture, protocols and IP oriented software mainly for Symbian-based products. Because we didn't have any "own" products it was hard to drive different requirements to [the technology platform], but somehow we managed to do it anyway. But it is truthful to say that this mode is far from the most optimal in driving new features into the Nokia portfolio, and hence it has required much more effort and patience from the IPC team members.

In addition to the applications and enablers there was plenty of work in the standardisation area where Nokia's position in forums like Internet Engineering Task Force (IETF) got dramatically better over the last three years. This is often seemingly invisible work that has huge consequences for the future direction of our industry, and should be kept active at least on present levels.

One, very important aspect of IPC’s mode of working was piloting and direct interface to the customer front. We did test and pilot our implementations in real life and on live networks, and this was an essential part of our work.

This cannot be underlined enough, since all these IP based applications are living manifestations of end-to-end implementations. In end-to-end environments every aspect starting from the user interface through SW layers and HW to air interface, through all network elements and possible servers and eventually to other terminal(s) user interfaces create a chain where all elements are part of the total user experience. These things cannot be simulated in laboratory conditions only!

In these exercises we did also get valuable help from the network side to get all elements in place, and all in all, had very good interaction and collaboration on many fronts. Also this aspect demonstrates in real life the need for end-to-end understanding.

One crucial aspect of this piloting was the fact that our people and R&D teams did know directly what was happening on the customer front and thus could react fast and also did have real motivation to make the needed modifications fast.

The learning from this is that it is worthwhile to have a dedicated, very technology-oriented customer interface, as the feedback is often directly applicable to products in a short-to-mid time frame, which allows Nokia to come up with products that have immediate pull on the market.

All in all, IPC did demonstrate in a concrete manner that 1+1 can be more than 2. Our team could deliver things which would not have been possible if they had acted as isolated islands across the Nokia's organisation.

I'm personally honoured that I have had the possibility to work with such a capable and innovative team!

Although IPC will cease to exist at the end of this year, the things we have done will be part of Nokia assets and thus help in making something new possible: something that wouldn't be there without the effort put in by all of you who have been part of IPC over these years.”

4.3 The reliability and validity of the research

This research has proceeded with iterative cycles increasing the researcher’s understanding about the research subject. The research method used follows the characteristics of normative action research. One basic element in action research is the subjectivity of the researcher. It has to be confessed that the researcher is a central instrument in the research. In qualitative research the main criteria for reliability is the researcher, and thus the evaluation of reliability concerns the whole research process (Eskola & Suoranta 1999).

Excessive reliance on participant observation notes can severely distort conclusions towards the researcher's personal preferences. This is especially true in action research, where the researcher may be subconsciously tempted to manufacture self-serving explanations for the lack of success of some of his or her own interventions in the client organisation. The over-reliance on participant observation notes is likely to lead to invalid research findings. Sometimes there is a researcher preference bias towards one explanation, because it may seem to lead to more "relevant" scientific findings that another explanation, which may look like a relatively trivial finding. The action researcher has to consider objectivity during the research. The action researcher cannot be strictly objective, but however, he or she should take this into account. The researcher should at least try to recognise his or her biases and values. Especially in participatory action research, objectivity is an important issue; the researcher behaves more or less subjectively.

Qualitative research focuses on only a few cases and aims at analysing them thoroughly. The criteria for the data in a scientific sense stand on the quality, not on the quantity. The responsibility of the action researcher is to pick out the data under his or her research. Action research and qualitative research in general is based on no hypothesis, i.e. the researcher does not have preconsiderations on the subject under study or the results of the research. However, the researcher has the history and former experiences, and they cannot be ignored during the research. These experiences must not limit actions during the research. The action researcher should create a new hypothesis, not prove an existing hypothesis.

Yin (2003) proposes four tests to establish the quality of any empirical social research: construct validity, internal validity, external validity, and reliability.

To meet the test of *construct validity*, a researcher must be sure to cover two steps: (1) select the specific types of changes that are to be studied and (2) demonstrate that the selected measures of these changes actually reflect the specific types of change that have been selected. (Yin 2003). The research problem of this study was viewed from five different perspectives utilising a cyclical, iterative research method. Each perspective was reflected through existing theories and research papers were written as four journal articles and one conference paper. Quantitative data for competence development (research paper 2), technology pilots (research paper 4) and software reliability (research paper 5) are already, or in the near future will be, available. Unfortunately, the effects and measures for business model changes are not available yet.

Yin (2003) argues that on one hand, *internal validity* is a concern for studies where the researcher tries to determine whether event x led to event y. If the researcher incorrectly concludes that there is a causal relationship between x and y without knowing that a third factor, z, may actually have caused y, the research design has failed to deal with a threat to internal validity. On the other hand, the concern about internal validity may be extended to the broader problem of making inferences. In the research environment there evidently were intermediate factors. As this research was conducted via sequential, iterative cycles from five viewpoints during several years, these criteria are met.

External validity deals with the problem of knowing whether the research findings can be generalised beyond the immediate context of the study. The analyst should try to generalise the findings to "theory" (Yin 2003). The research environment was unique, but the dissertation consists of five research papers that provide the theories and their exploitation in practice in the case unit. In that sense, the research findings can be generalised. However, one has to keep in mind that the research environment was just one R&D unit in one company and the research questions were focused just to solve the questions set in that unit.

The objective of testing *reliability* is to ensure that, if a later researcher followed exactly the procedures described by an earlier researcher and conducted the same study all over again, he or she would arrive at the same findings and conclusions (Yin 2003). As already mentioned, the research and the research environment were unique in nature and it is impossible to conduct exactly the same research; business environment is ever-changing, technologies are replaced by new ones, people with their tacit knowledge move from one position to another, etc.

