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Product Development Practices and Their Organisational Information Requirements

An Explorative Case Study of Product Development Management in Some Finnish Companies

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Ari J. Maunuksela

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Maunuksela, Ari (2003). Product development practices and their organisational information requirements – An explorative case study of product development management in some Finnish companies. *Acta Wasaensia* No. 111, 252 p.

Earlier empirical results on new product development success factors and development performance have shown that a link between the targeted type of success being pursued and development practices used should be achieved and managed. A strong means-ends type of contingency relationship moderates the relationship between strategies and development practices used by firms. A related research problem has been found from the literature, on how the technological and competitive settings of a firm might impact the uses of product development practices within a product development process. A more detailed research question can be defined for the analysis of this problem: *How could we analyse different types of product development practices and their implementation in the product development process of a firm?* This question has been analysed with an empirical case study and the results are described. In this thesis a means-ends type contingency model framework has been developed in order to test how the use of different product development practices are perceived and interpreted by the management team of a product development process. This approach is based on the underlying role of development orientation to major performance dimensions in product development. A model framework has been built which utilises an organisational information requirements framework. This enables an organisational interpretation system perspective to be applied to the evaluation of the roles of product development practices in the product development process of a firm. Empirical results from a survey in five case study companies are presented and analysed. Results from the study suggest that different product development practices may differ in terms of their use as means to achieve different types of ends and performance goals in a product development process. Implementation of product development practices is subject to the perceived uncertainty and equivocality among teams and groups with respect to orientation towards the development goals. Experience and knowledge in different product development practices can also vary. The results may add to our understanding about the premises of effective implementation of product development practices. Furthermore, the research and analysis method developed here complements the earlier ways of analysing product development practices. This is because the analysis of information requirements related with the use of product development practices does not have to be limited to project based analysis. Different team or group level organisation mechanisms used in the deployment of various product development practices can be analysed in further studies to find further evidence and verification on the value of the method and related analysis perspectives.

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Key words: product development process, development practices, organisational information requirements, technological competitiveness, product development performance.

1. INTRODUCTION

General interest in product development activities is often characterised by the continuous hunt for best practices (Griffin and Page 1996). This is probably because many times the imperative of competitive thinking surrounds product development activities. Key questions analysed in a number of studies have been how success in product development has been defined and what kinds of development practices can be associated with elements of success (Hart 1993, Montoya-Weiss and Calantone 1994, Hart 1996). Analogy in innovation process research is therefore basically that by linking development practices to types of success achieved it is possible to identify new best practices for product development activities. Hart (1993) has also argued that competitive impacts of product development should be used as guidelines in the studies of product development activities and new product development.

This view is an interesting way to look at the product development practices used by companies. Ittner and Larcker (1997:22) have argued that *firms should try to match their product development practices to their technological and competitive settings.* This thesis is focused on the analysis of the development practices used in the product development process of a firm. The goal of the study has been to extend previous empirical findings where companies have been reported to have used product development processes in ways where they have been tailored for the needs of a particular project (Tatikonda 1999, Kessler and Chakrabarti 1999, Tatikonda and Rosenthal 2000). This points us towards the analysis of product development practices used in development processes. What kinds of roles and purposes can various product development practices have in processes, and how do practices need to be adjusted with competitive premises?

This study addresses one of the recognised research gaps in the analysis of innovation processes. The gap concerns the role of organisational interpretation systems in the innovation processes of firms (Gales et al. 1992: 329). The thesis is based on the idea that a firm's product development process can be seen as an interpretation system, affecting the use of product development practices. The theoretical framework of Daft and Lengel (1986) describing organisational information requirements has been adapted and used in this research for the analysis of this kind of interpretation system. Daft and Weick (1984) and Gales et al. (1992) have defined organisational interpretation systems in a manner where both an organisation's culture or some aspects of the information requirements could be used in the analysis of organisational interpretation systems. This thesis focuses on the information requirements perspective.

Existing knowledge on the interpretation related issues in product development processes highlights two central issues. First is that it is important to define the type of success being addressed in the study of new product development activities. Second is that the type of strategies and practices used in pursuing a certain type of success are important. These premises can also be approached from a more theoretical perspective by arguing that the characteristics of new product success and improvement of development capabilities in a firm represent a phenomenon that can be described via an organisational interpretation system. This kind of interpretation process is an example of what Daft and Weick (1984:293) have discussed in terms of organisational interpretation systems: *the interpretation system view is concerned with specialised information reception, equivocality reduction and sense making.* According to Daft and Weick (1984: 293) there have been rather few studies on the processes of interpretation. However, they argue as follows...

"Interpretation may be one of the most important functions organisations perform. Indeed, the second research implication of the interpretation system perspective is that scanning and sense making activities are at the center of things. Almost every other organisational activity or outcome is in some way contingent on interpretation."

Daft and Weick (1984) have also defined interpretation as *the process through which information is given meaning and actions are chosen.* Gales, Porter and Mansour-Cole (1992:329) have also argued that this kind of interpretation system should be addressed in future studies of product innovation activities. Gales et al. (1992) have also proposed that the conceptual framework of Daft and Lengel (1986) could be used in this kind of study. The following figure illustrates the conceptual framework used in the literature analysis for this thesis where the Daft and Lengel (1986) framework has been utilised. The theoretical framework characterising the approach is presented below in Figure 1.

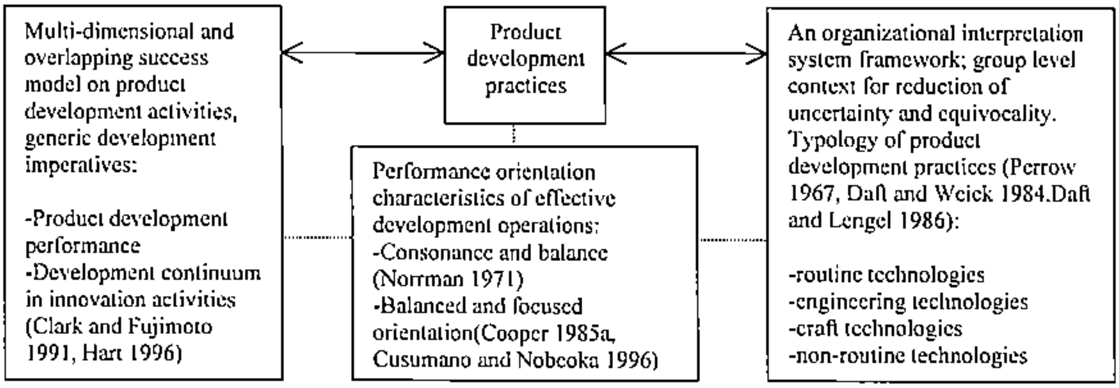

Figure 1. Theoretical framework and conceptual model for the literature review

1.1 Scope of the study

This study has been restricted to product development processes. This is because the competitive impacts of technologies and markets can be addressed with many important product development practice level issues within the product development processes of firms, and the firm's business practices, too (Friar 1995, Christensen 1997). Focus on product development processes may also be somewhat more general than with different products (Cooper 1993; Dooley and Van de Ven 1999). Accordingly we can also define here that in this study product development practice refers to different issues than a firm's product development process as a whole. Here, a product development practice means an approach taken to conduct some product development tasks in a way that is fit for a company and its development resources.

Earlier studies have highlighted how important the role of middle management can be for R&D and product development (Allen 1977, Nonaka 1990). It also appears to be an important issue for the study of product development process that we need to know more about the ways by which middle management becomes involved in the important issues of a firm (Floyd and Wooldrigde 1992, Nonaka 1990, Nonaka 1994, Nonaka and

Takeuchi 1995). One explanation for this is that middle management does have important responsibilities for the line control of the workflows in the context of the processes of an organisation (Pugh, Hickson and Hinings 1969). Another reason is that middle management often has competencies in technology and product development practices (Nonaka and Takeuchi 1995, Barclay 1992b). Thus focusing on middle management work in the control of the workflows in a product development process can help us in the analysis of the product development practices, too. On this basis this study has been focused on the analysis of product development process used by firms by addressing the work of middle management in the implementation and control over the uses of product development practices.

1.2 Key concepts

This chapter shortly introduces the major concepts used in this study. Concepts have been listed here alphabetically. The purpose of these definitions is twofold. Firstly, some links to related literature references have been adopted in order to show how these concepts have been used in earlier studies, and to show that these concepts are used in a similar sense in this research. Secondly, some conceptualisation has also been done in this research and these key concepts are also listed here. These definitions describe organisations' activities and general characteristics of their performance with terms related to product development. As an example, the idea behind the conceptualisation of the issues in this research is to address issues related with how companies and their competitiveness may depend on their product development performance. The purpose is not to analyse issues like "product development is effective in a specific company because they might be flexible in their processes", but the intention is rather to describe performance in more general terms like product development performance, which is an outcome of several different performance dimensions of development activities. One earlier example from operations research literature might be also shown as Richardson and Gordon (1980) have discussed the purpose and ways of analysing total manufacturing performance, instead of focusing only on single dimensions of performance.

The purpose of this concept list is to introduce the key concepts used in this study. Alphabetical ordering has been used for this purpose.

Equivocality is related with the different views and ambiguities surrounding a problem in a given situation. Equivocality describes issues that can have multiple meanings and interpretations among the members of the group and the organisation (see additional examples in Daft and Lengel 1986, Sicotte and Langley 2000).

Information processing reduces uncertainty and secondly, it involves also interpreting equivocal situations (Daft and Lengel 1986: 359).

New product performance is defined as analysis of the new product's technical and economical results achieved since the product has been launched and introduced to markets. New product performance can be measured with different ratios and measures.

New product success is an outcome measure for a product development project. New product development projects may be either successful or failed, to the extent that a firm achieves the goals being allocated for each particular project.

Product development has been defined as the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product (Ulrich and Eppinger 2000:2).

Product development performance is defined as something that is produced (the amount, quantity, or total produced) or it is resulting from the act of product development function of a company.

Product development practice is defined as an approach taken to conduct some product development tasks in a way that is fit for a company and its development resources. In this study four different types of product development practices have been used: routine practices, engineering practices, craft practices and non-routine practices. Definition of these concepts has been adopted from Daft and Lengel (1986).

Product development process is the sequence of steps that a firm employs to conceive, design and commercialise a product (Ulrich and Eppinger 2000).

Product development process performance has been defined here as a relationship between targeted development goals and the practices being used to achieve the goal. Process performance then has this operational performance aspect that is also related with the analysis of means ends relationships in the use of development practices to achieve specific type of goals for development work.

Project performance, "Performance in a development project is determined by a firm's product strategy and by its capabilities in overall process and organisation." Clark and Fujimoto (1991:18).

R&D (research and development) activities/projects include future oriented research and analysis work where new ideas and technical solutions can be studied before commercial applications are developed. R&D work often has some overlap with product development activities but key objectives and important resources may need to be managed and separated sufficiently for both R&D and product development.

Technology has been defined here as information requirements of technical tasks in the context of product development process. Four types of information requirements have been used in the description of such tasks: routine technologies, engineering technologies, craft technologies and non-routine technologies (Daft and Lengel 1986).

Technological competitiveness means that the company can create technology specific competencies with the business specific capabilities of the company (Maunuksela and Takala 1995: 169–171). This is a definition that has been developed in empirical analysis of small firms' activities in the early stages of their export operations and internationalisation. In this study, the purpose of the shown definition of the technological competitiveness is to describe company level performance, not competitiveness of product or products as such.

Technical superiority is an important success factor for new products. When a new product is technologically more advanced than other comparable products in the markets it can be also argued that this kind of new product represents the current state of the art in particular application where the product is used.

Uncertainty is a gap in the information required for the accomplishment of a task and the amount of information already known in the phase where the work is being initiated (Galbraith 1973).

1.3 Research problem

Different types of information flows can be modelled and analysed in product development processes. It is also an imperative to be able to do this as part of the innovation work because integration of varying elements of success can enhance learning for competitiveness (Van de Ven and Polley 1992). Issues of competitiveness and product development have been studied quite a lot. The nature of new product development and success in competition has often been analysed through the technical antecedents of new product success. Variables like technical superiority and technological competitiveness have been found to be significant new product success factors (Cooper 1985a, Hart 1993). The argumentation of Ittner and Larcker (1997) can be also used as an idea of how to develop the thinking on competitive settings in a slightly different way. The point is that we can actually delve deeper into the relationships between a new product's technological superiority or competitiveness and product development practices.

It is probable that different product development practices would need to be used in order to match the competitive requirements. The literature on organisation theory suggests that this kind of issue might be related with the ways by which information is being interpreted and how such activities are organised in firms. Thus the basic question addressed in this study is how could we use organisational information requirements (Nadler and Tushman 1978, Daft and Weick 1984, Daft and Lengel 1986) for the analysis of product development practices? The literature on new product development and organisation theory suggests that a link between success factors and use of development practices is an important issue in the management of product development activities. The question can be divided into the following sub-questions.

1) How might the technological and competitive settings of a firm impact the uses of product development practices within a product development process?

2) How could we analyse different types of product development practices and their implementation in the product development process of a firm?

There are many reasons behind this kind of research theme. For example, Souder (1978) has argued that it is difficult to find generally superior product development methods. Secondly, uses of different product development methods, practices and activities are often part of an unfolding process where work progresses at the pace of an innovation project (Gales, Porter and Mansour-Cole 1992). Product development process can also be seen in broader way, where product development practices might be naturally adjusted on the basis of uncertainty and equivocality.

1.4 Research approach, strategy and the structure of the study

This research has been based on an empirical research strategy with descriptive case studies. We have used both qualitative and quantitative research methodologies (Jick 1979, Brewer and Hunter 1989, Sekaran 1992). Eisenhardt (1989a) argues that it is possible to use case studies for the generation of new theories, and also illustrates a model for empirical research process, in which it is shown how different case studies can be used in the analysis of a phenomenon. Yin (1994) is more explicit in how we may perform a case study in a real-life context. The following figure illustrates the main phases of this research, Figure 2.

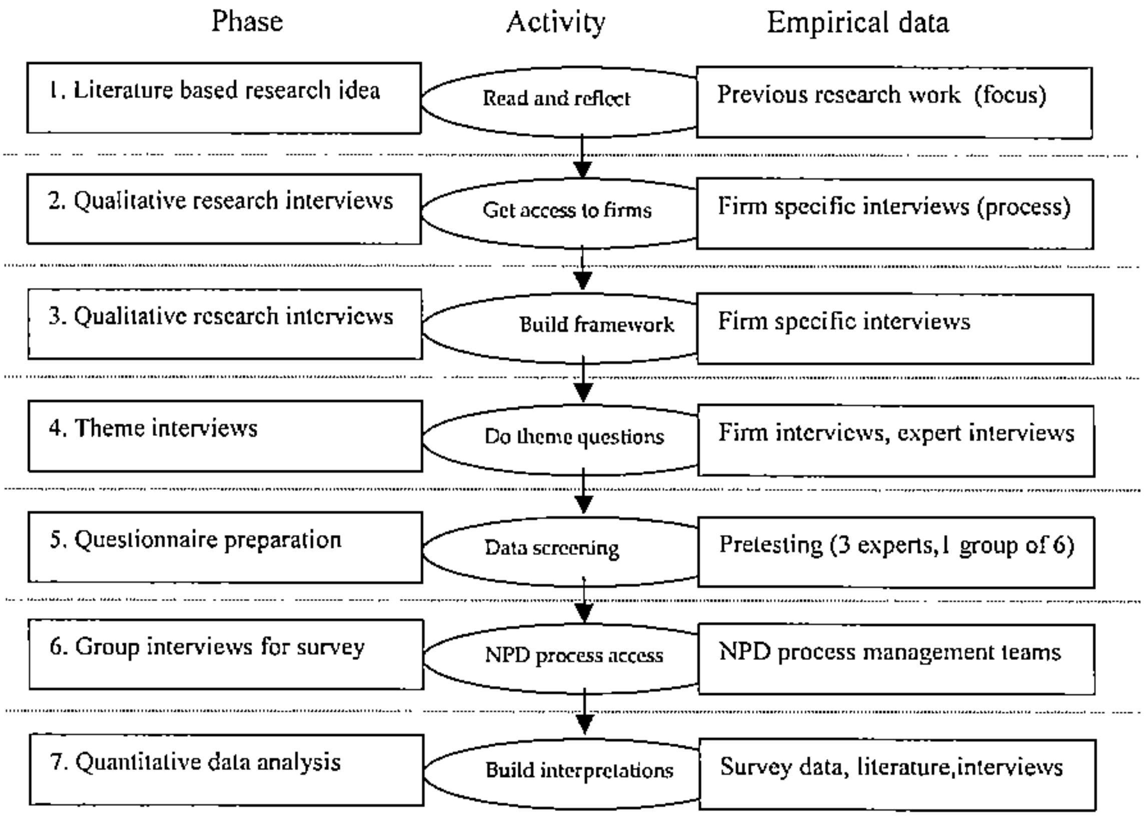

Figure 2. Research process and critical phases of data analysis and treatment with linkages to empirical data

This gradually progressing logic of a research process will be described here shortly in order to describe the logical structure of the study. More detailed descriptions of phases 1 –7 will also be shown in Chapter 3, titled Empirical Research Process. Different phases of the research serve a different purpose in the research process, which defines the main structure of the thesis report.

Step 1

The original idea for the research was based on the experience of the researcher. Some previous empirical research projects have been particularly important. A study by Maunuksela and Takala (1995) focused on analysis of technological competitiveness[1] that also became an important research project with some issues related with the product development of small and medium sized companies. The theme of technological competitiveness was also addressed in this study. Additional empirical studies were also reported in conference papers (Maunuksela, Takala and Keskinen 2000, Maunuksela and Koskela-Koivisto 1997). Research by Loch, Stein and Terwiesch (1996) was also very important for the decision to focus on the product development processes in the electronics industry. Some ideas related with the topic were successfully tested in a preliminary case study project where product development activities were analysed with some ideas from manufacturing strategy literature (Maunuksela 1997). Questions analysed in the initial phases of this study explored the applicability of a particular type of manufacturing performance management framework in product development. Empirical research work was then launched with a working definition of the goal of the research defined as “competitive priorities in product development”, using ideas from manufacturing strategy literature (De Meyer, Nakane, Miller and Ferdows 1987; Leong, Snyder and Ward 1990; Noble 1995, Takala 1997).

[1] Technological competitiveness means that the company can create technology specific competencies with the business specific capabilities of the company (Maunuksela and Takala 1995: 169-171)

Step 2

The next phase in the research was focused on the preparation of a detailed research plan. This plan was also used as a document when access to different industrial companies was being negotiated. Access was eventually gained to a number of firms. Different case companies were used as environments where it was possible to study their product development activities by interviewing the managers of product development process. Especially the contacts with case companies 1 and 2 were used in this phase to help the researcher in the building of pre-understanding of the research issues (Gummesson 1992). These interviews were also used in the detailing and definition of the research question. More focused and crisp definition of the research issues seemed to be necessary.

The results from step 1 and step 2 enabled a more precise definition of the research task in this thesis. These phases of the research process can also be characterised as quite hermeneutic and qualitative (Alasuutari 1993; Steyaert 1997, Steyaert and Bouwen 1997). It was important that the researcher's conception of the research problem was redefined and developed into a form of research framework. The notion of competitive priorities was abandoned as a framework and a more focused review of product development performance was now targeted.

Step 3

The idea of the competitive priorities in product development processes was found to be a similar type of problem as the multi-dimensional and complex nature of new product performance dimensions. Performance driven analysis of product development activities was analysed with questions such as: how can we deal with questions of competitiveness before a firm has launched its new products onto the markets? It was then discovered that a more focused and limited research framework would be useful. Different types of performance dimensions related with product development activities were analysed by means of literature review and empirical interviews. It then became evident that these results were often restricted with different types of constraints and contingencies. In a synthesis of both literature and interviews in cases 1 and 2 it became evident that it could be possible to conceive the meaning of "competitive priorities" by analysing the impacts associated with good management practises on product development processes, and the relationships between practices used in product development. This phase led to the development of the conceptual framework discussed in Maunuksela (2001) where some generic performance dimensions for product development activities were addressed. Figure 17 in chapter 3 shows this conceptual framework.

Step 4

Definition of the conceptual framework gave improved structure to the issues being analysed. Now it also became important to look for relevant literature where issues related with these performance dimensions like technological competitiveness and product development performance were addressed. Some references were found from the literature, but it was also becoming evident that different studies were using varying definitions and measures for these concepts. No particular definition was seen to be superior to others. The ideas behind this research had been related with multi-dimensional performance dimensions via a notion of competitive priorities. A similar imperative to be able to make a priority decision or a trade off solution was seen to be a necessary requirement for the conceptual framework. It was then decided that additional interviews could be used as a source of information material for this problem. The solution was achieved by building a structured theme interview questionnaire where the research framework could be utilised in the empirical research.

There were two alternative courses of action to proceed with this new instrument. The first one was to utilise questionnaire and theme interviews in the companies where case study interviews in the earlier phases had been conducted. The second alternative was to look for additional information with new interviews outside the case companies. This second option was adopted as a course of action. The reason behind this decision was the perceived need to find new material and learn more about the interrelationships between these concepts. Thus the next phase was a series of theme interviews with both Finnish and foreign experts. These scholars were familiar with these issues being analysed in this study. Many international scholars in the field of product development and technology management agreed to give an interview for this purpose. If the access to interviews with outside experts had been more difficult it might have limited data collection for the interviews in the case companies. Fortunately, it was possible to extend the data collection from case companies with these additional interviews. Theme interviews with scholars and managers in the industry helped to study the nature of the issues related with the research framework.

Step 5

Another important decision was made between steps 4 and 5. It was considered that a quantitative survey might be a beneficial method to crystallise the findings from the interviews. Secondly, complementing the interview data with survey methods could make the results of the analysis more traceable. It is typical to use surveys and questionnaires for data collection. It was decided that a specially developed data collection instrument could also be a way to implement the conceptual research framework in this research. Additional case companies were also included in the study when the research progressed towards a more robust research framework. Two new cases (case companies 3 and 4) were also interviewed. Summary and interpretation of the findings from cases 1-4 and expert interviews was developed into a set of product development practices used in the questionnaire. Qualitative information available from the interviews was analysed and synthesised into a set of product development practices that captures some important aspects of the interrelationships between technological competitiveness and product development performance. The original interview data and survey questions developed from this material are shown in Appendix 3.

Step 6

Interviews in different companies were extended to a level where four companies were included in the research phases between 4–5. When it was decided that a special survey instrument would be developed as a part of the empirical research process, it also became important to test and conduct a survey with the questionnaire. In this stage the group of four companies was very important. In a way, by continuing our case study with a survey it was possible to experiment with how well the approach constructed would work. The research approach used in this phase was constructed on the basis of empirical and theoretical knowledge. It was decided that a group of respondents from a firm would be needed because of the small size of the sample of 4–5 case companies. Groups of respondents provided more variance in the results of the survey.

It also became evident that some iteration was necessary in this phase before a workable survey tool was achieved. This is also reported in some detail in chapter 3 to show how the structure of the survey tool emerged through the empirical pre-testing and verification phases. The important thing is that all four case companies were interviewed in the course of this research agreed to participate in the survey. This made it possible to have quantitative data collected with the new survey tool. Analysis of these results has been discussed in conference papers (Maunuksela 2000, Maunuksela 2002) that provide more detailed insights into the company specific findings. It can be also mentioned that the results of these publications have been used in reporting the findings of the research back to the case companies as feedback.

Step 7

Originally the empirical work was planned according to the guidelines of case study research (Eisenhardt 1989a, Sekaran 1992, Yin 1994). The research process included different steps of iteration and progress. This has meant that that the nature and exact definition of the research question has evolved in the course of the research. This kind of gradual building process is possible in grounded studies. Sometimes case studies are reported only in terms of the qualitative findings, reflecting selected aspects of the empirical data. This kind of result may be somehow limited in the ways in which the findings can be validated, for example. Use of case specific reporting with qualitative material was also considered as an alternative way to present the findings of the research. However, there were some difficulties encountered in the reporting of the findings between phases 6 and 7. For example, some detailed analysis of company specific product development practices were seen as quite critical to these companies, so that these examples could not be used in the public reports of this research. On the basis of such experiences it was concluded that numerical survey information based on standard questions used in different case companies would be a more neutral way to approach these questions.

Moreover, the use of standardised questionnaires in a set of case companies enabled also a more quantitative analysis of the differences between the companies. Step 7 of the research process describes the analysis of the results of the survey from case companies. Another case, case 5, was also included in this stage in order to extend the base of the analysis with some additional material.

Step 7 also included additional issues and research challenges. The main issues concerning the analysis of the results are related with the statistical research methods. Since a new type of survey tool was developed in this research it meant that corresponding analysis methods would also be necessary. Synthesis in this phase was achieved through a triangulation process where literature, empirical data and qualitative research interviews were integrated together in a way that enabled a linkage between the theoretical premises and the empirical data collection.

It was necessary to delve into the depths of modelling of product development activities. Moreover, important implications of the alternative meanings of uncertainty and equivocality for the survey instrument were considered. This is a fact that is embedded in the research problem. The data analysis process included development of an appropriate interpretation and analysis method to describe the results. Group level responses enabled the building of interpretation of the premises of uncertainty and equivocality that were also evident in the data where different perceptions of individuals were analysed. Groups working together have to be capable of making interpretations and conclusions through dilemmas, where two sometimes superficially conflicting goals may be resolved in a synergy bringing fashion (Boisot, Griffiths and Moles 1997).

Thus finally the survey part of the study has been a field test for a new survey instrument. In-depth analysis of the rich material from empirical research work was continued until a sufficiently robust interpretation was achieved by means of phase-wise iteration and triangulation. The main principle was to perform a set of case studies in different firms. These case studies could be used for the study and analysis of the research question in different kinds of environments. We have studied both product development projects and company practices for the management of a product development process in the empirical part.

2. LITERATURE REVIEW

This thesis delves into the management of a product development process. The goal of this literature review is to present an overview of recent research on product development processes, and to address some areas where new research efforts might be needed. The literature review addresses a research gap in the analysis of innovation projects where the use of organisational interpretation system perspective has been described as an area requiring new research (Gales et al. 1992). The purpose of the literature review is to focus on the analysis of the research questions being studied in this thesis and the main goal is to describe how the product development process can be seen as an organisational interpretation system (Daft and Weick 1984). This perspective is then utilised in order to describe how different product development practices may represent varying types of organisational information requirements (Daft and Lengel 1986) in terms of the implementation of these practices. The literature review is organised according to the following structure: innovation process as a task environment within a firm; information requirements of a product development process; limitations of project specific approaches to the analysis of information requirements and a synthesis describing the research gap. The synthesis describes an approach for the analysis of the product development practices and their implementation in the product development process of a firm. This provides an answer to the research question being addressed in this study.

2.1 Innovation process as a task environment within a firm

Bourgeois (1980) has argued that it is necessary to make a separation between the opportunities in the general environment of a firm, and the respective choices within the task environment of the firm's functions like marketing and manufacturing. A business strategy may be used for "navigation" in the competitive environment of a firm. Other types of strategies can be more concerned with the implementation of selected objectives derived from business strategy of a firm (Bourgeois 1980). Many types of performance goals used in a firm may be based on the business strategy of a firm. A firm has to be also seen as a whole, as an organised entity that can simultaneously both integrate and differentiate its various activities and functions with and from each other (Lawrence and Lorsch 1967). From a product development perspective, Kessler and Chakrabarti (1996, 1999) have presented similar ideas to Bourgeois (1980). Kessler and Chakrabarti (1996) have argued that we need to make a distinction between strategic and administrative or more operational issues in innovation processes. Product development methods and practices can also vary in similar ways.

Kessler and Chakrabarti (1999) have actually extended the results of the analysis suggested by Crawford (1992) on the nature of accelerated product development. Crawford (1992:194) has written on some characteristics of innovation processes: *innovation is a process of defining an objective (performance, feature, customer saving or the like) and then evolving something that will achieve the objective; the process is focused creativity, not shooting in the dark.* These ideas underline that work in the innovation process is a focused effort, as in some particular cases it can be that a firm is facing pressure to shorten its product development times. Ideas on accelerated product development by Crawford (1992) can be used to illustrate this kind of example.

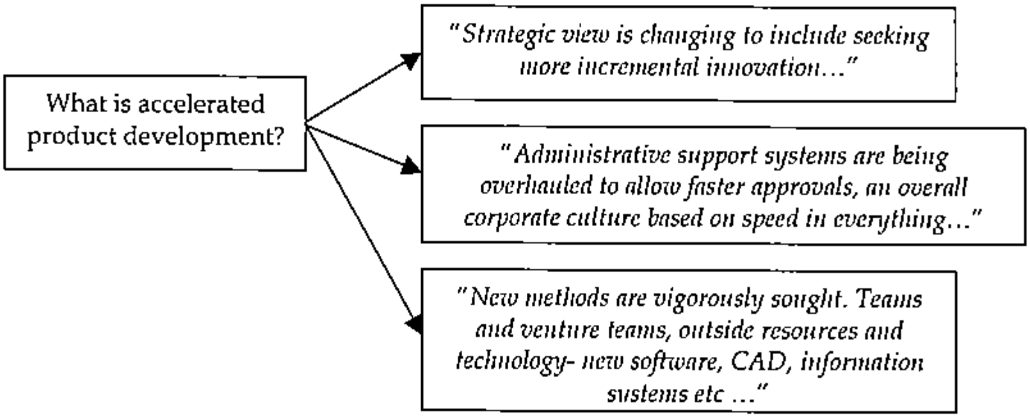

Figure 3. An overview of different perspectives to accelerated product development (text excerpts cited from Crawford 1992: 189)

Crawford's (1992) approach to innovation through accelerated product development is based on performance. Figure 3 above describes multiple issues that may be necessary to consider and manage in order to pursue the goal of accelerated development, at different levels. To be able to accelerate development work it can be necessary that multiple levels of activities need to be managed in order to achieve congruency (Nightingale and Toulouse 1977) in the activities of a firm's organisation. These kinds of issues have been analysed in terms of the product development projects. One such congruency-based view is the relatedness or coherence between various product development activities of a firm (Clark and Fujimoto 1991). Clark and Fujimoto (1991:18) have written "*Performance in a development project is determined by a firm's product strategy and by its capabilities in overall process and organization.*" Clark and Fujimoto (1991) have also described a hierarchical framework that captures multiple levels of issues in a firm's product development activities. Their perspective is especially related to the co-ordination of the development activities of a firm as a whole, to focus a firm's development capability strategically. Crawford (1992) discussed the acceleration of development activities. Another way to address similar types of questions could be to analyse whether a firm can make different choices in the timing of product development activities. A major issue in the timing of product development is the balance and focus allocated to technology development and product development, see Figures 4 and 5 on next page (Clark and Fujimoto 1991).

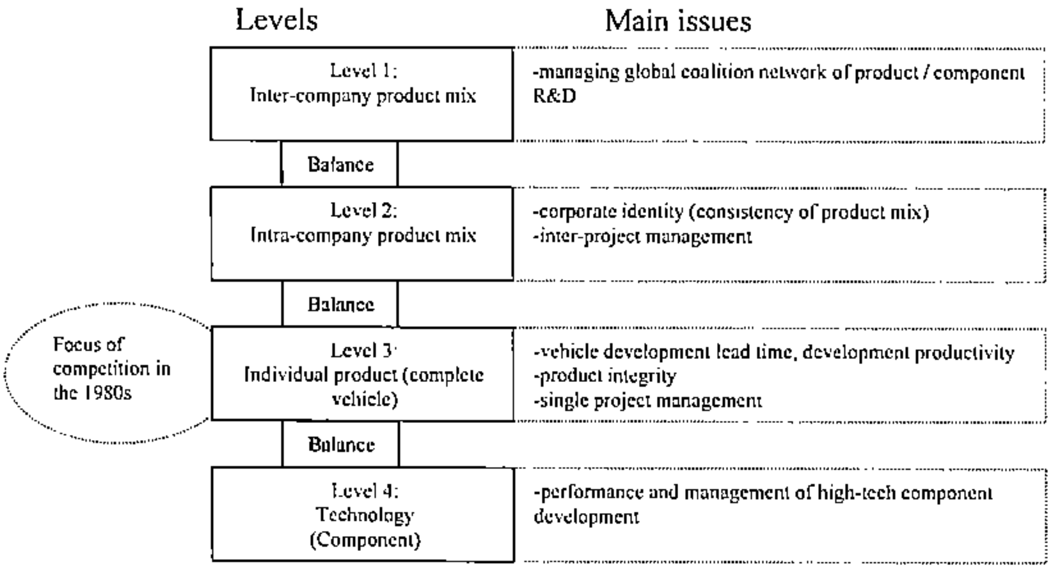

Figure 4. Hierarchy of product development management (Clark and Fujimoto 1991)

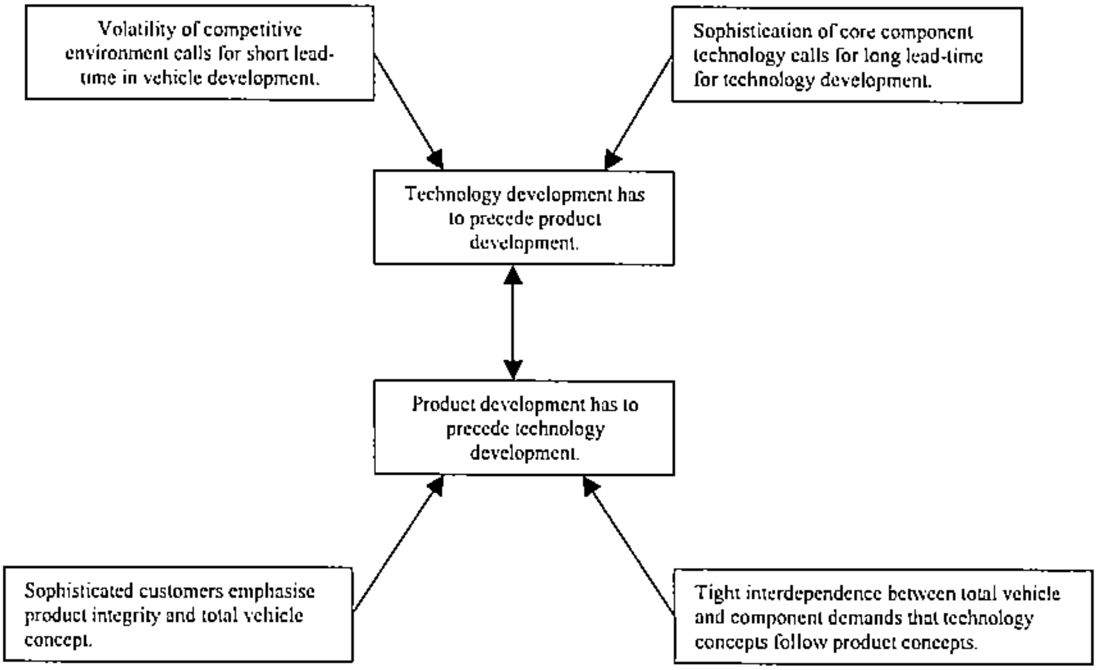

Figure 5. Technology development versus product development (Clark and Fujimoto 1991)

Conclusions from these descriptions might be that that there are many levels of decision-making and operations in the product development of a firm. Another way to say this it is that product development management requires multiple hierarchies and balancing factors with the firm level product development processes. These issues characterise also the innovation process of a firm as a hierarchical and multilevel task environment. Competitive impact from technology development can support product development, but in a way it can also become an obstacle for product development if a mismatch occurs. Illustrations from Clark and Fujimoto (1991) describe how product development and technology development can be multilevel issues for the product development of a firm, see Figure 4 on the previous page. A key issue is to manage the balance between technologies and products in order to manage the timing and other concerns like acceleration of some projects. Balance is an important characteristic of effective innovation processes, and it will be addressed here also with other complementary perspectives.

Management of balance with the perspective on product development management has also been discussed in other types of studies concerning product development. Cooper (1985a) has argued that successful firms may manage a difficult balance between technological and market orientation. This underlines the role of managing the orientation in innovation activities. Technology-based orientation for innovation is also a form of "market orientation" that is very important for product development (Gatignon and Xuereb 1997). Moreover, market orientation can be fundamental for the whole organisation and its capabilities for innovations (Hurley and Hult 1998).

Strategies for new products and programmes behind a firm's product development process can be keys to the balanced and focused efforts in a development process (Cooper 1985b). In his analysis, Cooper (1985b) has concluded that most successful new product programmes were characterised by a "balanced and focused strategy". Balanced and focused strategy categorisation of some firms was mostly related to appropriate integration of different orientations for markets and technologies. *At the same time, the strategies in these firms were technologically sophisticated, oriented and innovative, and* *also strongly market oriented* (Cooper 1985b: 191). Table 1, shown on the next page, illustrates some of the characteristics of such firms.

Cooper's (1985b) findings on new product programmes of firms imply that top performing firms can build focus by integrating both market and technological orientations with their new product programmes. Analysis of a firm's new product programmes has been used as a way to look for the relationship between strategy and performance, in the context of new product development activities of a firm (Cooper 1984). Principally it has been also suggested that the very issues related to the management of product development projects and processes should be balanced with the needs to be both flexible and focused in terms of the process as a whole (Cusumano 1992). A programme level perspective is a broader perspective than an individual project, or a pair of projects representing successful and failed new product development efforts. Perhaps the implication from Cooper (1984) *"that new product performance is largely decided by the strategy that top management elects"* summarises the primary issues concerning new product performance and product development processes. See Table 1 (below) to analyse some characteristics of high performing firms with balanced and focused new product programs.

Table 1. A profile of the balanced and focused strategy model as identified by data with multivariate statistical techniques by Cooper (1985a: 184)

Components	Balanced and focused strategy types (one of the 5 statistically identified clusters)
1. Technological sophistication, orientation and innovativeness	Very highly related
2. Production and technological synergy	-
3. Product fit and focus	Very highly related
4. Market newness	Low related
5. Market potential, size and growth	Very highly related
6. Marketing synergy	-
7. Marketing orientation and domination	Very highly related
8. Market competitiveness	Very low related
9. Product differential advantage, quality and superiority	Highly related
10. Product differential advantage, customer impact and superiority	Highly related
11. Premium priced products	Highly related
12. Program focus	Highly related
13. Competitive dominance	Low related
14. Market needs newness	Very low related
15. Offensive orientation	-
16. R&D spending	-

At the level of product development processes, beyond balanced and focused new product programmes, it is also important to know more about the elements of effectiveness and efficiency in order to adjust product development practices according to the levels of uncertainty and risk-taking appropriate for firms and management. In summary, it is possible to conclude that these examples describing the innovation process as a task environment in a firm show that different levels of management activities may have to be performed in order to manage a firm's innovation process.

Characteristics of best practices fit for the management of development activities have been described with examples like balance and focus in the implementation of innovation activities of a firm. Furthermore, it has also been argued that a balanced orientation between different requirements can be an important factor supporting the focus in development activities. Previous examples have been selected to illustrate earlier research findings on innovation processes of a firm, where a superior balance has been a trademark of successful and efficient product development (Cooper 1985a, 1993). The question of balance in product development can also be addressed by the innovative orientations of the organisation for strategic goals like new products (Normann 1971). It is important to make an appropriate separation between old and new and to manage balance between different types of development goals. Normann (1971) has addressed this with a concept of consonance.

"It is not easy to give a meaningful operational definition of product dimension. In studying complex systems, however, the processes of change are often central. From a methodological standpoint it is both easier and more important to know what is new about the product than to have a complete description of it. The ideal state of consonance is a useful concept in describing the purposeful behaviour of organisations and the various disturbances, successes and failures during the process of product development. Consonance is a state of correspondence or mapping relationships between environment, product and the organisation. Thus the product dimensions should correspond to the needs and values in the environment, while the specialised tasks of the organisation must correspond to the product dimensions. Lack of consonance will result in inefficiency (Normann 1971:204)."

Another citation from Cusumano and Nobeoka (1996) highlights linkages between practical product development concerns with the competitive position of a firm; again a different view to the balancing of development processes.

"*In reality, however, in automobile engineering departments as well in software factories, one might also conclude that the leading Japanese firms have merely sought to achieve a superior balance of efficiency and flexibility in their most critical operations,.. Theoretically, as discussed in another long stream of literature, no one strategy or organisation is inherently better for product development, manufacturing or any other activity... It would be unusual, for example, if a firm that wants a balance of technical excellence in its products with manufacturability were to achieve this without a very stable product design and manufacturing process or some sort of matrix organisation that combines people with expertise in both design and mass production.. There remains, consequently, a need for more empirical research s well as conceptual models that tightly connect a company's competitive positioning and product strategy with its organisational structure, management, and technology and then these variables with performance-for the individual project, families of related products, and the company.*" (Cusumano and Nobeoka 1996: 114–115).

Together these examples show that it is important to address the question of balance in product development with a particular problem associated with it. This is an important question suggesting that the role of product development projects could be used in deeper analysis of these questions. These issues will be next analysed more in terms of the information requirements of a development processes.

2.2 Information requirements of a product development process

This part of the literature review describes how product development projects and a product development process of a firm can be seen to be interrelated in a firm level analysis. The purpose is also to analyse some limitations of the project perspective, and to describe how new ideas might be developed on the basis of these shortcomings for the analysis of information requirements of a product development process.

The product development process is an environment for different types of activities. For example, Koivuniemi, Piippo and Tuominen (2000) have argued on the basis of a literature review that several different purposes associated with a product development process can be found: a) *to help carry out the right things in the right time with the right resources, b) to promote the controllability, systematic and risk management in product development, c) to ensure the availability of quality input information for product development, d) to co-ordinate the tasks of different functions and departments, e) to promote learning and continuous improvement in product development, and f) to help take the entirety into account in single decisions.* Roberts (1995) has also argued that decisions affecting only one product may be sometimes too slow from the firm level perspective. Obviously it is important to define a perspective for the analysis.

The previous example shows that different types of development tasks and activities may be related with a development process. There are also different definitions of a product development process. A textbook definition of product development process might be first given in a particular way: *product development process is the sequence of steps that a firm employs to conceive, design and commercialise a product* (Ulrich and Eppinger 2000). Also, Ulrich and Srnivasan (2001) have defined product development in a general way: *product development as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale.* This previous definition also includes some ideas of technology, in terms of product development. On the other hand product development can be also defined in ways that underline the new types of product performance (features, etc.) that can be seen as an outcome of product development activities. Cohen, Eliashberg and Ho (2000) have argued that new product development can be seen *as product performance production process that requires scarce development resources.*

Product development process can also be seen as a mechanism through which a firm can plan and implement its new product strategies. Overall, it has become strategic issue for firms to define what they do in their new product development. Cooper (1984:96) has argued that the *new product strategy firm elects, determines its innovation program results*[2]. Implementation of strategies is then often a challenge of management

[2] This example can be associated with the ideas of contingency theory, as Galbraith and Nathanson (1978:10) have described: *Our belief is that variation in strategy should be matched with variation in*

capabilities in the product development organisation of a firm, often focused on the new product development projects and their goals.

This perspective raises a question: how might the technological and competitive settings of a firm impact on the product development process of firm (Ittner and Larcker 1997)? Information on technological and competitive questions faced by a firm is critical input for the product development activities. It is possible to address this question by analysing some aspects related with the competition a firm faces, and the processes used by a firm (Galbraith and Nathanson 1978). As Galbraith and Nathanson (1978:5) have described the linkages between strategy, structure and process: *We view processes as the direction and frequency of work and information flows linking the differentiated roles within and between departments of the complex organisation.* Moreover, Henderson and Mitchell (1997:12) have proposed that a *firm's strategy and performance fundamentally arise from interactions between organisational and competitive factors at several levels of analysis.* Such dynamic interdependencies between a number of competitive factors and a firm's organisation may suggest that factors associated with the competitive performance of a firm need to be carefully considered in the analysis of a firm's capabilities. One of the characteristics of the study of Clark and Fujimoto (1991) implies that product development processes may be understood in terms of the linkages between various product development activities and competitiveness of a firm, see below.

"We look at the development process as a total information system and identify important problems from the perspective of information processing. By focusing attention on how information is created, communicated and used, this perspective highlights critical information linkages within the organisation and between the organisation and the market. In doing so, it helps to clarify the role of product development within the broader context of competition" (Clark and Fujimoto 1991:18–19).

Such a perspective can be helpful for the description of the characteristic issues of information requirements of product development activities of an organisation.

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processes and systems as well as in the structure, in order for organisations to implement strategies successfully.

The next question can be more related with the product development activities. How might product development activities reflect these types of dynamic relationships and linkages between competition, strategies and the conducting of the product development activities in a firm? Analysis of product development activities in the context of product development process may require that the performance aspects of development activities be addressed in the analysis. For example, Maffin et al. (1997) have reported that best practices for the management of the product development process may depend on the firm specific contingencies. This means that different factors present in a firm, and its environment may create unique context where product development activities are performed. This may underline the role of project-based approaches to manage development activities. The role of product development project is a central mechanism to analyse the linkages between a firm's competitive environment, adopted strategies, development activities and the performance achieved in the development process (Cusumano and Nobeoka 1996). New product development process helps to describe this with the gates that a project must pass to proceed; see Figure 6 below.

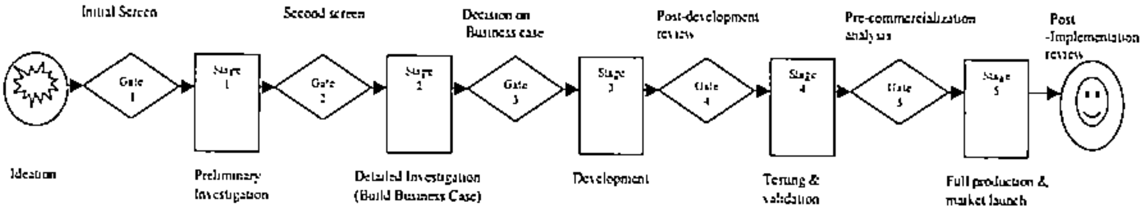


Figure 6. A stage-gate new product process framework (Cooper 2001)

Product development process is a sort of interpretation system for the management of product development activities. This view can be also supported with the analysis of proficiency of development activities, as Dwyer and Mellor (1991: 41) have described: *the quality of the tasks executed in the various stages of the new product process is associated with different measures of project success*. Project specific objectives may need to be controlled and managed in various steps.

The product development process can be seen as a structural framework that provides a template for the planning and conducting of product development projects. This can also mean that projects need to be managed in project specific ways in order to address the relationship between strategies behind a project and the development activities being used (Griffin and Page 1996). Another related example could be shown in the analysis of how much time and money are typically spent in these various phases of development projects, enabling a cross-project overview on the product development process factors within a firm. Empirical studies by Cooper and Kleinschmidt (1986, 1987) have shown that the product development phase in a new product process often requires most efforts in terms of the money and time spent in different activities in development processes, see Figure 7 below.

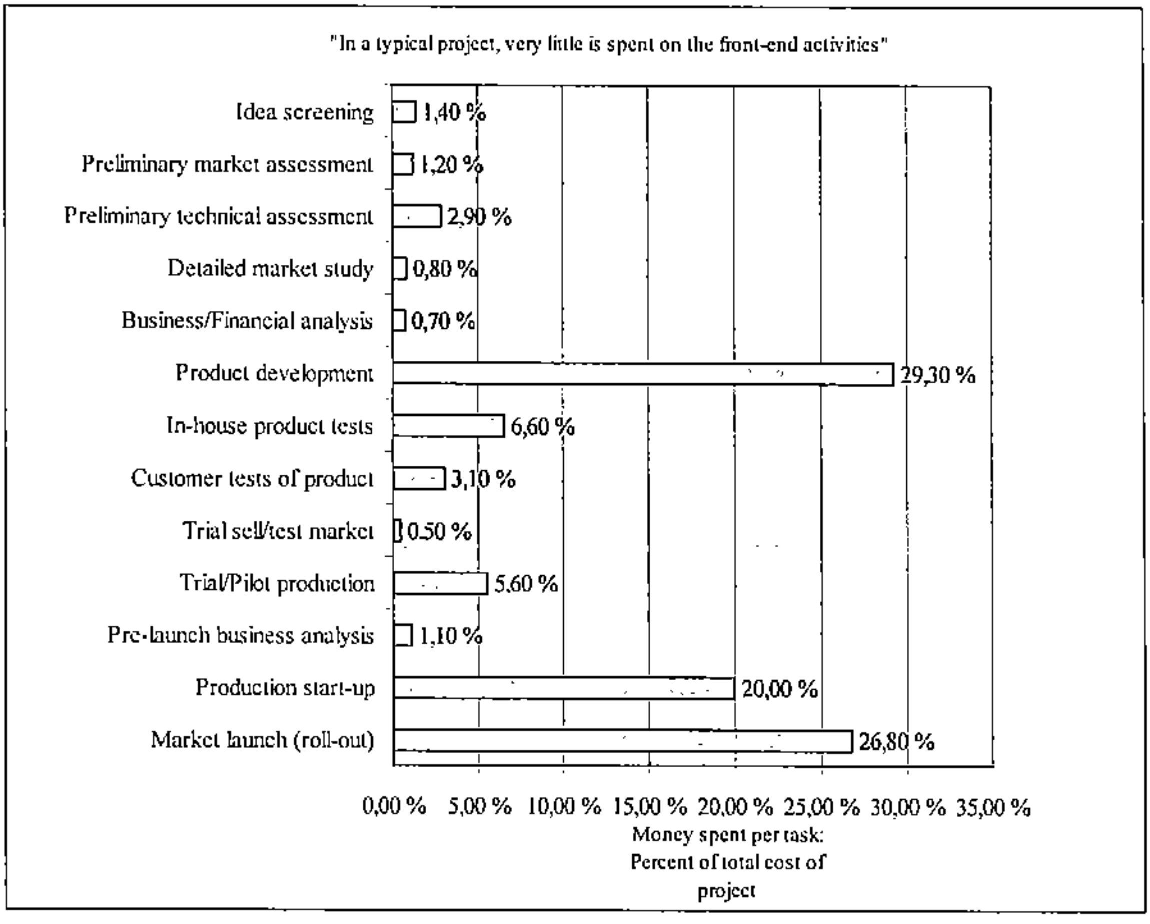


Figure 7. Money spent on each key task in a typical new product project (Cooper and Kleinschmidt 1988: 249–262, adopted here from Cooper 1993: 39)

Strategy and performance of a product development project can become interrelated throughout a process that is completed when a new product is ready and introduced to the market. Perhaps based on this kind of approach, earlier literature on new product success factors examined the links between project outcome (success/failure) and development activities (Cooper 1993). Analysis logic has been based on the analysis of new product performance and the proficiency of development activities (Cooper and Kleinschmidt 1986). In an empirical sense this has resulted in statistical analysis of questionnaire information, and the focusing on the differences between successful and failed new product development projects. Actually, this is how the ideas on systematic stage gate processes have been identified on the basis of extensive analysis of the new product success factors (Cooper 1981, 2001). Some challenges may arise when the project-based approach on analysis of performance does not cover all relevant aspects of product development activities, especially if limited to the success/failure type of analysis (Cooper and Kleinschmidt 1996). These issues will be discussed next in more detail.