4.4 Exploitation of the research

The contributions of this research benefit the case company. Individual studies introduced in the research papers can also be utilised outside the case company, one by one or all together. Next, the exploitation of the research papers is discussed.

Business models. There are different definitions for business models. Despite the definition, each company should reconsider its business model to prepare itself for new situations, especially in a changing business environment. For some industries this is of vital importance. This research paper builds business models from three elements - offering, value creation systems, and revenue modes – and proposes a framework for describing and building business models and a framework for business model evaluation. These frameworks can be exploited when considering the most appropriate business model for a company.

Competence development. The research paper on competence development utilises a theoretical foundation of the learning organisation, organisational learning, organisational culture, knowledge management and project orientation. The research introduces a framework for project management competence development. The framework consists of five elements: Project Academia training program, Project Coaching Principles workshops, Case Coach Simulation model, Coffee Room Culture and Visual Management concept, the Pit Stop facilitation method, and N1Race as web based learning environment. This framework can be utilised as a whole or its elements can be exploited one by one. The framework gives a foundation for a company to use it as such, or to modify it to correspond to the company's special needs.

Process renewal. TQM and BPR form the theoretical foundation for the research on process renewal in the research paper. The research paper talks about experiences from praxis when process renewal is driven by disruptive technologies. Of course, the situation in each company dealing with process renewal topics is different, but still the description given in the paper might give new ideas to a company facing with the same situation.

Technology piloting. NPD process, product platforms, continuous innovation and disruptive technologies change the prevailing situation in industries introducing new breakthrough products and lead to new approaches in new product development. The probe and learn process is validated by this study. The constructed piloting process is embedded in the NPD process in the case unit. The piloting process, utilisation of the probe and learn process and customer involvement in the case unit give valuable information for other companies as well.

Product reliability. The research on software reliability estimation exploits the theoretical foundation of quality, reliability, and estimation of software reliability by introducing seven software reliability estimation methods and their evaluation in the case unit. Additionally, the methods are situated in the NPD process of the case unit. This study tells how software reliability estimation can be conducted in practice, since the literature claims that more than one hundred reliability models are introduced, however not implemented in practice.

5 Summary

Today's telecommunications business environment is ever-changing; there is always a new technology on the way to replace the current ones. The speed of change seems to increase more in high tech industries than in traditional ones. This means that business cycles in high tech industries are shorter than in other industries. This research emerged from this turbulent environment. On one hand the purpose of this research was to understand the changing environment, and on the other hand to pursue action and research in order to create more applicable processes and better capabilities for the case unit and case company operating in these new circumstances.

The research problem of this study was stated as follows:

What kind of operational mode is needed to introduce disruptive technologies?

To be able to give a solution to the problem, this research was approached from different perspectives with five research questions, each of which is discussed in an individual research paper. Thus, each research paper corresponds to one research question rooted from the research problem i.e., missing refined and established methods, processes, and operational mode to promote development and implementation of disruptive technologies.

Table 9 summarises the research questions and their contributions.

Table 9. Research questions and contributions.

#	Research question	Contribution
RQ1	How to build and evaluate business models?	- Framework for creating and building business models - Framework for evaluating business models - Business model scenarios and a proposal for evaluating them
RQ2	How to develop competences?	- Framework for project management competence development
RQ3	How to renew processes?	- Process renewal procedure - Experiences on process renewal driven by disruptive technologies compared with management-driven process renewal
RQ4	How to involve customers?	- Introducing technology piloting concept in product development framework - Experiences from customer involvement in pilot projects
RQ5	How to estimate reliability of products?	- Integration of software reliability estimation methods to product development framework - Evaluation of software reliability estimation methods in the case unit

The research questions are intertwined; they are related to each other, even though their focus is different. Each of these areas is large and would be worth further study. However, this scope was chosen as an initial move. The research questions - from one to five – move from a wider to a narrower subject matter. These perspectives were chosen in order to understand the nature of the operating area as a whole since the operational mode consists of different elements.

As a conclusion, when introducing disruptive technologies the operational mode requires reconsidering business models; the old and proven way of doing business is not adequate any more. The new operational mode also requires special attention to competence development; in particular tacit knowledge is highlighted in project-oriented business. A framework for competence development gives a solid basis for development of competences and knowledge management. Further, the old and proven processes and quality tools used in development of continuous improvement products are no longer appropriate; process renewal is required to move to adaptable, flexible processes. The new operational mode requires more intensive customer involvement in product development; with highly innovative products customers are often unable to give specific requirements, as the technology is new and customers lack experience with such products. Technology pilot projects offer an efficient and effective way to involve customers in product development in the R&D phase. The customer point of view is also spotlighted in reliability estimation; reliable estimates of software reliability support managerial decision-making as to when to launch the software.

The contributions of this research benefit the case company. Individual studies introduced in the research papers can also be utilised outside the case company, one by one or all together. The research environment was quickly changing and research results focusing on changes in different sub-areas gave valuable input for the case unit IPC, which consisted of both R&D functions and business development activities. IPC was an experimental and temporary organisation, whose main objective was to find an efficient and fast way to develop new applications, technological enablers, and features for the use of NPD projects utilising new, disruptive technologies. IPC acted as a pioneer and an adventurist in creating and testing new technologies that would provide new opportunities for customers. IPC was established in 2002. From the very beginning it was planned to be a temporary organisation, and today it does not exist as such, but is merged with its operational mode and processes in the permanent Nokia organisational structure. IPC worked, in its way, for new technologies.

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