2.3 Limitations of the project specific approach for the analysis of information requirements of a development process

New product success is really an output measure reflecting firm level product development performance (Clark and Fujimoto 1991, Cooper and Kleinschmidt 1996). Activities implemented in the project execution phase cannot be directly analysed against the eventual outcome of a new product development. In many cases the in-process evaluation of product development activities needs to be performed with more preliminary and uncertain information, this kind of information can be used for different purposes such as go/kill decisions or to manage some interdependencies between overlapping activities in a project (Terwiesch and Loch 1998). According to a project specific approach, this may imply that firms should be able to manage their projects with performance goals defined for costs, time and quality (Smith and Reinertsen 1995) and other phase related criteria (Cooper 2001). These performance measures can also be used in the definition of the product development project objectives in order to describe the goals and context of a product development effort (Larson and Gobeli 1988).

Development objectives are used for the project management in product development process of a firm where different product development projects need to be managed in ways which may have to be contingent and even situational for given contexts, where "*different projects can exhibit different success factors*" (Loch and Kayser 1998, Dvir, Lipovetsky, Shenhar and Tishler 1998). Riis (1993) has also addressed a broader notion of needs to consider situational and context factors in more general characteristics of production management tasks. Product development tasks can also be analysed and defined according to what extent different tasks include issues concerning the external environment of the project, relations between project operations and the functional organisation, and internal project operations (DeCotiis and Dyer 1979). The identification of these distinct dimensions of project performance illustrates that a project can be both successful and unsuccessful at the same time (DeCotiis and Dyer 1979). Therefore the decisions on evaluation gates may not be always easy, as multiple perspectives may need to be considered.

Another issue arising from the arguments of DeCotiis and Dyer (1979) is what if the project level issues become mixed up with some broader issues than just the one project in case. One related example could be for instance the technology used in a product development project. This can be a result of many issues, but the important implication for product development processes is that effectiveness of proper execution of project management practices for a product development project can be adjusted for critical issues like technological novelty, complexity or process technology novelty (Tatikonda and Rosenthal 2000a, 2000b). In another paper Tatikonda (1999) has also argued that different product development projects can be managed by using the same type of project execution methods, which means that a product development process can be customised and fitted for different types of projects. This leads us towards more detailed analysis of the project and process characteristics in product development.

Earlier research on project management has identified important principles that can be used in this kind of issue. Phasing and stepwise progress is one way to adjust the product development work being carried out in projects. Cooper (1985b) has also argued that the information available on a new product development effort increases along the progress in development. For example, *elements of a product advantage need to be built into the project as the project and product evolve* (Cooper and Kleinschmidt 1993). Phasing of development activities is also used in the evaluation of R&D projects. Pinto and Slevin (1987) have described the dynamic and changing nature of success factors and decision criteria in the course of R&D projects. It was also important to understand how such criteria might vary between different projects. As Pinto and Slevin (1989) have written:

"*It is not accurate to view critical success factors as all being of equal and stable importance across the entire life of the project. Rather, the life cycle stage in which the project currently exists has important implications for determining which factors need to be given highest priority.*" (Pinto and Slevin 1989:31).

Ronkainen (1985: 171) adds:

"*The factors that determine whether a development program is allowed to continue at any particular time dictate the type of information to be gathered at each stage of the process, as well as which staff function is required.*"

Observation from these examples is that project specific criteria can be used to focus the development activities in order to address the appropriate goals being pursued with different projects[3]. Another conclusion from these examples is that criteria can also be used as an approach to manage a project with a "means-ends" type approach throughout the different phases of a development process. The question arising on the basis of these examples is what is then the role of product development process in the management of product development activities, if phases and gates can be defined with project specific criteria and goals. Particularly the question can be that if the project specific means-ends mechanism can be realised by deploying a project specific strategy and related stage-gate criteria, what is then the product development process level way to address perhaps more

[3] A citation from Rothwell (1975) in Griffith (1980) also describes this phenomenon observed already in earlier studies in innovation projects: The information seeking behavior of innovators tends to vary depending on the phase in the innovation process during which information is being sought, from an outward looking attitude at 'idea generation' to introspection during 'problem solving'. (Myers and Marguis 1969, Utterback 1971)

general and non-project specific issues related with the means ends logic. It can be also a key to the congruency between different types of projects and development activities.

A basic issue in the project level analysis of product development activities is whether adjusting the use of project management practices of a firm can be used for the management of some of the uncertainties of development tasks. For example, during the development phase it is not possible to know whether a product will be a commercial success, but the technical challenges like complexity or novelty of new technical areas can be resolved with project management. Product development projects may also face unanticipated problems and challenges. This means that formal project plans and control mechanisms may not always be sufficient mechanisms to resolve the uncertainty. Project management practices and other product development practices may need to be adjusted and used carefully in order to be able to manage development activities under uncertainties. Sometimes uncertainty in development activities can even rise to a level where practices considered "normal" project management practices, or product development practices may not enable the development activities to be continued. This kind of uncertainty can be related with issues like resources, funding and market development. There are also these kinds of situations when the information requirements of a product development process are not clearly articulated with project specific goals (ends) and the phase wise progress from one activity to the next (means).

Gales et al. (1992) have suggested that project based technological variety and analysability can become more and more problematic when a project progresses, thus requiring more efforts in the management of development activities. Also, Van de Ven et al. (1999) have discussed the criticality of equivocality and information processing. Van de Ven, Polley, Garud and Venkatraman (1999:95-98) underline especially the critical role equivocality[4] can have in the analysis of the information concerning the progress of innovation projects. This concept of equivocality needs to be described in more detail.

[4] Interpretative equivocality, Nonaka & Takeuchi builds on Daft and Weick (1984) who have argued that organizations can be seen as interpretative systems. "When the philosophy or vision of top management is ambiguous, that ambiguity leads to "interpretative equivocality" at the level of the implementing staff"(Nonaka and Takeuchi 1995: 79)

Equivocality is not similarly understandable as uncertainty in the organisational environment. Sicotte and Langley (2000:32) have also argued that *equivocality may be less manageable by formal mechanisms alone*, than uncertainty that can be better adjusted with project management practices (Tatikonda and Rosenthal 2000b). Secondly, it can be that uncertainty is more obvious and better detectable than equivocality (Sicotte and Langley 2000). These issues may warrant a concern that there can be some important issues related with product development process and development practices in a firm that simply cannot be easily noticed and addressed as some uncertainties that can be dealt within the use of project management practices. Thus a related question is whether it is possible to analyse factors that can be potential sources of equivocality in the product development process of a firm? And how could it be possible to analyse these issues concerning the different product development practices used by a firm, not necessarily limited to the analysis of project management practices. It can be argued that this is one of the areas requiring new research in product development activities of a firm, especially in terms of the approaches where innovation activities can be studied with some emphasis on the organisational information requirements and organisational interpretation systems (Gales, Porter and Mansour-Cole 1992, Daft and Lengel 1986, Daft and Weick 1984).

Summary of findings

The role of evaluation phases and gates are fundamental elements of the product development process. This view can also be complemented with other approaches that are more focused on the analysis of the nature and quality of development practices in a firm. For example, the Capability and Maturity Model (CMM) reviews (Software Engineering Institute 2002) can be seen as a related example of this kind of evaluation method where better focus on the processes can be achieved.

The previous overview of literature has described project-based approaches to the analysis of product development activities. This is because a great deal of earlier literature on product development activities has been based on analysis of product development projects. A lesson for future studies concluded on the basis of this review is that broader perspectives are being sought in order to extend our understanding of product development processes and development practices. It was also found that alternatives to the outcome oriented new product performance studies could also be important. Recent examples on issues like preliminary information and concurrent engineering reflect the kind of uncertainties that need to be managed during the process before the eventual information on new product success is available to us (Terwiesch and Loch 1998).

Another important finding from earlier literature has been the adoption of strategy versus performance based contingency framework in the empirical analysis of product development. One way to describe this is that new product strategy versus new product performance literature characterises the analysis of development activities (Montoya-Weiss and Calantone1994). Links between strategy and performance targets might also be studied in other ways enabling the study of the information requirements and uncertainties during the development process.

In summary it is possible to argue that a "means-ends" type of interpretation of the earlier results on product development activities would provide a way to analyse also the role of product development practices in broader ways than just via a project specific approach. Next, a synthesis is given of the literature review and also of the research gap and these also provide answers to the research questions of this study. Thus the summary of literature review on product development practices and on their use in development processes crystallises into two issues. Based on earlier literature it can be argued that means ends typified contingency studies addressing the use of product development practices could be seen as suitable ways to analyse the role and use of product development practices also in future studies. Secondly, it can be argued that there is a need to pursue further research in areas like interpretation systems and organisational information requirements in the area of innovation projects (Gales et al. 1992), which is an area closely related with the analysis of development practices.

2.4 Research gap

There are at least three earlier studies identified where the framework of Daft and Lengel (1986) has been used in the analysis of innovation and product development activities. Gales et al. (1992) have studied the progress of innovation projects and the uncertainty in the successive development phases. Lundqvist (1996) has studied the relationships between organisation and development processes used by firms. Lundqvist (1996) has addressed areas like equivocality in the deliberation shown in new product development projects and the development of the organisational processes to meet the development goal. He has also concluded that a greater need for making sense of and defining of what constitutes a process among the participants of development activities could be important for the success of development activities. Thirdly, Sicotte and Langley (2000) have utilised the framework of Daft and Lengel (1986) in the analysis of performance of various integration mechanisms in different types of development projects. Among these earlier studies, the framework of Daft and Lengel has been used in different ways. Furthermore, while Gales et al. (1992) and Sicotte and Langley (2000) have analysed projects it is only the work of Lundqvist (1996) where new product development practices like concurrent engineering have also been analysed in terms of the implementation issues.

Another aspect of the research gap concerns the analysis of product development practices and their relationships. Recent studies such as Koufteros, Vonderembse and Doll (2001: 98) and Koufteros, Vonderembse and Doll (2002: 332) show that the ideas of uncertainty and equivocality continue to arouse interest in the analysis of product development practices. In their review of literature a point has been raised where new research is proposed on areas where both new instruments and performance perspectives on product development practices might be needed. From the perspective of this present study it can be said that the possibility to contribute to some areas related with the analysis of the relationships between product development practices is quite well within the scope of this research. Also, the possibility to develop new instruments is also a possible way to address these issues as argued by Koufteros et al. (2001, 2002).

In this research I have attempted to focus on the relationships between product development practices and their use as means to address some goals and ends for the development activities. Next an overview of the conceptual framework of Daft and Lengel (1986) is given, which covers the underlying theoretical perspective utilised in this research.

2.4.1 Organisational information requirements

Recent empirical studies of innovation projects have applied the organisational information requirements framework by Daft and Lengel (1986) as a theoretical framework in the analysis of development tasks and practices (Gales, Porter and Mansour-Cole 1992, Lundqvist 1996, Sicotte and Langley 2000). One important feature of the conceptual framework of Daft and Lengel (1986) is that it describes an interesting way to address the "means ends" issues in terms of task level analysability and variety. The ideas of task variety and analysability suggested by Perrow (1967) concerns the comparison of organisations and differences between them. The theoretical model proposed by Daft and Lengel (1986) offers an interesting approach for the analysis of organisational information requirements. This model has been adapted here as a framework that can be used in the characterisation of product development practices. The original model framework is presented in Figure 8, shown here on next page.

ANALYSABILITY	Low	High
Unanalyzable	Unanalyzable, Low variety (Craft technology)Structure: a) Rich media to resolve unanalysable issues, b) Small amounts of information. Examples: Occasional face-to-face and scheduled meetings, planning, telephone	Unanalyzable, High variety (Non-Routine technology).Structure: a) Rich media to resolve unanalysable issues; b) Large amounts of information to handle exceptions. Examples: Frequent face-to-face and group meetings, unscheduled meetings, special studies and reports.
Analyzable	Analyzable, Low variety (Routine Technology) Structure: a) Media of low richness, b) Small amounts of information. Examples: Rules, standard procedures, standard information system reports, memos, bulletins	Analyzable, High variety (Engineering technology). Structure: a) Media of low richness b) Large amounts of information to handle frequent exceptions. Examples: Quantitative data bases, plans, schedules, statistical reports, a few meetings.
	VARIETY	

Figure 8. Relationship of Perrow's model of technology with the structure and information requirements for task accomplishment (Daft and Lengel 1986:563)

Concepts of variety and analysability are closely related with notions of uncertainty and equivocality. A closer review of these concepts can also be presented. Tushman and Nadler (1978) have argued that the implications of uncertainty may also be associated with the amounts of information being processed in the organisation. Tushman and Nadler (1978) have also suggested some ideas concerning the factors which from the uncertainty may arise in the first place. Factors like non-routine technologies, unstable environment, interdependent tasks and large size of activities can increase the uncertainty perceived by the management. Figure 9 (below) illustrates this.

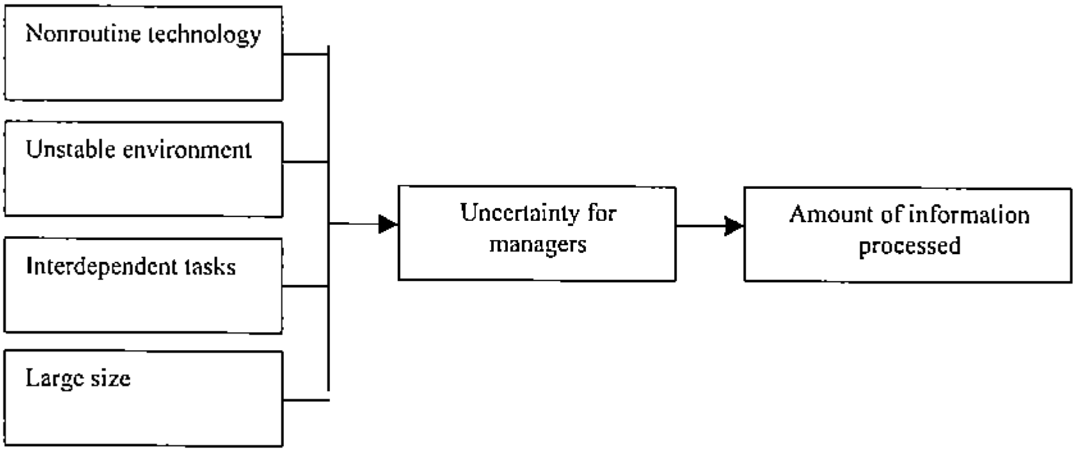


Figure 9. Sources of uncertainty and amount of information processed (Tushman and Nadler 1978, Daft 1986:306)

Furthermore, the concept of equivocality can also be described in more detail. Sicotte and Langley (2000: 4) have referred to Daft and Lengel (1986) in saying that *group meetings can be seen as a type of structural mechanism that can permit the reduction of equivocality through close interpersonal contacts.* Also Keller (1994) has argued that the project group could be a useful unit of analysis concerning the information requirements. Evidently there are both internal and external sources of uncertainty that might have some impacts on the management work and respective information requirements.

The benefit of ideas from uncertainty and equivocality is that their interdepencies can be used in the description of different types of typical events or situations where the relative level of uncertainty and equivocality can be somehow approximated or evaluated. An example of this might be, for instance, a need to decide what kind of activities need to be carried out in face-to-face meetings and what kind of issues can be done via routines like reporting (Daft and Lengel 1986). In a way, the ideas of Daft and Lengel (1986) represent complementary ways to study and evaluate the variances between different types of means ends situations critical to organised activities. See figure 10 (below) for the original description of the model by Daft and Lengel (1986).

HIGH	1. High equivocality, low uncertainty Occasional ambiguous, unclear events, managers define questions, develop common grammar, gather opinions.	2. High equivocality, high uncertainty Many ambiguous, unclear events, managers define questions, also seek answers, gather objective data and exchange opinions.
EQUIVOCALITY LOW	3. Low equivocality, low uncertainty Clear, well-defined situation, managers need few answers, gather routine objective data.	4. Low equivocality, high uncertainty Many, well-defined problems, managers ask many questions, seek explicit answers, gather new, quantitative data.
	LOW	HIGH
	UNCERTAINTY	

Figure 10. Hypothesised framework of equivocality and uncertainty on information requirements (Daft and Lengel 1986:557)

Analysis of information requirements may be seen as a way to look at the interpretative capabilities of an organisation (Daft and Weick 1984). What are then these information requirements? The ideas of Herbert Simon (1957) and Jay Galbraith (1973) have shown us that the design of the organisation's structure can be approached with the information processing complexities and respective work activities. For example, it can be probable that there are different aspects of uncertainty and associated management information requirements concerning various areas of the contexts and activities of an organisation.

Task variety and analysability provide a logical way to study the means ends type of relationships. Then the remaining question is that what kinds of ends can be used in this kind of analysis, as it has been already proposed that product development practices can be seen as means, when this kind of approach is being used.

2.4.2 Linking the theoretical model framework with product development practices

Previous parts of the literature analysis described the research gap. The next part presents additional areas of literature that may be used in bridging the research gap. These issues provide some ideas on how to approach the questions described in the discussion on research gap.

A major premise of the synthesis is that it is focused on factors related with the orientation to the performance requirements of development activities. The purpose of the thesis is not to analyse the actual outcome of projects in a firm, or how competitive a particular firm is. The perspective adopted and used in this thesis is more about the interpretation of the development imperatives (Wheelwright and Clark 1992) like lead-time, productivity and technical excellence, and the use of such generic goals as guidelines in the implementation of product development practices. Things like these development imperatives provide us with empirically based ideas to address the selection of performance dimensions important to development activies.

Earlier findings on the characteristics of effective development processes have been described as being both balanced and focused in the development activities (Cusumano and Nobeoka 1996, Tatikonda and Rosenthal 2000a, 2000b). These recent studies underline areas like the execution success of development activities, which brings up new types of performance issues. Focus on the execution success of development activities also emphasises new type of performance dimensions like flexibility (Thomke 1997, Tatikonda and Rosenthal 2000a, 2000b). New types of contingency requirements for product development processes could be described, for example, in industries where high levels of product development flexibility can be needed (MacCormack 1998, Iansiti 1998). Then the issue can be that if success in competition requires capabilities in development flexibility then product development practices enabling more iteration and changes in rapid time frames can become success factors for such development processes. This kind of description might also require that a process perspective on a situation where consonance (Norrman 1971) can be achieved can be described in terms of the contingent knowledge (Fleck 1997) required for the development work. Also, in other words, that kind of view of a product development process would suggest that some specific product development practices could be analysed in terms of their flexibility, if they were really carried out and deployed in an appropriate time frame (Thomke 1997, Thomke 1998).

One idea from the above examples is that the role of flexibility in managing the development process has also become an important variable characterising the environment of a firm. Endogenous performance such as "being flexible" within a company can be seen as a means to adapt the firm's operations and activities with the requirements of the environment where business is being conducted (Lawrence and Lorsch 1967). Then internal operations of a firm can be flexible in ways that allow the use of various practices and integration mechanisms in order to be able to deliver the requirements and commitments promised to customers, as in the form of new product introduction and frequent product releases (MacCormack 1998). Industries are different in these respects.

It can be argued that this kind of perspective may help us in the broadening of the research perspective besides the new product performance type of approach on development activities. Other aspects of capabilities like throughput and agility can also become competitive means for companies, in order to survive in the increasingly turbulent marketplace of electronics industry (Helo 2001, Hilmola 2001). There are also other ways to analyse the premises of effective implementation of product development practices in development processes. An important issue is what types of performance issues can be used in the analysis of working practices during the development, or even before the development activities are launched. This means that the key to the use of interpretation mechanisms and information requirements in the analysis of product development practices needs to be based on performance issues that are natural to the activities and situations being studied. In broader terms it leads towards suggestions where it has been argued that the theme of performance needs to be conceptualised and measured in terms that are inherent and even germane to the type of organisation (Keller 1994).

2.4.3 Synthesis on product development practices

Earlier empirical results on new product development success factors and development performance have shown that a link between the targeted type of success pursued and development practices used should be achieved and managed. A strong means-ends type of contingency relationship moderates the relationship between strategies and development practices used by firms. These kinds of issues have been reported in the analysis of development performance in electronics industries, see Table 2 on next page. Results from Loch at al. (1996) describe how different types of means used in the management of development activities can be related with different performance dimensions of product development activities.

Table 2. Analysis of development process performance across sub-sectors in electronics industries (Loch et al. 1996)

	Market leadership	Innovation rate	Product line freshness	Design to cost	Development personnel intensity	Development expense intensity
Focus and structure					Team structure (-) b	
Project management	Early use of prototypes (+) b					
Cross-functional integration	Early purchasing involvement (-) b	External sources of ideas (+) b)	Value engineering (+) b	Early marketing involvement (-) b	External sources of ideas (+) a	Design complexity (+) a
People management and learning	Team rewards (+) a			Job rotation (-) a		

a=significant on the 1 % level.
b=significant on the 5% level.
(+) Denotes a positive and (-) a negative impact.
Sample:computer and systems industries (size n=75)

The previous table illustrates *that achievements in different dimensions of development have to be achieved with different tools* (Loch et al. 1996). Similar types of ideas of means-ends relationship have also been discussed in the literature on organisational effectiveness and competing values of an organisation (Quinn and Rohrbaugh 1983; Quinn and Cameron 1983).

Previous examples showed that the role of a means ends type of relationship between types of development performance and product development practices have been discovered in the empirical analysis of product development in the international electronics industry. The basic nature of this kind of problem is almost identical with the identification of important research issues in new product success research (Hart 1993). A conclusion that can be made from the earlier studies is that these examples show similar characteristics as Pearson (1990) has discussed in the theme of innovation strategy. Pearson's arguments in the management of innovation projects were also describing the means-ends type of reasoning in the project management. Project management level challenges in the implementation of product development practices converge towards the challenge of how to achieve a match between the means and ends fit with the targets of each projects. Figure 11 below describes the innovation model presented by Pearson (1990).

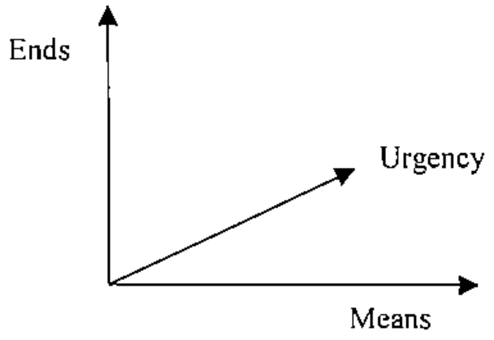


Figure 11. The innovation model (Pearson 1990)

Prof. Alan W. Pearson later elaborated implications of the model to the means-ends relationships for innovation projects in a research correspondence addressing this question.

"*The ends axis is certainly about focus, whether it be technical or market goal or both. As we know lack of clarity on this dimension usually reduces the success rate but equally important makes projects very difficult to manage. The other dimension 'means' is used to focus attention on the degree to which the technology is available to achieve the ends. It therefore reflects distance from the existing knowledge base and, also of course, the organisation's familiarity with their knowledge base, and their expertise/past experience in the area. In practice it is possible to identify the degree of uncertainty along these two dimensions for a particular project or activity. The obvious point to make is that this information can force people to think more carefully to see whether they can clarify the ends and/or choose alternative technological routes to reduce the uncertainty. They may of course do this through collaborations and/or joint ventures. If they cannot reduce the uncertainty they have to recognise that may have to change their management style or, in the extreme case, disband the project.*" (From personal correspondence with Prof. Alan W. Pearson, 12. September 2000.)

At this point it becomes important to address the studies focusing on the execution of product development project management. As Tatikonda (1999), Tatikonda and Rosenthal (2000a, 2000b) have argued, it might be possible to manage the execution phase of product development with non-project specific approaches. From the perspective of the present study, in order to be able to do this it is important to first resolve the notion of means and ends and how this could be linked with product development practices.

In order to achieve this kind of link between means and ends between product development practices and their use it is necessary to build the conceptual foundation of the modelling of product development process and development practices. A literature review focused on these issues has resulted in a synthesis where earlier literature on product development practices can be described with the following illustration, figure 12 below.

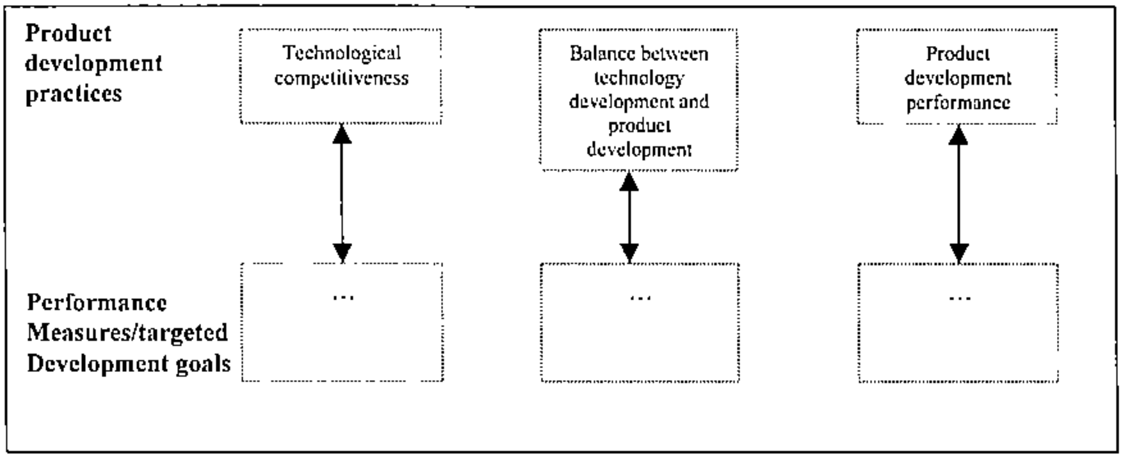


Figure 12. "Means-ends" contingency relationships between practices and measures

Next a table summarising some earlier studies describing these issues is shown, see Table 3 on next page.

Table 3. Earlier studies where development practices and goals for their use have been addressed in ways that are related with the means ends type of contingencies

	Technological superiority, technological competitiveness
DEVELOPMENT PRACTICES	Lead users (von Hippel 1988)
	Internationalisation of R&D (De Meyer 1989)
	Technological learning (Dodgson 1991)
	Business scope integration (Kauppinen 1999)
	Use of technical champions (Lee and Na 1994)
	Develop strong technological orientation (Gatignon and Xuereb 1997)
	Resolve problems related with the introduction and launch of new and pioneering products effectively (Lindman 1997)
PERFORMANCE MEASURES/ TARGETED DEVELOPMENT GOALS	Advanced, new product features (von Hippel 1988)
	Technical learning in R&D (De Meyer 1989)
	Technology focus (Dodgson 1991)
	Enhanced system delivery capabilities (Kauppinen 1999)
	Targeting for radical new technological innovativeness (Lee and Na 1994)
	Develop new innovations superior to the competition (Gatignon and Xuereb 1997)
	Strenghten the new product development capability base of a firm (Lindman 1997)

	Balance between technology development and product development
DEVELOPMENT PRACTICES	Define key characteristics of new product (Thornton 1997)
	Customised use of product development process for the type of development project (Tatikonda 1999)
	Analyse and define detailed task characteristics of development projects (Tatikonda and Rosenthal 2000b)
	Differentiated and integrated use project execution methods like formality, autonomy and resource flexibility (Tatikonda and Rosenthal 2000b)
PERFORMANCE MEASURES/ TARGETED DEVELOPMENT GOALS	Balance costs and quality during product development phase (Thornton 1997)
	Different project can be executed using same generic product process (Tatikonda 1999)
	Separate technological novelty and project complexity to manage tradeoffs between projeccts (Tatikonda and Rosenthal 2000b)
	Balance flexibility and firmness in execution of development project management (Tatikonda and Rosenthal 2000a)

	Product development performance
DEVELOPMENT PRACTICES	Increase use of new tools and techniques in NPD activities (Griffin 1997b, Maylor 2001)
	Use multi-functional teams (Roberts 1995b)
	Customise and tailor the use of concurrent engineering for varying design problems (Funk 1997, Swink 1998, Terwiesch and Loch 1998)
	Share knowledge in critical integration practices within development phases (Nonaka 1990, Hoopes and Postrel 1999)
	Increasing number of functions in a product adds the development project complexity (Griffin 1997a)
	Controlling operational outcomes of organisational processes with quality, cost and time-to-market goals (Tatikonda and Montoya-Weiss 2001)
PERFORMANCE MEASURES/ TARGETED DEVELOPMENT GOALS	Support performance enhancements in time to market, product cost and product quality (Griffin 1997b,Maylor 2001)
	Accelerate speeding of new products to market (Roberts 1995b)
	Succeed in effective overlapping between development activities (Funk 1997, Swink 1998, Terwiesch and Loch 1998)
	Avoidance of communication gaps and knowledge glitches in development work (Nonaka 1990, Hoopes and Portrel 1999)
	Higher product complexity increases NPd cycle time (Griffin 1997a)
	Support performance achievements on market outcomes (Tatikonda and Montoya-Weiss 2001)

Table 3 (page before) shows that there are different measures for the analysis of product development practices. Often the logic in earlier studies has been that by using a particular development practice a defined performance dimension can be improved, as in the analysis of Thomke (1997), where the use of advanced design methodologies has been shown to improve development flexibility.

The synthesis of the described linkages between product development practices and performance measures is that some basic aspects of the multiple performance dimensions could be chosen to depict the environment where product development work is being carried out. The decision has been to adopt a dualistic and overlapping framework between technological competitiveness and product development performance as a pair of key concepts that can be used in the further definition and development of the utilisation of organisational interpretation and information requirements on product development practices and their use (Daft and Weick 1984, Daft and Lengel 1986).

Argumentation behind the chosen types of information requirements-means ends logic

Hart (1996) has argued that there are various ways to describe the complex nature of technologies, products, processes and innovation. For example, Hart (1996) has suggested that innovation issues may be seen in a type of continuum where we may want to study the performance links from development activities to innovation, see Figure 13 below.

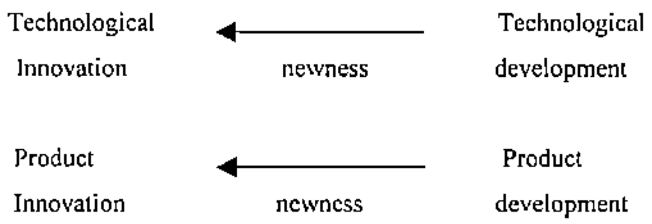


Figure 13. Adaptations of the newness continuum (Hart 1996: XI)

Hart (1996) does not actually recommend that this kind of practice of viewing development process as a continuum would be a good solution, because of the complexity of such approaches. In a way, this kind of conception of product development process as a continuum between innovation and development is very fundamental. Clark and Fujimoto have also discussed a similar theme (1991) in their analysis of product development performance in the automobile industry. The key issue is that the concept of product development performance is perhaps broader than new product performance. Then focus on product development performance also enables analysis of product development capabilities in ways that can complement the new product success and new product performance driven approaches.

It can be also argued that product development performance is a broader way to characterise information requirements and development imperatives than any specific individual performance dimension like lead time, quality or productivity. At least from the perspective of interpretation system and information requirements it is also possible to analyse how product development performance might be seen as a category of information requirements critical to the use of product development practices. Secondly, technological competitiveness could be seen as a well-known and clear goal for the product development activities. Technological competitiveness can be addressed with earlier examples from the analysis of the histories of the electronics and electrical industries, which show that this variable can be a multi-level success factor for development activities. In earlier literature technological competitiveness has also been often studied at the level of countries (Berman and Khalil 1992). Technological competitiveness has also been studied at the level of particular industries, as in studies of the history of technology in the energy, electrical and electronics industries (Aspray 1993).

"The Reagan administration, together with many of America's journalists and business school faculty: thus defined technological competitiveness as a competition among nations for technical prowess that was assumed to translate into economic advantage. Besides competition among nations there is, most obviously, competition among firms to use technology to provide products or services that compare favourably with those of competing firms in order to gain customers, profits or markets. There is also competition

within firms among different technologies, or among products or services based upon these technologies. Finally, there is competition among technologies themselves to become the dominant technology for a particular application."(William Aspray 1993: vii.)

It can also be argued that a development project level mission and deliberation of innovation activities can also be addressed with this kind of concept. In order to conclude this argumentation it can be said that these selected variables of technological competitiveness and product development performance represent general typical goals and ends for the product development activities.

Returning to the idea of looking at product development practices with a means and ends perspective it can then be asked what about the means, if the ends perspective can be resolved by a conceptual selection of general performance requirements like technological competitiveness and product development performance?

A "means" perspective on development practices

Product development practices represent a means to conduct the development activities. In this thesis the following definition has been adopted: *product development practice* is defined as an approach taken to conduct some product development tasks in a way that is fit for a company and its development resources. Practices can also be seen as alternative types of technologies representing issues like background technologies, enabling technologies and project specific technologies, according to a framework proposed by Dodgson (1991). The links between technologies, product development practices, projects and product development process can be addressed with these kinds of ideas. Dodgson (1991) has related the concept of technological learning to competitive pressures and business dynamics within the biotechnology industry. "*Technological learning is used in a broad sense as encompassing all those activities in a firm which assist the enhancement and expansion of knowledge and skill bases*" (Dodgson 1991). For some other kind of purposes technology may need to be defined in different terms. A figure by Dodgson (1991) may concretise the differences between technologies.

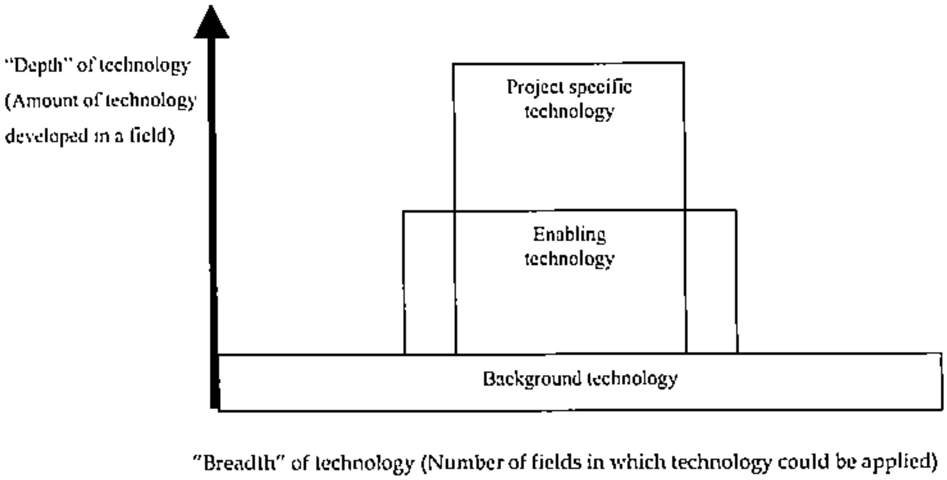


Figure 14. Celltech: Conceptualizing technology (Dodgson 1991:141)

Different technologies have different characteristics. The characteristics of technology may also change according to the goals for which technologies are being used in product development processes. Different kinds of technological characteristics can also be associated with the competitiveness of a company through product development processes. For example, Cooper (1993, 1985b) showed how technological superiority was found to be one of the most significant variables associated with new product success. Technological superiority can be an important characteristic for successful product development, especially in markets for demanding professionals (von Hippel 1988).

Ideas from Dodgson (1991) suggest that product development practices could also be analysed as enabling and background technologies besides project specific technologies. This kind of interpretation would also support the findings of Tatikonda (1999), who has argued that the project specific approaches can be complemented also with process level management practices of product development projects. Enabling and background technologies can be seen as product development practices, in ways that complement the project specific approach to technologies, and development activities.

The question remains, of how to analyse the means ends relationships in terms of product development practices, when development practices might also be conceived in broader ways than before, as enabling or background technologies. In the studies of new product success studies the main types of development practices have been identified by analysing the progress of an individual project through a new product process. Then the means-ends logic has been achieved in terms of the project specific analysis, how a project can proceed from an idea to the commercial launch of a new product through critical phase evaluations.

The literature review described here has focused on the argumentation of means ends perspective, and how this can be seen as one of the alternative approaches to product development. There has also been discussion on the differences between project specific analysis of development activities and more general ways to look at product development activities. Clark and Fujimoto (1991) have suggested an approach to describe the different levels of product development management: technology and component level, individual product/single project management, intra-company product mix/inter-project management and inter-company product mix/networked product and component R&D (see figure 4). These four levels may also offer ideas for the analysis of product development practices. In this research the scope of the analysis has been focused on intra-company issues, and mainly on earlier literature on the project management based approach to product development.

2.4.4 Ideas and findings to address the research gap with new research

This thesis has been focused on two research questions: a) How might the technological and competitive settings of a firm impact the uses of product development practices within a product development process, and b) How different types of product development practices and their implementation in the product development process of a firm could be analysed?

The literature review on product development practices has provided a possibility to discuss related findings from the literature and earlier empirical studies. A conclusion to the first research question can be given. It seems that use of product development practices is associated with various types of strategy versus performance, and other types of contingency questions. Theoretically earlier literature has also identified different types of contingency variables related with the use of product development practices, in ways that reflect the technological and competitive settings of the product development process of a firm. Product development practices and their use seem to be an area where focus and purposeful activities are necessary and important. Development activities can then also be seen as activities performed with many types of performance expectations. The use of development practices is not a random exercise, but a conscious process of implementing certain methods for more or less managed development problems. A highly rational sense in the use of development practices seems also to be linked with the understanding of different types of competitive requirements.

However, earlier literature on analysis of development practices has been limited to project based approach on the analysis of usage of development practices. This has been discussed as a starting point to find new complementary ways to analyse product development practices and their use in product development process. A conclusion that has been made from earlier literature is that some aspects of the technological and competitive settings can also be addressed at the level of development process, and general development imperatives for product development activities. It is not necessary to limit the analysis of product development practices only to project based approaches. It is also possible to look at the nature of product development practices in a more general manner.

The basic purpose of this review has been to identify the general success factors for product development process, and use this information as a knowledge base in the building of a model framework describing the product development process as an interpretation system. This perspective can then be used in the analysis and modelling organisational information requirements of product development practices. In summary, it can be argued that new types of analysis approaches for the use of product development practices within a firm's product development process can be described as an area that needs additional effort and new research activities. The conclusions from earlier literature and theory on the use of product development practices can be summarised as guidelines for further studies, addressing the second research question. The first phase of the literature review is focused on the argumentation that underlines that the generic forms of performance dimensions in product development process are technological competitiveness and product development performance. Analogy and argumentation are also provided as to why these can be both overlapping and distinct issues. These are the multi-dimensional performance aspects. Some related issues are defined below:

- What kinds of generic forms of performance dimensions have been identified in the analysis of product development processes? These can be used in the analysis of issues broader than project specific development practices. Specific performance dimensions can also be analysed in multiple ways.

Generic types of tasks in a product development process are also important. The second phase of the literature review has been focused on the argumentation that emphasises that the generic tasks in a product development process are basically variations of product development and technology development. A related perspective is defined below:

- Analysis of the generic types of tasks in product development process has been the key to earlier descriptions of product development processes. It is also possible to model development processes in other ways.

Important forms of orientation in product development operations can be related with success in the use of development practices. This notion of orientation is really an important issue, as the purpose of the analysis is to provide input for the building of a new construction reflecting the product development process as an interpretation system. Therefore important orientations in the innovation processes can be seen as important characteristics of the organisational interpretation system. Effective ways of working can also integrate different issues. Some related issues are defined on next page:

- Uncertainty and equivocality can be seen as information contingencies having some impact on the use of product development practices. Thus it can be argued that organisational information requirements reflecting the means-ends model to link product development process with practices can be seen as a theoretically suitable approach to analyse product development practices.
- The means-ends contingency model can be utilised in the analysis of product development practices with the organisational information requirements perspective.
- New types of product development practices can also be addressed and identified.

3. EMPIRICAL RESEARCH PROCESS

This chapter describes the empirical research design, research process and data analysis of thesis. The chapter is written in a phasewise manner according to the progress of the research. This research is based on an empirical research strategy with descriptive case studies. I have used both qualitative and quantitative research methodologies (Jick 1979, Brewer and Hunter 1989, Sekaran 1992). Figure 15 illustrates the main phases of the research.

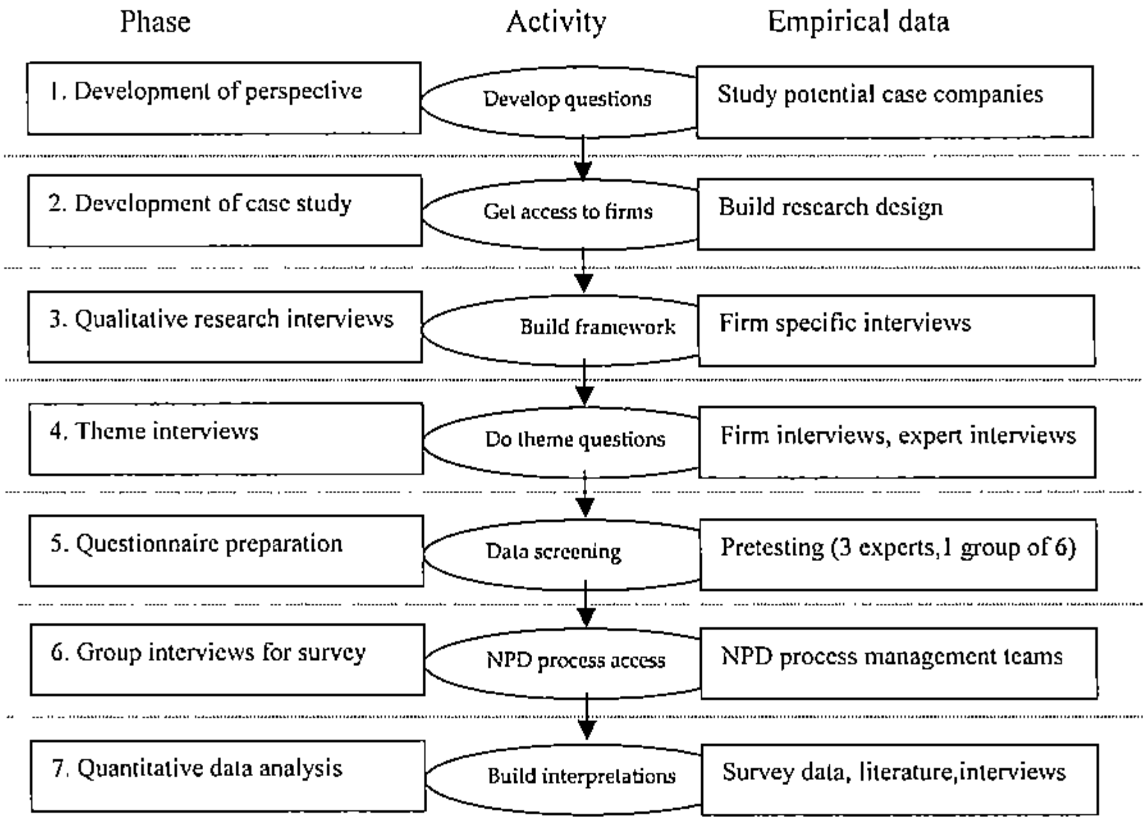


Figure 15. Empirical research process and critical phases of data analysis and treatment with linkages to empirical data

3.1 Development of the perspective for empirical research

It is possible to use different research approaches for the study of a problem. In this research I have used a descriptive, empirically based constructive approach for the study of the research questions (Neilimo and Näsi 1980 in Kasanen, Lukka and Siitonen 1991). I chose to do that because I wanted to increase the understanding of a complex and dynamic phenomenon, information requirements of product development processes and practices. This sub-chapter has been titled development of the perspective for the empirical research. It covers use of literature and empirical interviews for the focusing and building of the perspective of the study, as the starting phase of the empirical research. The research questions of this study deal with the following issues:

1) How might the technological and competitive settings of a firm impact the uses of product development practices within a product development process?

2) How could we analyse different types of product development practices and their implementation in the product development process of a firm?

The research questions address product development practices and their use in companies. The research gap identified in the literature review defines how the organisational information requirements framework might be used for the study of the development practices. This discussion on development of the perspective for empirical research describes how these issues have been approached in the study. To do this it may be first necessary to show how the ideas of empirical research and perspective development can be described. This is also related with how methods and ideas in case study research have been used in this research. It has been found that ideas of dimensional analysis could be suitable for the development of the perspective in case studies with qualitative research material (Glaser and Strauss 1967, Kools, McCarthy, Durham and Robrecht 1996). See Figure 16 for elaboration of the idea of the dimensional analysis concerning the aspects and richness of data analysis and information. It can be argued that this kind of approach may also be suitable for the structured representation of the premises of both theoretical and empirical research issues. It can be also used for the development of research design, case study criteria and units of analysis in empirical studies.

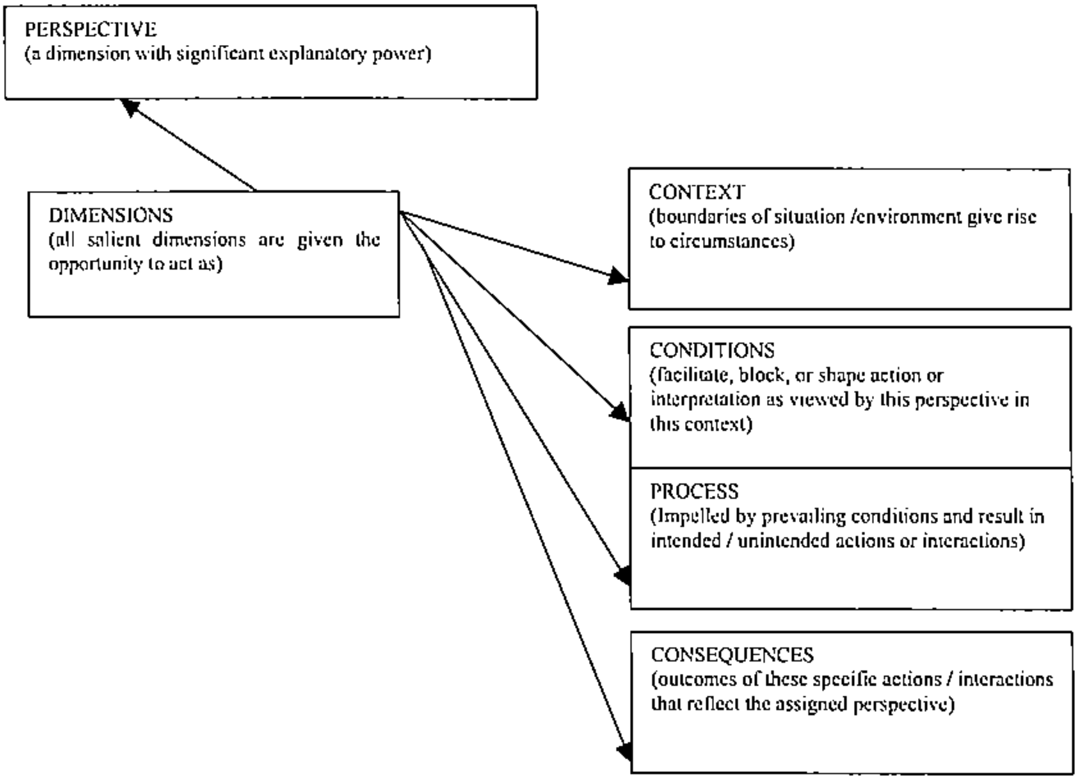


Figure 16. Development of the perspective in grounded research methodology (Kools, McCarthy, Durham and Robrecht 1996: 320)

Perspective

This describes how the analysis perspective has been derived from the literature. There are different ways to study product development. A topic of product development processes may be located somewhere between more direct studies of new product processes (Cooper 1993) and contingent effectiveness of product development practices in different industries (MacCormack1998). Today many companies are multi-focused in their operations (Spina, Bartezzaghi, Best, Cagliano, Draaijer, Domien and Boer 1998). They also have goals for different performance dimensions (DeCotiis and Dyer 1979, Cooper 1984, Clark and Fujimoto 1991). This also implies that different product development practices and performance dimensions may concern different areas of product development activities. For example, the differences and characteristics of the front-end and back-end activities in product development represent strategically different challenges for product development processes (Khurana and Rosenthal 1997,1998).

First, important issues in the design of the case study have been related with the decision of how to analyse product development practices empirically. Also, it has been important to select the type of material to be used, which impacts on the data collection activities. In literature review it emerged that important issues in the research gap concern the information requirements of product development practices, also that prior studies based on product development projects have their limitations as a base for the empirical analysis of product development. As a result of the premises of prior research, the perspective in this study has been chosen to focus on product development practices and company level analysis of the use of development practices within the product development activities of a firm. This may require analysis of company specific activities and arrangements in product development processes to obtain an empirical access for this kind of perspective.

Dimensions

Production and development operations and their performance dimensions can be described by models such as product-and process life cycle matrix (Wheelwright 1978, Hayes and Wheelwright 1984, Wheelwright and Clark 1992). Such grid-like presentations have a strong descriptive power. Models like product and process life cycle matrix may offer ideas for new theory building. Multiple performance dimensions are related with the analysis of development activities. Issues of multi-focus are also critical to product development work, especially at the level of process perspective. Process level studies of organised activities may require specific approach on the analysis of performance aspects. In the literature review it has been concluded that a means ends type contingency approach might be typical for the analysis of product development activities. This also suggests that related empirical research work should cover the process performance issues carefully.

For the theme of product development processes it has been concluded that companies' success in product development processes depends critically on how well their development work is matched with the competitive requirements of the market and industry where they compete (Burns and Stalker 1961, Loch, Stein and Terwiesch 1996). At the level of product development processes this requires also careful selection and implementation of development activities against specific goals. Loch, Stein and Terwiesch (1996) have also described how product development process level development performance may be contingent to competition in different industries. Management has the challenge of identifying the appropriate product innovation arenas of a firm and their performance requirements (Cooper 1993:308–315). The literature review of product development performance dimensions I became especially convinced that the relationship between new product performance success factors (Cooper 1985b, Cooper 1993, Hart 1993) and product development performance (Clark and Fujimoto1991; Loch, Stein and Terwiesch 1996) is very interesting. This is because the previous approaches to product development are complementary to each other and also overlap to some extent. Many new product development performance dimensions also overlap with each other as can be learned from the multidimensional nature of new product success (Hart 1993). These issues define the base for information requirements of product development activities.

Contexts and market conditions

Performance requirements of development activities naturally overlap between successive stages of development processes. Projects need to win competitive screening phases in order to be able to continue towards the next development phases. Project level information flows are often characterised by this kind of successive phases. The aim of this study has been to study information requirements of development practices. This also presents some requirements on the empirical studies to clarify and focus on specific types of contexts used for data collection. It can be argued that earlier research on NPD processes has mostly been carried out in industrial companies (Cooper and Kleinschmidt 1991, Cooper 1993). This kind of separation between industrial and consumer markets may help us to better describe and prioritise the business strategic nature of the NPD processes under study (see Hambrick and Lei 1985). This study continues in the mainstream direction of NPD studies focused on industrial product development processes and practices. It also helps to maintain focus on industry specific issues.

Conditions (industry characteristics)

These perspectives seemed to summarise the essential features of empirical work on both new product success and product development operations, as theoretical guidelines for the future studies of product development processes. Also, another finding from the literature analysis was that the dependencies and relationships between different performance dimensions of product development are of interest for the study of product development activities (Hart 1993). This issue has been considered to be an important factor related with the empirical research design. For example, in the industrial electronics business it is often necessary to focus on technical superiority because professional buyers and competition may be based on such criteria.

Process

Research issues identified in the present study have also been described with some limitations of project-based approaches to the analysis of product development. Another point is that there are different types of product development practices. This has constituted an important question for the empirical research of this study: how to study the information requirements of product development practices, not necessarily based on product development projects as the main source of data. The decision on this question has been made in the following way: iterative research work may allow the use of phasewise use of different sources of data from a case company, while the purpose and scope of the case study is kept clear. Another issue in the analysis of product development projects is that a project-based approach may help researchers to focus on specific aspects of product strategy, technologies and development practices with deliberate use of product development projects as a source of data. Indeed, a product development project is the central unit of observation in many studies of product development activities (Cusumano and Nobeoka 1996). A related conclusion for the development of the perspective in this present research is that project level focus on the development activities can be argued to be a good way to start the empirical data collection. This approach has been used in this study as a way to launch case studies.

Consequences

Previously shown aspects of the perspective development have been used as elements of the development of the case study design and criteria. In this study the focus has been on the product development processes and practices of industrial companies. Particular types of product development projects have not been deliberately focused on as factor setting requirements for the empirical study. Characteristics of product development process performance (means ends approach) as a research topic may require that different companies be used in the empirical research in order to obtain different perspectives on the product development processes and practices of companies. This also means that the research setting does not have to be limited to any specific category of product development processes like stage-gate processes (Cooper 1993) or development project portfolios (Wheelwright and Clark 1993).

Eventually it is possible to summarise the chosen empirical case study research strategy, and the related criteria for the case study design (what should be observed in the empirical study) can then be listed: access to the product development process and development practices used within different companies; the case study companies should have a product development process; market based success factors can be used in the definition of common characteristics of the firms; industrial or consumer oriented industries and companies can be separated; conditioning factors of competitive advantage typical to product development processes in certain industries can be identified; case study can be started from a product development project, but it does not have to be limited to a specific project, and different organisational mechanisms can be used for the analysis of the product development practices in the case companies.

This sub-chapter has covered some aspects behind the development of the empirical research perspective. In conclusion it can be said that different arguments have been presented concerning what kind of issues should be considered as guidelines for the research design of the empirical research. The selected research approach has been chosen as a constructive case study approach. Next, a deeper description of the development of the research design is given with observations from the start-up phase of the empirical research.

3.2 Development of the research design and case study environment

The main principle in this research has been to perform a set of case studies in different firms. According to the empirical research strategy, the purpose has been to construct sufficiently defined and grounded framework to address the research questions of the study. Here it is important to remind the reader that the empirical research has been initiated based on the research questions, and related underlying theoretical aspects of the study. Theoretical analysis and interpretation have been developed in an iterative manner throughout the empirical research process. This chapter describes why and how some selected case companies have been used to achieve this purpose.

Initially the strategy for the first phase of the empirical work was to perform follow-up interviews with some industrial companies where different contexts, conditions, processes and consequences would be looked for (Kools, McCarthy, Durham and Robrecht 1996) that could help in the understanding and description of relevant variables associated with the topic of product development processes and their performance. The nature of the first phase of the research was quite hermeneutic and qualitative (Alasuutari 1993; Steyaert 1997, Steyaert and Bouwen 1997), to a great extent relying on the rich information available from interviews in industrial companies.

The purpose of conducting a case study was to explore and analyse product development processes and practices in some selected firms. The reason to use case studies was that they were found to be an appropriate way to address areas where new research is needed

(Eisenhardt 1989a). The main reason and criterion for including different case study companies in the research is that product development practices and processes may need to be studied in ways where firm level differences can be observed. The conducting of the empirical case studies covered both company level and product development project level issues. Different companies within a specific industry were studied, in order to maintain a market based perspective on the characteristics of the product development process performance in a given industry (Loch, Stein and Terwiesch 1996).

In the previous section it has been already suggested that project level analysis of product development activities might be an appropriate way to focus or start the data collection activities. In earlier research activities project level approaches have often meant that a survey of concluded development projects can be used as base for the data collection in different companies. In these kinds of studies the selection of particular type of product development projects such as failed and successful has been critical to the definition of the research sample (see Cooper 1993, 2001). It is then also necessary that in this kind of survey specific criteria for the selection of product development projects to be studied can be used.

In the present study selection of case companies has been based on focus on a specific industry, in order to be able to address the theme of product development performance in a somehow comparable manner between companies. Industry level focus on analysis of development activities has been an established way to conduct analysis of product development practices also in prior studies (Eisenhardt and Tabrizi 1995, Iansiti 1995, MacCormack 1998).

Selection of companies covers the industry aspect of a research design. Further differences or similarities between case companies are also dependent on other goals of the research, what kinds of issues are being addressed with the research questions. Another requirement for the case study companies is that they have product development processes and utilise different product development practices, in order to develop a research setting that corresponds with the characteristics of the research questions.

In this present study, the research design and settings have been developed gradually. Firstly, case companies were selected so that they represent different business areas, resources and size of activities. Secondly it was felt important to analyse companies that have either long or shorter experience in development activities. The resulting research design achieved as a result of this study has offered possibilities to conduct empirical data collection in both large and small companies, with differences also in their development experience. Another important aspect of the case company selection has been the organisation level approach to address the analysis of product development practices in the case companies. The approach used in the research was also developed in an iterative manner by building on literature reviews, empirical interviews and interpretation of the tentative findings. The solution eventually has been that the main focus in the case study concerns data collection from management teams of product development processes of these case companies. A group level approach on product development process management perspective has enabled an analysis of the aspects of the company specific product development practices. In this way, the case study selection and analysis issues have been focused on the product development process of a firm, and the product development practices being co-ordinated by the management of the company specific processes. A selection of case companies represents ways to study product development in different kinds of organisational environments where issues like tasks and information requirements may differ between firms, also in their technologies. In order to make this possible, product development project level interviews were used as a way to build pre-understanding and interpretation capabilities of the development processes in the case companies. Entry phase into the company's product development activities has then also been done via starting the data collection with specific project level issues. This kind of gradual approach has also been recommended when using qualitative material and case studies as a source of empirical data (Eisenhardt 1989a, Gummesson 1991, Yin 1994).

Case study setting-selection of cases and preliminary interviews

The empirical research process was launched in summer 1996. Some companies were approached with a preliminary inquiry over the telephone. This stage of the research was related to the writing of a paper by Maunuksela (1997). First, a longitudinal case study process was started systematically at the beginning of 1997. It was agreed with case company 1 that it would be possible to conduct interviews with a group of people in order to study their product development process. At first, there were some meetings with the whole group of people who were working on a product development project. The project under observation was a third generation product improvement effort, which also included also new product development tasks. Notes describing observations were taken and analysed. It was also possible to analyse related project documentation. And to attend some project group meetings where progress of the work was evaluated and analysed. During the same time another case study connection was also established with case company 2 in the spring of 1997. Research arrangements were replicated from the first case company. Now I could conduct empirical follow-up interviews in two companies. Two streams of interviews in these companies were pursued. Interviews with both managers of the product development process and project level teams were used as informants.

These interviews were conducted for the collection of qualitative research material according to the principles of qualitative field research (Alasuutari 1993). Here it is important to clarify that the companies chose the case specific product development project that was being studied by interviewing different people involved in them. The researcher's external perspective into the company specific product development work evolved slowly through the interviews and discussions. This could be summarised as a phase of two on-going interview processes with separate companies. The companies were not competitors, which is an important point. They were operating in the field of industrial electronics, but in different markets.

The early phases of the interview process were very insightful, mainly because it was possible to build up the interview process along the way, as one could learn more about the companies. This current research was based on trust and the privacy of the interviews, in order to gain understanding of the management perspective for product development. The choice of these specific companies was also based on ideas gained from the study of Loch, Terwiesch and Stein (1996). Thus the approach was to focus on companies within more mature and professional segments of the electronics industry. In retrospect, we may also argue that the role of technological competitiveness in these kinds of businesses is quite important. Both case companies 1 and 2 have been among the technological leaders in their areas.

As mentioned before, it was possible to carry out freeform interviews. During the spring of 1997 it was possible to attend some company meetings and to obtain personal interviews with different individuals from the same company. As the work progressed it was found that an interview scheme with two or three persons was quite reasonable for the purpose of these early stage interviews. Two series of interviews, in different companies, with the manager of product development (or research and development), product manager and project manager were pursued. In the beginning these interviews were documented by hand-written notes by the researcher. The interviewees from the companies checked the notes in order to correct possible mistakes and misunderstandings. Later on, I tape recorded most discussions for further analysis.

This phase of the research work could be described as a development of the empirical research setting with selected case companies. The phase represented a stage where two first case study processes were launched and practised. The data collection pattern emerged through interviews and discussions (Yin 1994). Interviews within two separate companies included communications with about 5-10 people. Each individual, or informant, was seen or telephoned approximately twice a month. Consequently, it was also possible to move now to the next phase in the empirical research process. This timing was one of the practical milestones during the research work, and it was a quite good yardstick for the overall research process. Phase two began from May of 1997. The following summer and autumn were spent with deepening the literature analysis and continued case study interviews with the companies. Comparison of the two cases was also illuminating.

This phase of the research process helped to test the attractiveness of the ideas of competitive priorities as a research framework to be pursued. Here it should be noted also that the starting phase of the interviews was launched under the tentative research concept of competitive priorities in product development[5]. It was possible to observe how case companies 1 and 2 were very different in their development activities. There were quite a lot of project specific issues that were observed and analysed in these interviews.

Inclusion of new case companies

In April 1998 I decided to extend the empirical base with two additional case studies in different companies. This also meant that new interviews with case companies 3 and 4 were now conducted in similar manner to cases 1 and 2. This was because more experience from different product development processes was needed. I managed to gain access to two other companies, and also started interviews in these companies. Later on, a fifth case company was also added at a stage when the research had progressed beyond these phases. As a whole, the year 1998 was mainly used for empirical research. Analysis of the material available from the literature and empirical interviews helped to focus and find the basic ideas on how to model the product development and research issues that were targeted.

Characteristics of the business in industrial electronics

Companies involved in the present research have been focused on the industrial electronics business. Finnish companies have been strong players in specific businesses like industrial automation, process control equipment, energy production and

[5] This theme has gradually been refined into an approach where organisational information requirements approach has been chosen as an underlying theoretical perspective to interpret and analyse the priorities and performance of product development processes in the companies. Competitive priorities have then been used as a conceptual framework that has evolved towards more theoretical depiction of the interpretation and analysis perspectives.

transmission and environmental applications. The success of Finnish companies in the industrial applications of electronics has been enabled by success in more traditional sectors of our economy, like the paper and pulp and metal industries. These industries are still strong and evolving areas of the Finnish electronics industry. The industrial electronics business is however not as fast moving as some companies in the consumer business. The markets for industrial electronics may be quite fragmented. The nature of the industrial product development processes is also driven by the needs of demanding customers. Overall, the Finnish business environment has been internationalising quite rapidly during recent years, even though Finland has a strong tradition in international trade. The Finnish electronics industry is a case of its own. The electronics industry is by nature quite an international one. This is an important issue to be noticed, for at least two reasons. The electronics industry is often directly facing international competition since its components and technologies for design and manufacturing are bought from the international market place. Secondly, this strong international aspect may have some role in the development of both business and R&D practices in this industry. Business culture and practices used between companies may be inherently more international than in many domestically focused industries. This study focuses on product development processes in the electronics industry and the uses of product development practices in the pursuit of different types of goals for product development.

3.3 Building of a framework

Analysis and interpretation of research material from empirical cases and literature is a stepwise process where you cannot proceed unless you pace that process with modelling and reflections. The analytical efforts of this study have resulted in a new conceptual model, developed on the basis of product and process matrix (Wheelwright and Hayes 1978). The model differentiates between technological competitiveness and product development performance. The model was based on the analysis of the empirical interview data and literature. Next, step 3 is shown in order to describe the development of the model framework.

I decided to try to build a conceptual framework according to the principles of product-process matrix (Wheelwright 1978, Hayes and Wheelwright 1984), complemented by relying also on the information requirements framework of Daft and Lengel (1986). I could rely on the premises embedded in the synergy between technological, marketing and product advantage issues (Cooper 1993:310) and also use the associations between various product development performance based development imperatives, at firm level (Cooper 1985b, Clark and Fujimoto 1991, Wheelwright and Clark 1992). This phase could be summarised as the conception of information requirements of product development processes with a modelling of the balance between technological competitiveness and product development performance. The exact definition of the concepts and their relationships was also yet to be done. This conceptual leap from step 2 to step 3 may be illustrated with Figure 17, see below.

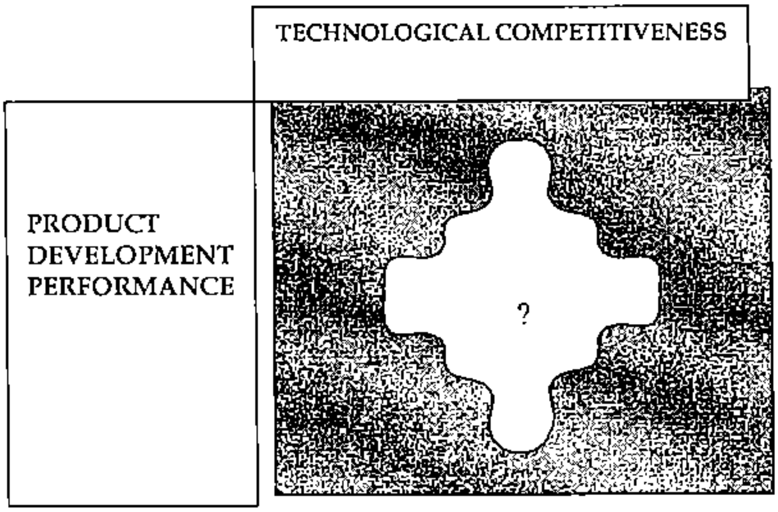


Figure 17. Positioning of the core concepts into a framework for a research design (Maunuksela 2001)

The basic premise behind this conceptual framework is presented. Technological competitiveness illustrates the critical success factors of new product development projects, and also success factors for the business in industrial electronics. Product development performance represents on the other hand the development imperatives for product development activities. Both variable dimensions have been also discussed in the literature review.

This model represents a constructive approach to building a framework capturing the synthesis from interviews in industrial companies. The development of this construction to be used as a research framework synthesised a triangulation process between literature, empirical interviews and modelling attempts to cover the nature of the empirical phenomenon targeted in this study. At this stage, conception of this kind of framework concretised and enabled next steps to be taken in the research process.

To develop a way to make our research framework operational in an empirical sense, we constructed a series of theme interview questions (see Appendix 1). This was one of the critical stages of the research. It was enabled by development of a conceptual framework based on the earlier observations. We elicited these theme questions from the experiences with the first stages of case studies. The structure of the theme interview questions was built analytically from generalities towards details and different contexts, also trying to maintain the prescriptive requirements from Doty and Glick (1994). The theme interview questions emphasised management of product development, reflecting the dimensions and issues depicted by the conceptual framework. Next I started to look for appropriate people who would be knowledgeable on issues such as technological competitiveness and product development performance. While this process of extending the original case study interviews with outside expert interviews was beneficial for the analysis of the research issues in many ways, it was also noticed that similar type of theme interview would be a convenient way to end the case studies with the industrial companies. Accordingly I produced a closely comparable set of interview questions for the theme interview to be carried out in companies.

Simultaneous interviews in the case study companies were carried out and appropriate experts to be interviewed for this study were also looked for. These people were selected from outside, and independent from the companies that were already involved. Then I decided to extend these theme interviews also to the case companies. Eventually I concluded the series of interviews in all case companies (1–4) with a themed interview with the managing director. This was a quite appropriate way for me to reflect on the findings within the company specific product development process. These interviews resulted in very valuable observations. In particular, the operational experiences and observations from the interviews around a particular product development project could be reflected in a theme interview with the managing director of the company. This enabled me to really justify the management level analysis of the findings from the context of the company specific product development processes. The theme interview questionnaire for the discussions with managing directors of companies is shown in Appendix 2.

3.4 Theme questions and expert interviews-main findings

The next step was to test the model with a series of expert interviews. A deeper understanding of the concepts of technological competitiveness and product development performance was needed, and their relationships as a way to study information requirements of product development processes. This would be necessary for two reasons: a) to build robust definitions for the concepts, and b) to test these concepts in discussions with different professionals involved within the area of product development. So far I have discussed how I elicited a conceptual model by synthesising literature analysis with field research in industrial companies. It was found that a conceptual pair of technological competitiveness and product development performance would be an appropriate way to build a framework for the analysis of organisational information requirements of product development processes. I also discovered a need to refine the definitions of concepts. Here I aim to discuss what can be done with the model. The nature of the research framework is a sort of dualistic typology between two types of general success factors for product development performance. It was noticed that some ideas from the literature concerning development of typologies and theory building could be useful for the purposes of this study (Eisenhardt 1989a, Doty and Glick 1994). See table 4 below.

Table 4. Guidelines for the development of typologies (Doty and Glick 1994)

1. Typological theorists should make explicit their grand theoretical assertion(s)
2. Typologies must define completely the set of ideal types.
3. Typologies must provide complete descriptions of each ideal type using the same set of dimensions
4. Typological theories should explicitly state the assumptions about the theoretical importance of each construct used to describe the ideal types.
5. Typological theories must be tested with conceptual and analytical models that are consistent with the theory.

I have interviewed 11 experts in the field of product development and technology management, and four managing directors working in the companies where interviews concerning product development projects had been carried out. These theme interviews were done either by telephone or during personal meetings. Most interviews were tape recorded and transcribed into written text. The data from selected interviews will be presented and analysed in some detail. These citations will also show who was interviewed for this study. Such qualitative data was very valuable for the analysis of the conceptual approach used. I learned that there are a lot of interesting and valuable perspectives to the concepts of product development performance and technological competitiveness. Each expert responded in his own words so I could analyse different perceptions to the questions. Overall, additional information from both expert interviews and company specific interviews with their managers could be found, as compared also with the literature review.

Critical observations from theme interviews (expert interviews)

I tape recorded all interviews and transcribed them in detail. The interviews revealed many interesting perspectives and views on product development performance and technological competitiveness (Maunuksela 1999, Maunuksela 2000, Maunuksela 2001). The analysis of the interview data was focused on the associations between technological competitiveness and product development performance. Here I cite material only from two theme interviews (Kari Rintala (4/1998); Yrjö Neuvo (February 1999)). This is because I found them to be associated together in some important ways. Both experts brought up a very human approach to the questions being looked at. I selected the two citations from Neuvo (1999) and Rintala (1998) because I believe they represented a most generic way to look at the associations between product development performance and technological competitiveness, these example capture also the core of the observations from interviews, by focusing on the different capabilities and orientations of individual to the issues addressed with the interview questions.

They addressed the question at the level of individual capabilities and orientation. "Individual" based approach to these questions could also be quite easily framed into extended questions concerning project teams and product development processes (Brown and Eisenhardt 1995). By starting from the idea that there may be some differences between individuals' beliefs and views on these issues I made a minimum amount of assumptions concerning other factors that might also be important for product development performance. These citations are adopted from interviews that were performed as part of this study. These citations are presented here in the form of critical observations. These observations are also such examples that address the issues related with the information requirements perspective by Daft and Lengel (1986). The examples shown here were so to speak the enablers for the saturation of the qualitative interview part of the research process (Eisenhardt 1989a).

Elaboration on key observations from the expert interviews

It has been mentioned that a series of expert interviews and interviews with case company managers were conducted as part of the empirical research process. These interviews were carried out as theme interviews, reflecting the questions shown in Appendices 1 and 2. All interviews were transcribed and analysed in order to develop an interpretation and synthesis representing the research issues, especially the framework shown where relationships between technological competitiveness and product development performance were addressed. Basically all respondents gave answers that were often individual and reflected their views on the questions. This showed that the material collected from the interviews did not necessarily converge in simple way. The development of the interpretation process was more a selection of a perspective that could summarise and be representative of the data sample. Eventually a conclusion was made that the responses where technological competitiveness and product development performance were related with orientations and motives of the individuals working in the development organisations would be a satisfactory perspective to summarise the findings from the interviews. This conclusion was especially based on two examples picked up from different interviews, these items have been adopted here as examples of key observations from the interview process being carried out.

Both of the citations have been translated from Finnish to English language by the researcher. The first citation has been adopted from the interview with Mr. Kari Rintala, April 1998, (the related discussion was adopted from responses concerning question number 15 in the expert theme interview questionnaire). The second citation has been adopted from the interview with Dr. Yrjö Neuvo, 1999 (question 9).

Excerpt from the discussion with Kari Rintala, text below in italics:

Question asked by the interviewer:

"How would describe the role of business transaction complexity (high, medium-high,medium-low,low) on the impact of product development performance or technological competitiveness in the competitiveness of the firms?"

Answer:

"In small and medium sized companies the quality and performance of product development activities may sometimes suffer if there is too much interaction with customers, this may mean problem solving and correction of bugs. If interactions can be limited to the early phases of the product development process the possibilities of success can increase, but if there is interaction throughout the process then the start phase isn't good, overall efficiency becomes weaker. In the case of industrial electronics this may not be so much of a problem, but if this happens in the consumer electronics business then problems can be significant. If the company's practices are not kept updated and contemporary the competitiveness of a firm may suffer. This is more general in consumer electronics, but in future also in other sectors of electronics industry where integration increases."

Interviewer's comment:

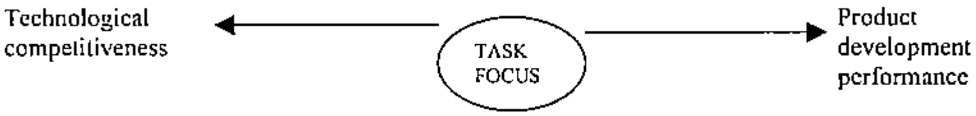
"Do these issues impact on the organising of product development, like in terms of a functional technology based approach, project organisations, or product based, especially product architectures?"

Answer:

"Product based and product architectures might seem to be practical, it depends on the nature of the industry sector."

Interviewer's comment:

Could it be possible to separate different kind of prioritisation or task focus principles against the concepts of technological competitiveness and product development performance? (See below an illustrated picture drawn by the researcher at this point of the interview.)



Response from Mr. Kari Rintala:

"This matter is more complicated. A sort of dynamic view on the role of seniors is also important. This is a question of individual human characteristics. Other people are more satisfied with needs for strong focus while others may be more driven and attracted by newness. It is a management problem, how you can balance these things."

A figure drawn by the interviewee:

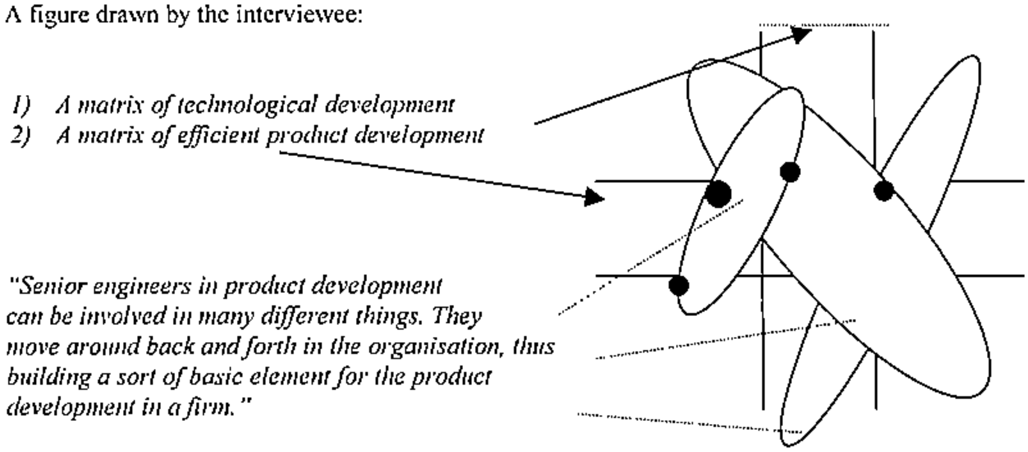


Figure 18. A double matrix model of product development suggested by Kari Rintala (4/1998), and related to discussion in the interview situation

In another case, we had also an opportunity to interview Dr. Yrjö Neuvo. A citation on next page illustrates a selected part of the discussion (as translated by the researcher).

Question asked by the interviewer: "What kind of interdependencies, differences or similarities do you see between product development performance and technological competitiveness?

Interviewee: "*They are both a little bit similar. A good product has both of them. Product development is efficient and competitiveness is good. That is how it goes and they can also strengthen each other. You need both, but you have to have the right balance of those. That is evident. If you have very good product development, but you work with bad technologies, that does not work. And the other way around, too. It can be quite easy to forget either of these for the company. It may be that if you have a new spin-off company from a university moving on with technological competitiveness. And another case could be when a more established company, or a company with different kind of objectives, is focusing on fast development work. Then you might be faced with a situation where neither technological competitiveness nor product development performance is good. You need to be good in both areas. It may often be the case that this question is related to different people in a company. An organisation must have people who take care of this technological competitiveness. And then they will bring it to product development. If we look at a highly trimmed product development organisation they have only very few possibilities to look around, perhaps asking that what kind of technologies we could use in our work. This is quite important. We have to refine and develop new technologies inside the company to the level where they can be swiftly adopted to product development. We adopt them into efficient product development. In a way, you look at product development as a moving train. And when the train is going you try to throw new elements of technologies into it".* (Yrjö Neuvo, February 1999.)

These examples highlight ideas selected to be representative excerpts from the series of interviews with experts. The decisions to limit these citations were based on two things. The first point is that both respondents argued for this issue in a convincing and converging manner. Secondly, given the possibility to interview different people with these topics it became obvious that every respondent gave more or less different answers from the other. So in this way, by looking at the individual level orientations on these issues, I would actually adopt the nature of the substantial findings into a similar form of inquiry for the survey. It needs to be seen as a "matter of managed balance". People as individuals may have different kind of roles or orientation needs to be considered as critical factors in product development. This is basically a very human question, but also a quite important one for the management of product development. The examples shown can be interpreted as one of the fundamental trade-off questions associated with the interpretation of information requirements in product development processes. We must also look for additional responses to these questions.

3.5 Preparation of the questionnaire

This step 5 describes how the survey instrument was developed in the course of the empirical research process. Discussion has been organised into a structure where the main issues related with survey approach, response scales, pre-testing example, design of the overall survey instrument, data collection procedure and preparation of group interviews have been included.

The model framework was built around technological competitiveness and product development performance. Practising product development engineers are not always informed of these questions. One R&D manager (Company 2) said: "*Product managers and project development managers should be knowledgeable about these issues*". In another firm, the manager of a product division (Company 1) said, "*Basically product managers and product development managers are the people who are responsible for issues like product development performance.*" My interpretation from the previous examples is that these concepts of technological competitiveness and product development performance may or may not be taken into the professional vocabulary of the product development processes of different firms. At this stage a choice had to be made on how the model can be studied in the context of product development processes. One alternative would have been to study and report in-depth case studies from the different product development environments. By doing that, we could have highlighted only a small group of issues associated with technological competitiveness or product development performance. I adopted a different approach. Instead of writing a specific case study report I decided to develop a questionnaire that was going to be tested in the different companies. This strategic decision grew out of the reflection between literature and analysis cross-case comparisons between companies.

Development of the survey research approach

The model of information requirements was operationalised into a framework of two strategic performance areas: namely, technological competitiveness and product development performance. So far, my own data collecting work was focused on interviews in different companies, complemented with expert interviews. From these sources large amount of qualitative information was obtained. The nature of the data was descriptive, because I relied on the comments and replies of individual people. So if the importance of financial performance or quality improvement were discussed, answers given to us by the informants were made use of. The idea behind the work was that I could utilise this information in a form of questionnaire development. But this was now a challenge of how to link together the original research design, model framework and survey research methodology.

Development of a response scale

I was specifically looking for opportunities to test the model framework against the realities of the observation environments that had been used in the interviews. So far, I had already developed and elicited a conceptual model of the information requirements of the product development process. I had not exactly defined what was meant with these concepts. After all, I had performed a series of interviews targeted for the clarification of these concepts. It was clear that some limitations and definitions were needed before these concepts could be applied in the development of the survey questionnaire. Development of the questionnaire was an iterative process. First I selected a list of key issues and concepts from the interview data. Secondly these were developed into statements to be used in the questionnaire as items or specific questions. There were some real challenges in the definition of the questions. My decision was to operationalize the model developed earlier into a form of a response scale. I thought this could be possible because I had a fairly broad approach for pre-understanding over the research problem (Gummesson 1991). Eventually I decided to develop a new kind of research questionnaire. The questionnaire was built according to the principles of scale development (Hensley 1999) and typology-based theory building approaches (Doty and Glick 1994). The model for statistical scale development process (Hensley 1999) nicely describes the second step of the research. See Figure 19 on next page.

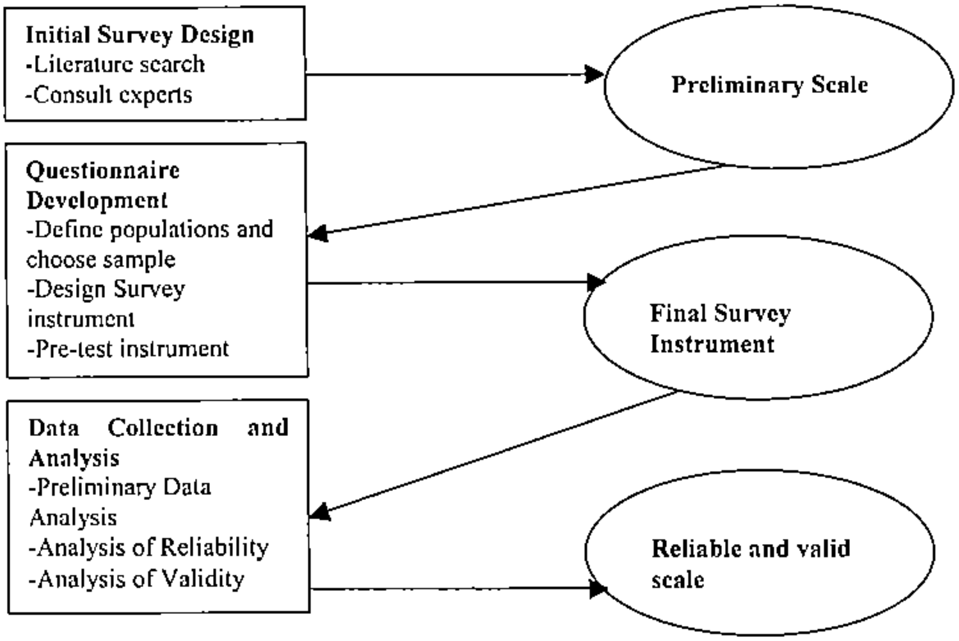


Figure 19. Typical scale development process in operations management (Hensley 1999: 355)

One key finding from the literature on product development processes is that performance dimensions should be balanced, as a whole. Also, what was found from the expert interviews suggested that perhaps two very different concepts could be integrated into a response scale. Originally, product development performance and technological competitiveness were used as broad and open questions in the theme interviews. For the development of the questionnaire we focused on the observations drawn from the interviews with Kari Rintala and Yrjö Neuvo. A combination of views where extreme (individual) nature of the concepts was associated with the need for balance between them was seen as a concise way to look at the problem. This interpretation was not a straightforward conclusion. In fact, I was already working in the field with the questionnaire when it was discovered that the questionnaire was not ready. It happened that in early June 1999 I tried to test this questionnaire in company 3 that was involved with the research. We had planned for a meeting where this questionnaire would be completed by the group of managers responsible for the product development process level work in this company. During that meeting it became evident that the operationalisation of the questionnaire was not mature enough for the its practical use in companies. Below I have included a couple of examples from the first version of the questionnaire, see Table 5 below.

Table 5. An example of the first version of the questionnaire

Question 1.

Technological competitiveness and product development performance are balanced during our work in a new product development project, ...

Response scales

My opinion in general		Confidence level	The extent this is true in our company	
STRONGLY DISAGREE	STRONGLY AGREE	CONFIDENCE (FROM 0-10)	STRONGLY DISAGREE	STRONGLY AGREE
0 1 2 3 4 5 6 7 8 9 10		________	0 1 2 3 4 5 6 7 8 9 10	

This version of the questionnaire was strongly criticized. One product manager said that these concepts of technological competitiveness and product development performance are two issues that are very much opposite to each other, at least for him. For him, it was difficult to see how these concepts were built into this questionnaire. So even though I had built the structure of the thinking being looked for into the questions, we were still missing the operational level required for survey research based objectives. Here I encountered a problem of operationalisation, that was actually somehow converging towards the findings from the expert interviews. The following text illustrates what happened in the first group interview. For this purpose, you may read an illustration of the situation that occurred in case company 3, as the researcher perceived it. To describe this, a part of the case company interview with case 3 (June 1999) is reported below, according to the experience I had in the use of the questionnaire. This excerpt shows in detail how some feedback from the respondents in the case company 3 helped to find new ways to improve the questionnaire. Elaboration of the interview process includes narrative discussion from the researcher, and some comments from the respondents that are shown in italic fonts.

This company was a product division operating as a business unit of a medium-sized Finnish high technology corporation. Previously the researcher had had an opportunity to do a series of group interviews with a couple of people from this company. Actually these interviews were quite open discussions where a specific team of product development manager, product manager and a manufacturing engineer were explaining how one of their product development projects was progressing. So the researcher knew a couple of the people before this situation was arranged. I had made an appointment with a group of people from company 1. This group of six people was named person by person by the manager of the product division, when he was asked for permission to conduct a group interview with the people responsible for the management and implementation of the new product development process at operational level. We could call this group a product development process management team. (The demographic data of this group is introduced in Table 13).

This particular meeting began with a presentation made by the researcher. The purpose of this group meeting was introduced; namely to collect a set of responses to a survey questionnaire designed and developed by researcher. So first the basic nature of the questionnaire was introduced with some examples from the current literature on product development processes and their management. Secondly, the precise nature and background of this meeting were illustrated. After the purpose of survey was introduced it was possible to distribute the questionnaires to the group. Then, before they began to fill in these questionnaires the researcher made a special remark on the nature of the key concepts in the research. The researcher introduced special definitions for the concepts of technological competitiveness and product development performance. This elaboration on the key concepts was seen as a necessary thing because otherwise every respondent might develop their own interpretations of the core concepts that were used in almost all questions. After this stage it was then possible to let the team members get going with the completion of the questionnaire. (Here one may also reconsider why in the first place it was thought necessary to do a group interview within the company premises. Experience from empirical research suggested that if you really need your questionnaires to be returned you may consider the option of getting them back while your are visiting a company. Otherwise it may be difficult to get back some of the questionnaires.)

Some time had now elapsed and all six group members were filling in their questionnaires. Some concepts had to be clarified by the researcher but otherwise it was going quite well, thought the researcher. Then after about ten minutes one of the product managers became irritated by the difficulties with the questionnaire. So he made a strong question; " *I can not answer these questions. You are asking us to evaluate some factors against the balance of technological competitiveness and product development performance? Right, the researcher said. This is because in many cases it has been shown that balance is an important characteristic of many research results concerning product development. The product manager replied: "for me, technological competitiveness and product development performance are some kind of polar ends of different things (showing a t-symbol with his hands).* " He continued; " *if I answer your questions you will only get very fuzzy answers, that will be very chaotic to interpret. Therefore I do not want to fill out this questionnaire.* " So he put his questionnaire back on the table. After that the other members of the group began to participate in this discussion with comments. "*Yes, this is very difficult for me.*" "*I just filled them in, I did not think about it that way...*" So the outcome of the process was that everybody returned their questionnaires without fully completing them.

The researcher was rather stunned; his questionnaire backfired and caused problems that were not noticed in a couple of pre-test interviews carried out earlier. Perhaps it was because this particular product manager had long experience in the design and analysis of market research questionnaires. So he explained to the researcher after the questionnaires were collected back.

At the end of this group meeting the other members of the group made some suggestions for the improvement of the questionnaire. One woman who was a product manager said: "*if you are so interested* *abou tin balance of these concepts, why don't you just make a specific response scale where you could use technological competitiveness and product development performance as the ends of the scale while putting a balanced number like zero at the middle of the questionnaire."* The researcher replied that this kind of version was considered earlier. But the researcher rejected it because it might be too difficult. But it was not a better way to try to embed the question of balance with the questions as statements used in the questionnaire. (A group interview with case company 3 in early June 1999).

So it happened that our first group interview with the questionnaire survey turned into a situation where the questionnaire was criticized and evaluated. The original plan to perform a short group interview with a questionnaire was becoming a real pre-test situation with the questionnaire under debate. It was a hard lesson. It is also important to notice how the group behaved in this situation. The experience from this interview was invaluable. Suppose the then suggested form of the questionnaire had still been used in the other companies. We might have ended up with serious problems of reliability with the questionnaire data analysis. So I started to redesign the questionnaire. But I did not change the decision to proceed with the intent to carry out a survey within the different companies. This was because I wanted to try to build some tools and frameworks that could be replicated in new research efforts. We talk here about building a survey questionnaire instrument. This instrument would be grounded in the qualitative data from interviews and discussions in different companies. Actually the research approach was very much empirical. I wanted to aim for results that would not be very case sensitive. So far, the research had actually progressed much according to the stages of scale development. Hensley (1999) has presented a review of empirical scale development papers concerning the area of operations management. The final form of the response scale can be seen in the questions presented in Appendix 5.

Survey instrument

A number of critical choices were made in order to make the survey research approach operational. These choices were related to the content of the questionnaire, structure of the questionnaire, response scale development, linkages between existing literature and the present work, data sample and data collection procedures and analysis methods. These are addressed in the following sequence.

Content of the questionnaire was limited to the core questions of the research. This was resolved by selecting a set of interview results that were seen as essential for the description of the research question. In chapters 3.1.2/3.1.3 we described how some ideas about the linkages between technological competitiveness and product development performance were found. Now that we were developing a questionnaire based on the interview results some representative ideas and questions from our interview data could be selected. This procedure made it possible to link together qualitative research and development of a more quantitative survey research tool. For most of the questions to be included in the questionnaire, these were elicited from transcribed documentation from the theme interviews with experts. Original data behind the questions is shown in Appendix 3. There are also some citations from the literature that were thought to be a necessary ingredient for the material from the fieldwork.

Structure of the questionnaire was developed simultaneously with the response scales to be used in the questionnaire (see Appendix 5 for a copy of the questionnaire). The survey questionnaire instrument consists of three parts. The first part contains basic demographic information on the respondents. The second part contains a series of questions concerning the perceived impacts (benefits, performance improvement, etc.) from the use of a formal new product development process (Cooper and Kleinschmidt 1991, Cooper 1993, Griffin and Page 1996). This series of questions was included in the questionnaire because it represents a dynamic kind of inquiry where you are very likely to need non-financial performance information. The third part contains a series of statements associated with the management of product development activities. The number of these statements was limited to 33. These represent product development practices chosen from the empirical interviews.

An important feature of the questionnaire is that it contains two different kinds of **response scales**. This was done in order to test the operationalisation of the research concepts. The first response scale is a Likert scale ranging from 0 to 10 (strongly disagree, strongly agree) combined with an estimate of the confidence level of the response (0-10). A similar structure has been used, for instance, by Cooper (1993: 335–339). A second response scale was developed in this research process. It is a scale that combines two different kinds of concepts and their balance, in an ordinal sense. I will elaborate this second response scale here with some additional remarks.

When we want to design a new questionnaire instrument we need to take care of a variety of things. Usually we also need to make plans for the mailing and collection of the questionnaires. These previous questions are often dealt in the design of the data sample and data collection procedures. In this case I focused on the research strategy. Therefore I decided to stay with the companies that I already knew to some extent from the longitudinal interviews. This meant that I would eventually look for data collection opportunities within the companies involved in this research. Another observation from many empirical research projects is that usually we can only get back a limited number of questionnaires that we have sent to different firms. Depending on the project the average response rate may range from 20-40 %. These kinds of results are typical of large-scale questionnaire surveys. When thinking about this question with the present research problem it became obvious that the needs for empirical information were different. There was an opportunity for group interviews in the companies that were already known. I decided to aim for company-specific group interviews for the data collection phase. The survey instrument developed in the course of this research is presented in Appendix 5.

Details of the survey instrument-some remarks on the balancing aspects

I wanted to design a questionnaire that would facilitate a kind of "balance mapping". For example, Pine (1993) has used response scales where scales were anchored with dualistic typologies between concepts like one-of-a-kind or mass production. These may be called a form of semantic differential scale (Nunnally 1978). We may compare the examples from Case (1998), Pine (1993:267–276) and Cooper (1993:327–339). Pine (1993) used a variety of different response scales that were often based on the use of semantic differential scales (Nunnally 1978:612–613). Cooper (1993) has used more traditional rating scales combined with additional confidence level indicators. I adopted some principles from both kinds of examples. The survey instrument is shown in Appendix 5. Questions 1-10 were constructed using Likert scales that are similar to earlier studies such as Cooper (1993). Questions 11–43 were written with the second response scale in the ordinal scale type. In summary, some constructive research phases were carried out during which a survey model framework, conceptual definitions for technological competitiveness and product development performance and survey questions reflecting product development practices were developed. The form of the response scale uses the theoretical framework used in the expert interviews and then it has been accordingly used in the building of a semantic-differential response scale.

3.6 Methodological aspects of the empirical survey

In the literature review part of this research, a conclusion has been presented where a particular type of conceptual framework has been adopted. This is the idea of organisational information requirements by Daft and Lengel (1986). This theoretical framework has also been used here in the empirical analysis of the survey data. Methodologically this presents a synthesis in the research process in this project. Here an overview will be presented in order to describe how the ideas of the organisational information requirements have been used in analysis and building of the empirical survey and interpretation perspective. The purpose of this discussion is to integrate together key aspects of the literature review and empirical research process.

The empirical research process described earlier has focused on specific concepts like product development performance and technological competitiveness. These concepts present the approach and perspective chosen here for the analysis of the product development processes and development practices. These concepts have also then been analysed with the ideas of organisational information requirements for product development practices. The empirical research process described has focused on the interpretation and individual orientation to the concepts of product development performance and technological competitiveness. Secondly, these concepts have also been utilised in the development of the survey questionnaire. There remained two issues that needed to be completed in order to finalise the empirical research process. The first one was to make the survey questionnaire operational. The second was to define how the organisational information requirements perspective would be applied in this research. The resolution of these questions crystallised during the preparation and analysis of the empirical data.

Both technological competitiveness and product development performance could be seen as representative information requirements for the use of product development practices, and also for the management of the product development process. Key issues observed in the empirical interviews were related to a question representing the underlying theoretical perspective: how can we study information requirements through the practices used by firms? This question became a matter of importance. The answer to this question was then developed. It may be possible to analyse the practices used by firms with the information requirements typical to product development processes and how individuals and groups might interpret such issues. These questions have been addressed here by linking organisational information requirements perspective with the use of product development practices. Empirically this was resolved by designing a structured method to use the questionnaire in the collection of empirical data. This was also complemented by developing a statistical analysis perspective that enabled the construction of the analysis according to the ideas by Daft and Lengel (1986).

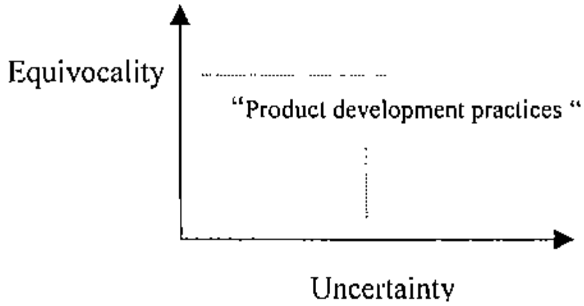
The starting point for the analysis has been to focus on product development processes and development practices. The second issue has been that the ideas of organisational information requirements suggest that issues like equivocality and uncertainty may be related with the organisational tasks and practices (Daft and Lengel 1986). These guidelines have been used in the development of the survey questionnaire and its use.

The ideas of Daft and Lengel (1986) suggest that there might be two different types of variation regarding the organisational information requirements. These are equivocality and uncertainty. In the literature analysis it has been concluded that these issues can be also seen as information contingencies from the perspective of effective information processing in the context of the product development organisation. The example of Daft and Lengel's (1986) conceptual model suggests that it is possible to separate four types of organisational information requirements: originally conceived as routine technologies, engineering technologies, craft technologies and non-routine technologies. These four types are based on combinations of both high and low equivocality variables, used together with similarly categorised levels of high and low uncertainty. The notion of technology has been replaced here with a concept of practice, enabling the use of the descriptive framework then in terms like routine practices, engineering practices, craft practices and non-routine practices. Using the concept of practices instead of technologies may be more suitable for the related discussion where product development processes and practices will be analysed. Organisational practices can also be used in a comparison and analysis of organisations and their differences, as was also the original purpose described by Perrow (1967), whose ideas Daft and Lengel (1986) have further extended towards the information requirements perspective.

According to Daft and Lengel's model (1986) it may be possible to argue that uncertainty and equivocality may vary together, as a function of the organisational unit or resources performing the information processing and problem-solving activities. It was then also possible to arrive at the conclusion that product development practices and their use may be related with the co-variation of uncertainty and equivocality, as interpreted by both individuals and groups participating in the product development processes. This finding led to a "bottom-up" idea where the basic elements of the survey instrument and empirical data could be used in a way that is comparable and consistent with the ideas of Daft and Lengel (1986). In summary, it can be concluded that this empirical research process has been converging towards a new survey instrument and its utilisation in distinct phases: selection of main concepts (technological competitiveness and product development performance); picking up of related observations (derivation of product development practices); construction of a survey instrument (modelling of the use of product development practices within product development process of a firm); understanding of variation with the ideas of organisational information requirements and finally the statistical treatment of the data with specific frames of interpretation. These main issues will be next described shortly, starting with a Table 6 shown below, that presents the flow of the analysis.

Table 6. Derivation of interpretation between theoretical framework and empirical survey method

1. Co-variation of uncertainty and equivocality (Daft and Lengel (1986)



2. Representation of product development practices in the questionnaire

xx. Top management of our company is typically prioritising issues which are important for ….

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

←--------variation type A----------→ ←variation type B→

(Inter-quartile range) (Median)

3. Utilisation of the variables in the analysis of equivocality and uncertainty

Equivocality can be estimated from variation type A by calculating inter quartile range statistics describing the levels of responses reflecting respondents perceptions in the use of product development practices (means) in order to address specific ends like technological competitiveness, product development performance or a balance between them.

Uncertainty can be estimated with a median statistic that characterises the variation in the levels of confidence reflecting levels of uncertainty in the questions as the respondents saw it.

The underlying framework of information requirements has been a guideline for the analysis. A key decision in the approach chosen has been to view equivocality in ways that might be argued to be associated with the relative deviation and variation in the responses concerning the positioning of the questions in terms of the ratings between technological competitiveness and product development performance. Relying on the basic statistical information from the empirical survey has enabled the partitioning of the data sets into these groups. Two types of partitioning have been applied. The basic idea in this partitioning has been based on the idea of using appropriate statistics for variables based on the ordinal response scale (Vartia and Vasama 1971a, 1971b). Median and inter quartile range values have been calculated from the survey data according to such principles. The core ideas behind this statistical ordering and stratification can be described best with a figure of flowchart showing the process flow of the data analysis. Similarly this kind of table is a convenient way to visualise how the logic of the original framework of Daft and Lengel (1986) can be adopted as a procedural guideline for the analysis of the empirical survey data. See Table 7 on next page.

Table 7. Data analysis flow

1. Collect and type the survey data into a spreadsheet program	2. Calculate median and inter quartile range statistics for each variable in original data set	3. Order the original data according to the inter quartile ranges calculated from the rating scale A into descending order
4. Calculate then a median value of the inter quartile range statistics from the rating scale A (Inter quartile ranges for variables based on rating scale A enables the use of dispersion in the responses to be analysed as a characteristic of the equivocality of the issues.)	5. Split the original data set into two subsets (1,2) below and above the median of inter quartile ranges from the rating scale A (Variables ranked below median can be grouped together, remaining variables equal or greater than median value are put into other group.)	6. Order the data sets 1 and 2 based on the medians from rating scale B, Calculate then a median value of the variable medians from the rating scale B with the values for both subsets 1 and 2, (This enables use of rating scale B in the partitioning of the data based on uncertainty Median of medians statistic enables distribution free partitioning of the variables based on ordinal response scales into two subgroups.)
7. Split the new subsets of data (1,2) into their further respective subsets (1a, 1b; 2a, 2b) below and above the median of the medians from the rating scale B	8. Analyse the basic statistics available in the four subsets of the original overall data in order to classify each set with the descriptive ideas from the model of Daft and Lengel '86	9. Interpret and analyse the results with examples provided by the Daft and Lengel (1986) descriptions. Validity and verification of the results is also recommended with feedback interviews.
An example; High equivocality, low uncertainty "Occasional ambiguous, unclear events, managers define questions, develop common grammar, gather opinions." (from Daft and Lengel 1986) -high values of inter quartile range from rating scale A, -high levels of confidence from rating scale B (above the median), etc. (All four main categories can be linked to the stratified subsets of the data from the survey questionnaire).		
Additional comment: -All four subsets of the data also contain the information based on the meaning of the rating scale A, to evaluate each practice between technological competitiveness, product development performance, or a balance between them. -The median of rating scale A can be used in ordering the variables within the subgroups. This gives more logical structure to analyse the results as each variable can be also evaluated in terms of how it has been interpreted by the respondents. For example, some practices seem to be clearly more related with the technological competitiveness, while others can be also related with product development performance. These differences give insights into the role of different product development practices as seen by the respondents. This complements the analysis.		

Equivocality has been estimated by calculating the inter quartile range statistic for each of the variables from the response scale A. The inter quartile range (IQR) statistic provides a method to describe dispersion in data which is based on the ordinal response scales. Then variables were ordered according to the relative level of dispersion of the variables. Higher ranges in IQR-statistics represent accordingly more variance in the judgements of the respondents. Lower levels of the range then imply more consistent rankings for the variables. In this way it has been possible to utilise inter quartile range statistic (IQR) as a measure of dispersion, reflecting the relative consistency in the responses of the groups. The first partitioning task has been to divide the data set into groups where variables above and below the median of IQR were separated. This provides a way to describe the relative differences in the equivocality of the role of the development practices.

Uncertainty based partitioning has been carried out by using the ordinal response scale for the confidence level related with each question. Again the basic statistic for the confidence levels has been the median. After the first phase of partitioning the subgroups reflected the proposed high and low equivocality differences between the variables. The second phase of the partitioning concerned the uncertainty related with the practices.

The statistical nature of the second partitioning has been different. It was possible to utilise the high and low values of confidence levels. Therefore the median of the responses of each practice could be used. The remaining partitioning task was to divide these two groups into their subgroups based on the differences in the uncertainty levels. The nature of the partitioning problem could have been approached in different ways. It was decided that a median of medians based partitioning would be possible. This means that the medians of different practices can be used in the analysis of the partitioning problem. By calculating a median of the medians from the confidence level responses concerning the practices it is possible to find a way to divide the practices into above and below the median, hence presenting differences between practices in their high or low uncertainty.

These two partitioning phases are based on the methods fit for the use of the data based on the ordinal response scale. Median and inter quartile range can be used for this kind of data as measures of central tendency and dispersion. Median and inter quartile range can be used in the analysis of the different product development practices. Then the utilisation of the relative differences between these statistics enables an ordering procedure that is based on the ideas of the Daft and Lengel's (1986) conceptual framework for organisational information requirements.

3.7 Empirical research design and structured approach for data collection

Having developed an approach to use empirical data in a way that can be linked with underlying theories, it is then also important to cover the data collection issues and the principles in the use of the survey tool. This study has been designed on the basis of an empirical research strategy. It was decided that a questionnaire would be used in empirical data collection from case companies. This was linked to the opportunity to work with different companies that had already been involved in the study.

Five different companies were used as cases, in order to obtain more variation in data collection. The companies represent varying types of businesses related to industrial electronics. This specific business sector was used consistently in order to get sufficient focus on an industry. Each case was analysed with a similar type of systematic process where we started with follow-up interviews at a project level and finally closed the project level data collection through an interview with the managing director of a firm where we could verify our main findings from the cases. Table 8 shows information on the characteristics of case companies.

Table 8. Description of the case companies

	Case 1	Case 2	Case 3	Case 4	Case 5
Firm	Product division	Product division	Product division	Medium sized	Medium sized
Turnover	< 1 billion FIM	< 1 billion FIM	< 500 million FIM	< 500 Million FIM	>500 Million FIM
Profitability	Very good	Good	Very good	Improving	Improving
Employees	<500	> 500	< 200	< 500	<500
Markets	Global	Global	Global	International	International
Annual growth	5-10 %	5-10 %	5-10 %	10-15 %	4-8 %
Product strategy	Technology leader	Technical leader	Product leadership	Custom products	System supplier
Technical characteristics of the project	Product family renewal	System product platform extension	New product family	New customer project	System product
Product development process characteristics	New product process	Software driven process	Software driven process	Project management	Project management
Experience in Product development	>10 years	>5 years	>5 years	1-2 years	5-10 Years
Process Management Approach	Department level	Department organisation	Department organisation	Project	Department organisation

The selection of these case companies occurred gradually along with the progress of the research. The main criteria in selecting such companies were based on the need to collect evidence and examples from different kinds of product development processes. It is also possible to say that the case study logic behind the selection of the companies was congruent with the purpose of covering different aspects of information requirements on the product development processes.

Each company has a business and technology focus in their own markets and customers. Still these companies operated in a similar type of industry in industrial electronics. Gaining access to different companies within a particular industry has been a critical issue in this research. Each company then also fulfils a place in a case study setting, which is important. For example, the analysis of product development performance in different companies may have enabled a comparative analysis of technological competitiveness as a critical issue for the management of the firm's development processes. The comparison of the case companies can also be illustrated with a matrix characterising the resulting research design including these five organisations, see figure 20 below.

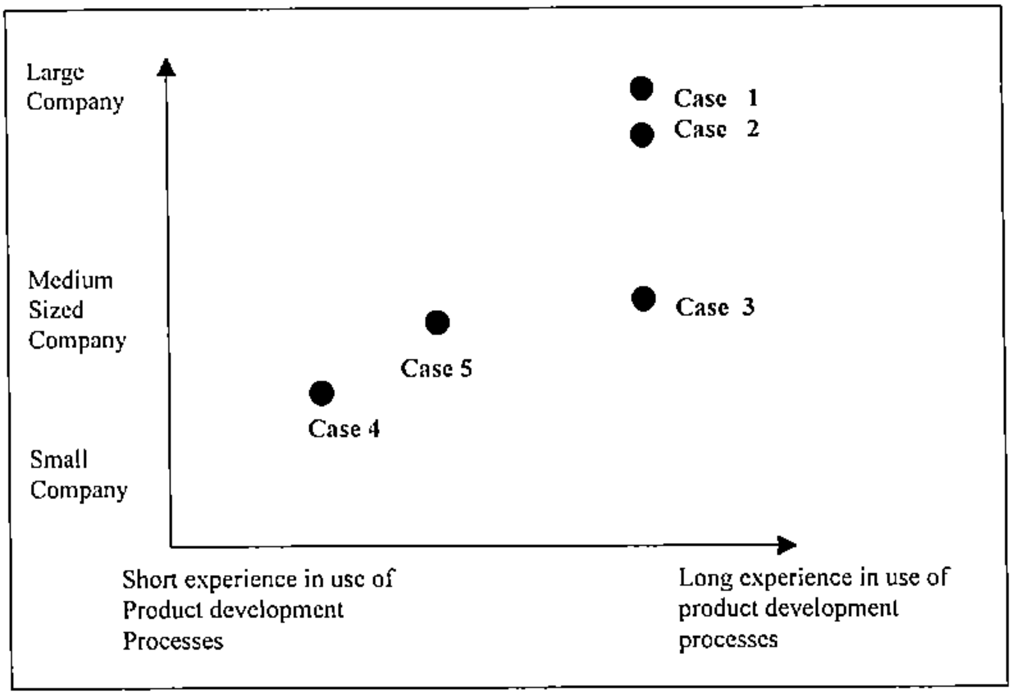


Figure 20. Case study selection and development of research design for multiple case studies

After having developed a response scale for the survey we could present the overall research framework developed for the analysis of product development process and development practices. An illustration below shows the structured approach for the empirical data collection and analysis of product development process and development practices, Figure 21 on next page.

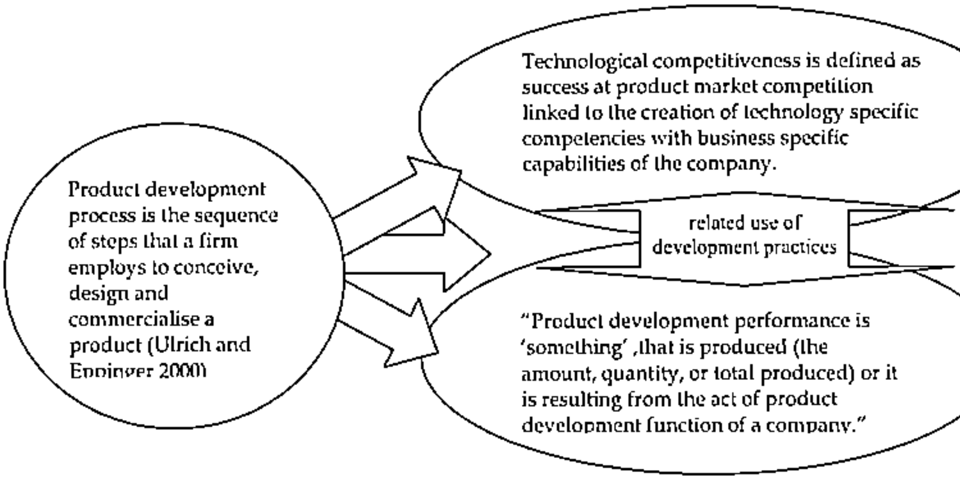


Figure 21. Empirical modelling of product development process level use of development practices, with definitions of key concepts

The model framework covers two overlapping definitions of elements of product development process level performance issues. Notice how the basic definition from Ulrich and Eppinger (2000) has been used as a starting point to approach process performance. This modelling framework shows also how we have approached the concept of product development performance here in this study. The sequence of steps also underscores the phase wise approach that is often used for the management of a development process.

Firstly, the product development process is seen as a sequence of steps used by a firm in the conception, design and commercialisation of product. This definition highlights a stepwise nature of development activities, without limiting the notion of product development process to any specific step of development. Next the performance targeted with the product development process is modelled with a principle where technological competitiveness and product development performance are used. Technological competitiveness has been defined in a manner that seeks to describe a linkage between commercial success in product market competition and its leveraging impact on the development of both the technical and business capabilities of a firm. Technological competitiveness is then related with the ways in which new products are commercialised in a firm, with the help of their product development process. This aspect of the modelling framework describes the longer-term development and impact of learning from new product success on the development activities in a firm. Secondly the concept of product development performance is used as a complementary performance dimension to the technological competitiveness. Product development performance has been defined here in a way that is more generic than any particular dimension of process performance like time, quality, costs or flexibility. This whole concept of product development performance underlines that there are important performance expectations for product development activities in a firm. The idea is that performance is so important an issue for firms and development managers that the role of product development performance is managed in ways where the overall output from development activities is analysed. This suggests that besides longer-term measures and achievements like technological competitiveness the short-to medium term issues are also critical to the management of product development processes. Project-specific definition of time, quality and costs are basic ways of how to actually measure development performance. Use of a more general definition of product development performance characterises more generically the role of product development performance as an important goal for a firm and its product development process. It is also a matter of how product development performance is interpreted by different individuals and groups. In this present study these definitions have been used in order to develop an interview process. These definitions have also been critically evaluated in the pre-testing phases, and it has been concluded that these provide differentiated roles for both technological competitiveness and product development performance in overlapping ways. Technological success alone is not enough but other additional performance dimensions are also critical to the benefit of a firm. This modelling framework describes how the survey instrument was introduced and presented to the teams responding to the questionnaire. The conceptual definition of technological competitiveness and product development performance was carried out through reflecting the original premises behind this study, the findings from the literature analysis, results from the case studies and expert interviews, and finally pre-tests of the questionnaire.

Finally, an empirical survey was performed in different firms. Data collection was carried out via group interviews while the researcher visited these firms. Basically data collection was carried out in a normal meeting, as scheduled by the firm. To be more specific, I prepared a structured interview session for this purpose. The session was started with an introduction by the researcher and then continued in a stepwise manner where the respondents filled two parts of the questionnaire after the researcher had made sure that the basic concepts and question forms were described and shown with examples to the respondents. As a part of the session protocol we used a specific definition of the product development process. For this purposeI adopted the definition for a product development process by Ulrich and Eppinger (2000): *product development process is the sequence of steps that a firm employs to conceive, design and commercialise a product.* This kind of generic definition of a product development process was used in order to align the respondent's orientation towards the theme of the survey. The real-life nature of the survey process could be quite important for case study research (Yin 1994). The goals with carrying out the survey in the companies were twofold. First I wanted to analyse how the management groups of the firm's product development processes have responded to these questions. This will tell us something about the differences between firms and their product development processes. Secondly, as the survey was exploring some new issues and methods, I wanted to be very careful in collecting the material with this kind of structured method.

4. RESULTS

This chapter contains the results from the empirical survey. The purpose of the analysis and discussion is to provide answers to the research. The discussion is structured so that the first part of the text is related to the introduction of a new survey and analysis method, and the second section focuses on the substantial interpretation and elaboration of the case study results collected with the survey approach developed for the resolution of the research problem theme. By the end of this chapter we will have produced empirical results and analysis that concern the two questions given below:

1) How might the technological and competitive settings of a firm impact the uses of product development practices within a product development process?

2) How could we analyse different types of product development practices and their implementation in the product development process of a firm?

4.1 Survey

This part describes the analysis of the empirical results obtained with the survey approach that has been developed as part of this research. Specifically, this discussion and analysis also responds to a research question we have stated for this study.

In the literature review we have discussed how organisational information requirements link together both the information processing context and the substantial issues being processed there. Here such information requirements have been analysed in terms of the product development performance. Product development process performance has been discussed in ways where both project level and company level issues are addressed. Long-term aspects of product development process performance can be depicted in the analysis of new product performance and product development performance. Meanwhile in the process while the project is in progress it has also become more important to be able to ensure organisational effectiveness and balance in product development activities. Some characteristic measures like balance and focus have been related with effective product development processes (Cusumano and Nobeoka 1996). But still the underlying nature of development activities often remains contingent to firms, its strategies, resources and technologies. This is in a way a synthesis where it is argued that perhaps new ways to model the product development process level performance activities can be developed in order to improve our understanding of effective product development processes. Different aspects of such processes have already been discussed in the literature review. This chapter builds on the earlier discussion and shows the results collected from empirical case studies in the industry. The research framework and approach have been planned to cover some of the challenges related with the analysis of product development process performance.

The analysis is presented in a structured manner that integrates together the research design, research approach, case study environments, data analysis, discussion and implications.

4.1.1 Data sampling and case study research design

The study focused on five firms conducting their business in the industrial electronics industry. The background characteristics of these firms have already been discussed in the description of the empirical research process. Here I want to present the empirical results from the study of different kinds of product development processes in a way where the firm level differences may be used in the discussion of the results. The basic logic for the study is based on case study research (Yin 1994). Considering the nature of product development processes, we could draw a figure that illustrates some principles considered in the selection of the cases. Moreover, it was important for the case study to be able to cover varying types of product development processes. Especially in terms of the issues related to equivocality and development group experience we have therefore focused on the analysis of management teams of a product development process in different firms. There was the possibility to conduct the survey in five companies; these are all different from each other (and they are not competitors). The differences between these firms also justify their role in the research design. The firms have used different types of product development processes and practices. We have not gone into the details of the technologies and products being developed by the firms. Rather we have tried to find different kinds of business environments of firms operating in the same type of industry and to develop the possibilities to carry out a survey with a standardised process in these firms. Thus the intent of the case study has been to test and experiment the analysis and data collection procedure we have developed here in this research. Then the background information from the cases can be used in the interpretation and review of the results obtained. Table 9 below describes some statistics describing the companies. The following tables also give detailed background information on the respondents to our survey in different case study companies.

It is also important to note that the differences between companies enable us to construct a research design as described in the research methodology design.

Table 9. Survey participants: Management team demographic data from the case companies

Case		Experience in task (years)	Years in company	NPD process experience (years)
1	Valid (N)	**8**	**8**	**5**
	Missing	0	0	3
	Mean	**1.6**	**10.9**	**3.3**
	Std. Dev	1.3	5.8	2.0
2	Valid (N)	**13**	**13**	**12**
	Missing	0	0	1
	Mean	**5.9**	**11.9**	**7.9**
	Std. Dev	3.2	3.7	4.7
3	Valid (N)	**5**	**5**	**5**
	Missing	0	0	0
	Mean	**6.3**	**7.5**	**7.5**
	Std. Dev	5.4	5.7	5.7
4	Valid (N)	**4**	**4**	**4**
	Missing	0	0	0
	Mean	**1.8**	**2.0**	**1.8**
	Std. Dev	0.5	0.8	0.5
5	Valid (N)	**6**	6	4
	Missing	0	0	2
	Mean	**2.8**	**3.5**	**3.7**
	Std. Dev	1.9	2.2	2.3

The data above shows that management teams in five companies differ in their size (4-13), company experience and NPD task experience between organisations. There is also variation in the length that these people have been working in the management team. I will show more detailed data on these groups when I discuss the company specific findings. Here in the beginning it can be perhaps sufficient to summarise that these different groups offer us an environment of different cases for the empirical analysis. Moreover, the purpose and opportunity of visiting different companies also offered us a way to create additional variance necessary for the examination of the underlying theories behind the intentions of the study. As could be expected, that companies' management practices for the product development processes varied, and companies also used different kinds of technologies and product strategies. Companies were also different in their experiences and resources for product development and R&D activities. Together these company level differences and characteristics enabled us to combine both group and individual team member level demographics as descriptive variables related to the characterisation of the case companies. Different companies could be then mapped into a two-dimensional grid linking the size of the management group with the experience of the people in the management team, see the illustration below, Figure 22.

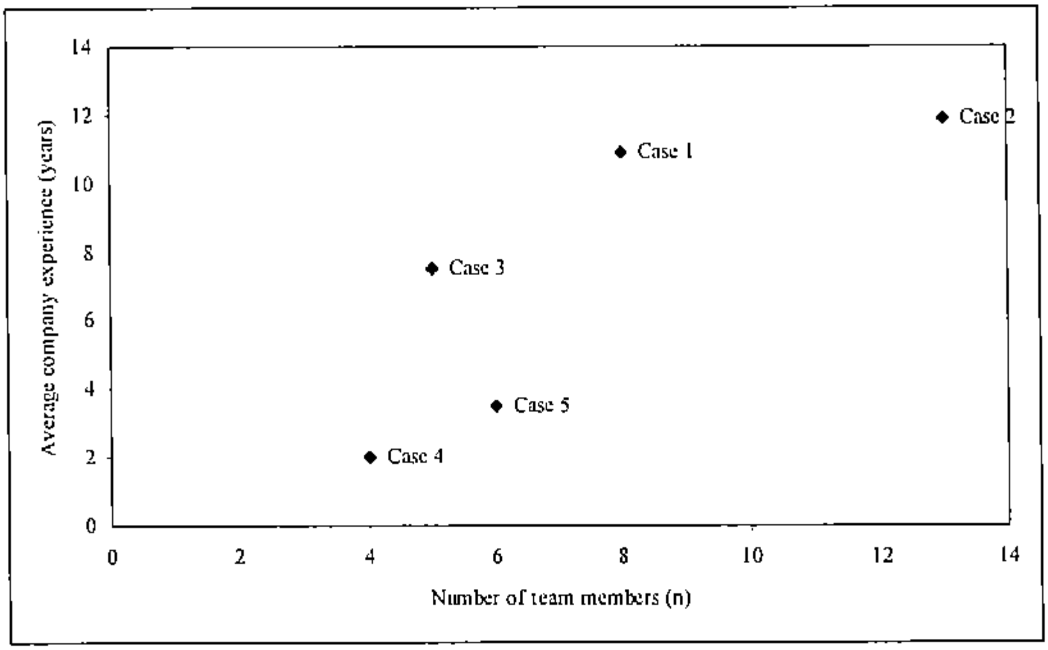


Figure 22. Differences between the case companies[6] at the level of the management teams of their product development processes

The figure above can then be used as a framework in the presentation of our results, and also in order to illustrate the differences between companies. Tables 10-14 show the demographic data on the case companies product development process management teams. These groups participated in the survey.

[6] These numbers are averages from tables 21-25. The size of the management team and their experience of working in the company is compared.

Table 10. Survey participants in case company 1

Position	Education	Experience		
		This task	Company	NPD process
Product Development Manager	M.Sc (Eng.)	3	10	5
Product Development Manager	B. Sc. (Eng.)	2	10	5
Product Development Manager	B.Sc. (Eng)	1	8	*
Product Development Manager	M.Sc. (Eng)	1	7	3
Research Manager	M Sc. (Eng)	4	>25	*
Product Development Manager	B Sc. (Eng)	1	10	*
Product Development Manager	M.Sc. (Eng)	0,5	10	*
Product Development Manager	M.Sc. (Eng)	0,5	7,5	3,5

* These items were not available in the survey data

Table 11. Survey participants in case company 2

Position	Education	Experience (in years)		
		This task	Company	NPD process
Project Manager	M. Sc (Eng.)	8	13	*
Product Manager	M. Sc. (Eng.)	6	6	6
Project Manager	B.Sc. (Eng)	5	14	10
Technical Support Manager	B Sc. (Eng)	0,1	10	1,8
Product Manager	M. Sc. (Eng)	10	16	7
Project Manager	M. Sc. (Eng)	5	10	3
Director, R&D	Dr. Sc (Eng)	5	16	16
Project Manager	M. Sc. (Eng)	2,5	15	2,5
Project Manager	M. Sc (Eng)	>10	4	4
Project Manager	M. Sc. (Eng)	<1	12	8
Product Manager	M. Sc. (Eng)	9	15	15
Project Manager	M. Sc. (Eng)	7	11	11
R&D Manager	Lic. Sc (Eng)	1,5	12,5	10

* These items were not available in the survey data

Table 12. Survey participants in case company 3

Position	Education		Experience	
		This task	Company	NPD process
Product Manager	M.Sc. (Eng.)	8	17	17
Product Manager	M Sc. (Eng.)	2	2	2
Product Manager	M.Sc. (Eng)	4	8	8
R&D Manager	B.Sc. (Eng)	15 *	5	5
Product Manager	Lic.Sc. (Eng)	2,5	5,5	5,5

* This particular respondent may have responded based on career experience, not on task experience in this, which is noted here.

Table 13. Survey participants in case company 4

Position	Education		Experience (in years)	
		This task	Company	NPD process
Designer	Engineer	2	2	2
Designer	Technician	2	3	2
SW designer	B.Sc, M. Sc.	2	2	2
Design Engineer	M.Sc.	1	1	1

Table 14. Survey participants in case company 5

Position	Education		Experience (in years)	
		This task	Company	NPD process
HW Designer	Engineer	5	5	5
Technology manager	Dr Tech.	1	1	1
HW Designer	Engineer	2	6	6
Senior design eng.	Engineer	3	3	3
HW Designer	Technician	5	5	*
SW Designer	Engineer	1	1	*

* These items were not available in the survey data

4.1.2 Case study design elaboration

The five case study companies have been analysed here as a group of companies. These companies have distinct roles in the research design. Case companies 1 and 2 are product divisions of bigger international corporations. Several research interviews were carried out with these companies in 1997-98. Their role in this research design is to present such companies that are bigger and often have longer time experience in more systematic product development processes and practices. This issue can be for instance described in the observations that both cases 1 and 2 have simultaneously relatively larger and bigger investments in new product development and technology development if compared to case companies 3, 4 and 5. Similarly, the product development organisations in these firms are more established and also larger in their scale of product development operations. This big firm perspective offers us a way to look at their management team approach for the running and organisation of development activities. These management groups in cases 1 and 2 have had rather organised meetings for a number of years where the roles of management teams have also been established into better routines and developed than in small companies. Management team members in these bigger companies were mainly project managers and product development managers. This is an example of the natural difference between bigger and smaller companies (3,4 and 5) where in these latter cases the management team representatives were often designers or engineering specialists. Thus the management of product development process in the bigger companies is based on this side on more high-level task positions in organisations than in smaller firms. Also, the size of the product development and R&D resources in these companies was bigger. In comparison, the size of the organisation in the bigger companies was around one hundred people or even more. This difference in the size and resources of product development organisations does have some important characteristics when compared with the smaller firms. For example, the uses of performance measurement mechanisms and project management approaches have been better systematised and established in these firms. One additional observation concerning the role of the bigger companies is also that they may need to use a wider repertoire of product development practices and organising means in order to effectively run their development operations. This is also quite directly linked with the approaches used for the management of the development work. In bigger firms it was observed that the use of technology strategies and new product strategies was more complex and somewhat more advanced than in the smaller firms. From the perspective of the product development processes this implies that the dimensions and aspects of product development process level performance were also more complex than in the smaller firms. Also, in the bigger firms their relationship to the balance between technology development and product development is more delicate. In order to manage a bigger organisation these firms have used teams, quality programmes, and matrix organisation and supply management co-ordination. Cases 1 and 2 also represent examples of multi-product firms where the overall role of R&D and product development is often co-ordinated at the level of corporate technology management and R&D. Moreover, in the case of bigger firms it was observed here that their product development operations are often more distributed and internationalised than in the smaller companies. This makes it necessary to be able to run product development processes and projects in distributed and international environments. The observations have been here collected from these firm's Finnish locations, so the international or distributed nature of their operations is not directly considered as a parameter of the research design of thestudy. Nevertheless, these issues are also important attributes of these firm's development practices.

Case companies 3, 4 and 5 are thus a little different from the bigger firms mentioned here previously. Particularly cases 4 and 5 could be sometimes seen as suppliers and subcontractors to companies like 1 and 2. These cases 4 and 5 have a strong manufacturing emphasis in their operations. In a way, we can argue that the importance of the smaller firms here is an important perspective, as we can also see product development processes from a specialised suppliers perspective. Also, we need to notice here that companies 4 and 5 are not really very small companies. It might be better to describe them as small and medium sized companies. The role of product development in these firms is also strategically different than in the cases of firms 1 and 2. For these smaller firms, the role of product development has been a business based imperative when the supplier's competitiveness in their business may have required more enhanced capabilities for supplier involvement. This also is a factor that implies that the relative history and experience in product development in these companies is shorter when compared to the longer history and traditions in the bigger firms. One very important aspect here is that for these manufacturing oriented companies the relationship between technology development and product development is a different type of challenge than in the bigger firms. Small firms like these are not always so fully self-sufficient in their knowledge and resources for new technologies. Whereas the bigger firms can often carry out deeper and long-term research activities, these small firms focus more on business and application oriented product development. For these smaller firms studied here it has been typical that their product development activities have been started in order for them to be able to improve the value-added to key customers, especially customer relationships developed between such companies. In case of really demanding and changing technological challenges it might thus be possible that these smaller firms may have to rely on their partners and consulting relationships in order to resolve critical problems. In a way it can also be argued that manufacturing based firms like cases 4 and 5 are sometimes dependent on their key customers for the new knowledge on technical development and application knowledge. This kind of customer relationship in their business can also be a source of strengths and opportunities but also a risk of lock-in and dependencies (Christensen 1997, Yli-Renko 1999).

Case company 3 presents a little different perspective to the industrial electronics business and industry. Case 3 is in fact a technology-based company with quite long and established traditions in the development and commercialisation of new technologies. Here in our research setting this particular company brings additional variety and scope to the empirical material. The group of people interviewed there have been basically working on product development management issues related to commercial product development projects. This company has also some research activities focusing on the nature of the technologies being developed for the future use of selected business. In this company it was also observed that the role of technological competitiveness of their products was critical to the success in their business. They were working on some selected areas of product development, directed to the needs of some defined customer segments and market areas. The role of the product development activity in this company was also of high importance. The selected case company was founded a few years ago when the corporation decided to enter new technology-based market areas.

Overall, the companies we have been able to interview and study in this research have been selected for inclusion in this study because they represent different perspectives to the type of companies operating in the industrial electronics business. There is also variation in the history, resources and experience of the firms in product development. As a whole the observations from these companies can be regarded as important characteristics of the research design we have used here for this study.

4.2 Presentation of the data analysis process with single case company data

The main goal in this part is to show how the quantitative data collected with the survey instrument has been analysed in terms of the ideas developed from the information requirements framework of Daft and Lengel (1986). In the study the emphasis is given to company level data and comparison between cases. Let us begin from case company 1. We can describe here in a step-by-step manner how the data can be summarised, ordered and analysed. Then after this company specific description we can extend our analysis with the data available from other case environments. This kind of logic gives us a consistent way to address the main issues related to the research issues. Firstly we want to show here the raw data collected with the survey tool. It illustrates a response profile from company 1, see Table 15 on next page.

Table 15. Response profile for case company 1

Variables	Response profile N	Median*	Quartiles 25%	75%	IQR	Confidence responses N	Median
A broad range of technological capabilities is important for	8	-5	-5.75	-0.75	5	8	7
Product development engineers in our company are best motivated with goals for the improvement of	8	-4.5	-5.75	-2.25	3.5	8	6.5
Achieving "critical mass effect" is important for	8	-3	-4.75	1.5	6.25	8	6
Synergies from technological discontinuities are important for	7	-3	-4	0	4	7	5
Top management of our company is typically prioritizing	8	-2	-4.75	4	8.75	8	6.5
Project specific strategies for supplier involvement in product development are important for	8	-2	-4	1.5	5.5	8	6
Making authorized technology choices on behalf of our customers is important for	8	-1.5	-4.75	0	4.75	8	6
Real benefits from the internationalisation of product development work are important for	8	-1.5	-4.75	0	4.75	8	5.5
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	8	-1	-6.75	3.75	10.5	8	8
Cross-functional product development teams are important for	8	0	-3.75	5.75	9.5	8	7
Pilot projects with selected customers are important for	8	0	-4.25	2.5	6.75	8	7
Separation of technology development projects and product development projects is important for	8	0	-3.75	3.75	7.5	8	6.5
Management of the whole R&D project portfolio is important for	8	0	-2.25	0	2.25	8	8
Wide discussions in our company on the relative position and importance of product development are important for	8	0	-3.75	0	3.75	8	7.5
Use of selected key technologies in product development is important for	8	0	-1.5	1.5	3	8	7
Our concepts for products and technologies are important for	8	0	0	0	0	8	7
Company-wide efforts for "design chain integration" product development activities are important for	8	0.5	-2.25	1.75	4	8	6
The business we are in requires that we can compete with	8	1	0	3.75	3.75	8	7.5
Product development engineers in our company havea strong task orientation for	8	1.5	-5.25	3.75	9	8	7
Prototyping and testing principles in our organisation are based on	8	1.5	-1.5	5	6.5	8	7
Development of product and technology platforms first from low-end towards high-end price segments is important for	8	1.5	-2.25	5.25	7.5	8	6
Situations where we can use new technologies for existing or traditional kind of products are important for	7	2	-3	5	8	7	7
Flexibility of the external subcontractors for product development activities is important for	8	2	-2.25	4	6.25	8	7
This product development organisaton where we are working is often described as oriented towards	8	2	-5	4.75	9.75	8	6.5
Customer specific product development projects are important for	8	2.5	0	4.75	4.75	8	6.5
Building and use of performance measurement systems is important for	8	3	0	5.75	5.75	8	7.5
Some long term customer relationships are important for	8	3.5	-2.75	5	7.75	8	6
Our company evaluates and measures its product development activities specially for the development of	8	3.5	0.75	5.75	5	8	7.5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	8	4	0.75	6	5.25	8	8
Prioritisation of time based results over cost issues is important for	8	4	0.5	5.5	5	8	7
Our company's own sales and distribution network is important for	7	5	-3	6	9	7	7
Integrated timing and scheduling for internationally distributed product development teams is important for	8	5	0	6	6	8	6.5
Synergies from common technical functionalities between products are important for	8	5	4	5	1	8	6.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.

IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

This table (15) above shows the responses in an ordered manner, where the statistical mean describing the balance between technological competitiveness and product development performance has been used as a sorting key. The information shown in the table shows therefore a flow of the issues describing the questionnaire statements ranging from technological competitiveness to product development performance (top down manner). The meaning of such ordering is from our interest in analysing which kinds of product development practices would be perceived to be more associated with technological competitiveness than with product development performance. In a way, this is a sort of sense-making review of the varying development practices as seen in one company. Basically it shows us that there are some kinds of semantic differences between the issues seen to be associated with technological competitiveness and product development performance. Different statements seem to receive different kinds of perceptional rankings from the respondents. Accordingly to our data analysis logic, this previous table then covers steps 1 and 2, as given in the figure on page 93. Next we will describe how the data analysis can be continued with more detailed treatment of the data available from two response scales.

In order to analyse the differences between different survey questions we can perform a type of stratification process that can be used in the ordering of the data from the overall data set. For this purpose we need to also consider the uncertainties related with different questions, as this information was also available from the survey data. Again we can begin from the overall data set, as presented in a previous table, Table 15. There is lot of information, and the overall character of the data has variety in it. This data set comes from an interview with a group of 8 managers participating in the management team of product development process in this firm. Another table shows the education and position of the respondents.

Our analysis of the empirical set of data and the idea of the framework of Daft and Lengel (1986) has led to a development of a data ordering procedure, where the issues of equivocality and uncertainty could be mapped with the empirical data. Calculating first the basic set of statistical variables for each of the questions 1-33 states the analysis. These statistics are available in the table. It was then possible to look for the various analysis possibilities with the data, besides the model of Daft and Lengel (1986). This kind of data represents only the responses from different groups, thus it was not our purpose to really predict or explore any variable relationships in the way often done in hypothesis testing kinds of analysis of survey data. Rather the purpose here was to develop new, theory based approaches to analyse the empirical data from product development processes.

As already argued, the basic raw data provides us with information from a company specific product development process. As we have discussed in the literature review the roles of balance and focus have been problematic in the empirical study of product development processes. Our model of a product development process incorporates these ideas of balance and focus into the overlapping response scale between technological competitiveness and product development performance. Empirically this relationship can be analysed with the statistical information collected from the survey. Thus as a way to specify the research question we have been analyzing here, we can study the relationships between group level perceptions over the roles of varying product development practices in the basic problem of finding a match between technological competitiveness and product development performance. In other words, the survey data offers ways to examine different product development practices as a mechanism to use specific practices in a balanced manner, or to address more focused issues related to technological competitiveness and product development performance. In order to be able to use the framework of Daft and Lengel (1986) in the analysis of the data we have applied a data ordering procedure to develop an appropriate variable grouping characterising the links between our data and the Daft and Lengel (1986) framework.

The analysis was carried out in the following manner. I needed to construct both equivocality and uncertainty dimensions from the Daft and Lengel (1986) model. Two major choices were made in the analysis process. Firstly I found that the response scales in the survey represented different issues. The other response scale was directly associated with uncertainty through the perceived uncertainty of the respondents to different questions. Secondly, the notion of equivocality was interpreted in a way here where the response means to the first response scale for each question were analysed in terms of the inter quartile range (IQR) values. There were some responses where high levels of consistency were identified by observing low levels of related dispersion in the responses. Other variables were then seen to show higher levels of inconsistent responses that also increased the respective levels of inter quartile ranges. A procedure was then constructed where these differences could be analysed in a systematic way. This procedure uses the median statistic as counted from the medians of the variables as a way to divide the original data set into sub sets. Steps of this procedure can be shown in a stepwise manner, see Table 9 presented earlier.

Results from this ordering process can be shown in the four Tables below: see tables 29–32. These tables can be also named according to the ideas of the model framework of Daft and Lengel (1986). These tables are from case company one, where a group of 8 people responded to the survey instrument. This sub sample from case company 1 is used here as an introduction to the analysis of the results. Survey data has been categorised with the ordering procedure, making it possible to replicate the structure of the conceptual framework by Daft and Lengel (1986) in this way. Descriptive analysis of the results from case company 1 is also provided. See Tables 16–19 below including the ordered data.

Table 16. Low equivocality, low uncertainty variables (case 1)

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
A broad range of technological capabilities is important for	8	-5	-5.75	-0.75	5	8	7
Management of the whole R&D project portfolio is important for	8	0	-2.25	0	2.25	8	8
Wide discussions in our company on the relative position and importance of product development are important for	8	0	-3.75	0	3.75	8	7.5
Use of selected key technologies in product development is important for	8	0	-1.5	1.5	3	8	7
Our concepts for products and technologies are important for	8	0	0	0	0	8	7
The business we are in requires that we can compete with	8	1	0	3.75	3.75	8	7.5
activities specially for the development of	8	3.5	0.75	5.75	5	8	7.5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	8	4	0.75	6	5.25	8	8
Prioritisation of time based results over cost issues is important for	8	4	0.5	5.5	5	8	7

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 17. Low equivocality, high uncertainty variables (case 1)

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
Product development engineers in our company are best motivated with goals for the improvement of	8	-4.5	-5.75	-2.25	3.5	8	6.5
Synergies from technological discontinuities are important for	7	-3	-4	0	4	7	5
Making authorized technology choices on behalf of our customers is important for	8	-1.5	-4.75	0	4.75	8	6
Real benefits from the internationalisation of product development work are important for	8	-1.5	-4.75	0	4.75	8	5.5
Company-wide efforts for "design chain integration" product development activities are important for	8	0.5	-2.25	1.75	4	8	6
Customer specific product development projects are important for	8	2.5	0	4.75	4.75	8	6.5
Synergies from common technical functionalities between products are important for	8	5	4	5	1	8	6.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 18. High equivocality, low uncertainty variables (case 1)

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	8	-1	-6.75	3 75	10 5	8	8
Cross-functional product development teams are important for	8	0	-3 75	5.75	9.5	8	7
Pilot projects with selected customers are important for	8	0	-4 25	2.5	6 75	8	7
Product development engineers in our company have a strong task orientation for	8	1.5	-5 25	3.75	9	8	7
Prototyping and testing principles in our organisation are based on	8	1.5	-1 5	5	6 5	8	7
Situations where we can use new technologies for existing or traditional kind of products are important for	7	2	-3	5	8	7	7
Flexibility of the external subcontractors for product development activities is important for	8	2	-2 25	4	6 25	8	7
Building and use of performance measurement systems is important for	8	3	0	5.75	5.75	8	7.5
Our company's own sales and distrubution network is important for	7	5	-3	6	9	7	7

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 19. High equivocality, high uncertainty variables (case 1)

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Achieving "critical mass effect" is important for	8	-3	-4.75	1 5	6 25	8	6
Top management of our company is typically prioritizing	8	-2	-4.75	4	8 75	8	6 5
Project specific strategies for supplier involvement in product development are important for	8	-2	-4	1.5	5.5	8	6
Separation of technology development projects and product development projects is important for	8	0	-3.75	3.75	7.5	8	6 5
Development of product and technology platforms first from low-end towards high-end price segments is important for	8	1 5	-2 25	5.25	7.5	8	6
This product development organisaton where we are working is often described as oriented towards	8	2	-5	4 75	9 75	8	6.5
Some long term customer relationships are important for	8	3.5	-2.75	5	7.75	8	6
Integrated timing and scheduling for internationally distributed product development teams is important for	8	5	0	6	6	8	6 5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Next these tables (16–19) and statistical information are interpreted and analysed with background information from case company 1. The purpose of this part of the discussion is to show how the parts of the analysis framework are described with the results.

Analysis

Together these tables can be argued to represent an analysis of the empirical data according to the organisational information requirements framework by Daft and Lengel (1986). The basic idea behind this kind of sorting here is that different types of problems require different types of integration mechanisms and problem solving methods. This data is derived from a small group survey, and thus it can be also argued that in this setting the data shown above also presents the group level perceptions to the product development practices and how their use should be matched with the requirements to choose a balance between technological competitiveness and product development performance. Interpretation of the data can then be supported with the ideas from Daft and Lengel (1986). An example of the data analysis can be shown, perhaps appropriately beginning from the issues that seem to be quite well perceived and consistent in this particular data set. Namely we can take a data set describing issues categorised here as of low equivocality and low uncertainty for a detailed examination. Nine variables were grouped into this data set, shown in Table 16. We can start from the variables associated with technological competitiveness and then move towards the variables related more with balance and product development performance. It is again important to note here that this kind of analysis is just a descriptive analysis of the information. From the literature we can also cite two excerpts from Daft and Lengel (1986: 557, 563) in order to build some background for the interpretation on the routine practices.

-*"Clear, well-defined situation, managers need few answers, gather routine objective data." Or,*
-*"Analyzable, Low variety (Routine Technology), <u>Structure:</u> a) Media of low richness, b) Small amounts of information. <u>Examples:</u> Rules, standard procedures, standard information system reports, memos, bulletins.*

Routine practices include here 9 different types of product development practices. It seems that the median of the statement responses shows that these practices have received rankings that are relatively much oriented towards balance between technological competitiveness and product development performance. A key issue here is that the inter quartile range values of the statement responses are lower than the median of all the responses. This means accordingly that the consistency of responses in the statements concerning the orientation in the use of the practices is more homogenous than in other groups. Among these variables there is one that is an exception, being clearly more related with technological competitiveness. This variable is entitled "a broad range of technological capabilities is important for technological competitiveness". This specific question has received responses in ways where nearly all respondents have given more emphasis to technological competitiveness than product development performance. This can be seen from the value of the 75% percentile value which is –0.75, implying that over 75% of the responses have been given in ways emphasising technological competitiveness more than balance or product development performance. Other product development practices seem to be more related with product development performance, as can be seen from the median values of the different practices.

The approach and interpretation adopted here suggests therefore that these specific practices belonging to the routine practices may be more clear and perhaps better known among the group of respondents than other product development practices. This is an interpretation made on the basis of the data analysis. For example, it would seem that a product development practice like "prioritisation of time based results over cost issues" is more related with orientation on product development performance than technological competitiveness. Moreover, this practice can be relatively well known or similarly perceived by the respondents. This interpretation of such product development practices implies also that information requirements for routine-like practices may be more analysable and clear than in the case of ambiguous practices.

This interpretation is based on the statistical, subjective information based on the analysis of the survey data. This interpretation could be compared with more objective data, describing the performance of the development activities in this organisation. This kind of comparison is not, however, included in the present study. The value of the analysis of the product development practices comes more from the comparisons between practices and the different emphasis groups have given to these product development practices.

Another important aspect of the interpretation of the results is that the orientation towards technological competitiveness and product development performance enables us to make some conclusions on the different roles of the product development practices. For example, a specific practice named as "use of selected key technologies is important for" has been related with the needs to achieve a balance between technological competitiveness and product development performance. It makes sense since it is also comparable with the earlier literature where key technologies have been used as means to focus product development appropriately (Meyer and Roberts 1986). This example shows how the means-ends type analysis aspect has also been enabled in this kind of interpretation and analysis approach.

This first part of the data sets is only a partial way to look at the organisational information requirements with the framework of Daft and Lengel (1986). Three other groups of variables can also be used. The other data sets are equally important to be able to develop a more holistic overview of the information requirements of the product development practices. This kind of analysis gives us also some type of means ends like logic to analyse how different product development practices can be managed towards the goals of the product development processes. This kind of analysis can be used as a way to characterise the organisational information processing requirements of product development process performance. Different aspects of technological and competitive settings can be found included in this kind of analysis framework. We cannot argue that this sort of analysis would be the best or the only one possible. Instead there are many alternative ways to analyse data from product development processes.

This kind of analysis is also a rather complex challenge of giving an emphasis to balanced description of both company specific and cross case level based analysis of the data. Next we will describe a deeper cross-case analysis of the results from this study. This example from case company 1 is just a starting point, but it serves well as an introduction to the analysis possibilities of this kind of approach.

5. FINDINGS, PART 2: CROSS-CASE ANALYSIS

This chapter includes a cross-case analysis of the empirical survey results. The text has been organised in the following manner. Firstly an overview of the data analysis method will be given. Secondly, each category of the research framework will be presented with the related empirical material, analysis and interpretation. It is also possible to include a complementary perspective on this analysis phase. All variables used in the survey have been derived from qualitative interviews that have been conducted in the earlier phase of the research. This enables a comparison between the initial interview data behind each variable to be included in the interpretation of the responses and categorisation. In some cases it may be that the linkages between the interview data and survey data are circumstantial, but when possible, it can be used in giving some perspective to the comparison between companies.

Each category of Daft and Lengel's (1986) routine, engineering, craft and non-routine practices will be discussed in this cross-case analysis. Finally the chapter will be concluded with a summary and conclusions from this analysis.

5.1. Data ordering and analysis of the empirical results

In the previous chapter we have presented data from the company level results. Here we will take a cross-case perspective on the similarities and differences between the case companies with a similar type of approach. Data available from all companies has been integrated into four tables that summarises the different elements of the model of Daft and Lengel (1986). This kind of cross-case comparison performed with the ordering process makes it possible to examine the role of different product development practices in different companies. Basic data from different companies is also given in Appendices 6–9, in a similar way that has been already described with case company 1.

It has been necessary to make some choices regarding the depth of analysis. In this cross-case analysis it has been decided to analyse such variables that have been categorised similarly in four out of the five companies. This limits the number of variables included in this cross-case analysis.

Data sets from five companies have been used. The purpose has been to perform a comparative review of the results with the quantitative data available from different cases. In this way we can achieve a cross-case perspective with the data that can be presented in a manner based on the original thinking of Daft and Lengel (1986). We will show this data here in detailed way and illustrate the observations made from it. After the review of the data we will then summarise the main points of the discussion, with a discussion on the observations and the earlier presented research questions and literature review.

The sample sizes are not very big. The nature of this analysis is descriptive. All case company specific data ordering steps have been performed before this cross-case comparison. In this way, already partitioned data tables from different companies have been integrated together according to the underlying research framework.

The following procedure has been performed to prepare the empirical data for cross case analysis. All five case companies have been used here. Stratification of the company level data has been performed in a similar way for all companies as has been described in the earlier chapter for case company 1. Both original and categorised data sets for all companies have been included in the Appendices (6–14). Using this data as a basic base level data we have integrated case company data into four different tables as a result of the initial categorisation performed according to the Daft and Lengel (1986) model. This integration has given us four tables that each represents a specific part of the organisational information requirements model by Daft and Lengel (1986).

Original company level data has been firstly integrated into distinct tables reflecting the elements of low equivocality and low uncertainty (routine practices), low equivocality and high uncertainty (engineering practices), high equivocality and low uncertainty (craft practices), and high equivocality and high uncertainty (non-routine practices). As a result of this ordering, we have a collection of variables from different companies. In order to clarify these data sets a simple alphabetical ordering has been performed, which has resulted in a list of variables belonging to each data set. The role of alphabetical ordering has been important because it is a way to analyse the relative occurrence of similar types of variables in each of the four data tables. The similarities or differences have been picked up for a closer analysis of the case companies.

5.1.1 Low equivocality and low uncertainty-characteristics of "routine practices"

First we can recollect from the earlier part what kind of descriptive illustrations Daft and Lengel (1986) have related with this first element of the model. Issues like routine technology, common situations, and routine data collection procedures were related to this kind of part of the organisational information requirements framework where both uncertainty and equivocality were described as being low. Some citations from Daft and Lengel (1986:557, 563) represent this. Then we can show the empirical data related with this part of the model.

Interpretation guidelines for routine practices, adopted from Daft and Lengel (1986):

-"Clear, well-defined situation, managers need few answers, gather routine objective data." Or,
-"Analyzable, Low variety (Routine Technology), Structure: a) Media of low richness, b) Small amounts of information. Examples: Rules, standard procedures, standard information system reports, memos, bulletins.

The nature of the descriptions from Daft and Lengel (1986) suggest that issues characterised with low uncertainty and low equivocality may be related with quite well known themes in an organisation. They can be familiar practices and operations policies used in a firm's product development activities. Performance measurement routines can even be applied in these areas. The analysis performed here gives an insight into which kind of development practices can be seen as belonging to these kinds of routine practice oriented themes. See Table 23 on next page showing the data. This table shows the routine practices.

Table 20. Routine practices (low equivocality and low uncertainty, cross-case data tables)

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Case	Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
1	A broad range of technological capabilities is important for	8	-5	-5.75	-0.75	5	8	7
2	A broad range of technological capabilities is important for	13	-4	-4	-3	1	11	8
3	A broad range of technological capabilities is important for	5	-3	-3.5	-3	0.5	5	8
5	A broad range of technological capabilities is important for	6	-1.5	-4.5	0.5	5	6	6.5
3	Building and use of performance measurement systems is important for	5	3	1.5	4	2.5	5	8
4	Building and use of performance measurement systems is important for	4	0	0	2.25	2.25	4	4.5
5	Building and use of performance measurement systems is important for	6	4.5	2.25	5.5	3.25	6	6
5	Company-wide efforts for "design chain integration" product development	6	0.5	-1.25	3	4.25	6	5.5
2	Continuous increase in know-how for advanced technologies and computerized tools for product development methodologies is	13	0	0	3.5	3.5	11	7
2	Customer specific product development projects are important for	12	-2.5	-3	0	3	11	7
3	Development of product and technology platforms first from low-end towards high-end price segments is important for	5	0	0	1	1	5	8
4	Development of product and technology platforms first from low-end towards high-end price segments is important for	4	1	-1.5	2.75	4.25	4	5.5
2	Flexibility of the external subcontractors for product development activities is important for	13	3	1	4.5	3.5	11	8
4	Flexibility of the external subcontractors for product development activities is important for	4	1	0	3.5	3.5	4	6.5
5	Integrated timing and scheduling for internationally distributed product development teams is important for	6	3.5	1.25	4.25	3	6	7
2	Making authorized technology choices on behalf of our customers is important for	13	-3	-4.5	-2	2.5	11	7
1	Management of the whole R&D project portfolio is important for	8	0	-2.25	0	2.25	8	8
2	Management of the whole R&D project portfolio is important for	13	0	-3	0	3	11	7
4	Management of the whole R&D project portfolio is important for	4	0	0	0	0	4	4.5
1	Our company evaluates and measures its product development activities specially for the development of	8	3.5	0.75	5.75	5	8	7.5
4	Our company's own sales and distribution network is important for	4	0	-1.5	1.5	3	4	4.5
1	Our concepts for products and technologies are important for	8	0	0	0	0	8	7
2	Our concepts for products and technologies are important for	13	-3	-4	0	4	11	7
4	Our concepts for products and technologies are important for	4	0	-3	1.5	4.5	4	6
1	Prioritisation of time based results over cost issues is important for	8	4	0.5	5.5	5	8	7
4	Prioritisation of time based results over cost issues is important for	4	1.5	0	3	3	4	5
3	Product development engineers in our company have a strong task orientation for	5	-3	-5.5	-3	2.5	5	8
3	Prototyping and testing principles in our organisation are based on	5	-4	-5	-3	2	5	8
4	Prototyping and testing principles in our organisation are based on	4	-1	-2.75	1.5	4.25	4	5.5
3	Situations where we can use new technologies for existing or traditional	5	-4	-5	-2.5	2.5	4	8
5	Situations where we can use new technologies for existing or traditional	6	-3.5	-5	-2	3	6	6.5

Table 20. Continued…

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Case	Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
3	Some long term customer relationships are important for	5	0	0	2.5	2.5	5	8
4	Some long term customer relationships are important for	4	0	0	2.25	2.25	4	6
3	Synergies from common technical functionalities between products are important for	5	3	2.5	4	1.5	5	8
5	Synergies from technological discontinuities are important for	6	0	-1.25	0.5	1.75	6	6
1	Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	8	4	0.75	6	5.25	8	8
5	Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	6	1.5	0	3.75	3.75	6	6.5
1	The business we are in requires that we can compete with	8	1	0	3.75	3.75	8	7.5
2	The business we are in requires that we can compete with	13	-1	-3.5	0	3.5	11	7
4	The business we are in requires that we can compete with	4	0	-2.25	0	2.25	4	6.5
2	This product development organisaton where we are working is often described as oriented towards	12	-2.5	-3.75	0	3.75	11	7
5	This product development organisaton where we are working is often described as oriented towards	6	1	-0.75	3.5	4.25	6	5.5
1	Use of selected key technologies in product development is important for	8	0	-1.5	1.5	3	8	7
2	Wide discussions in our company on the relative position and importance of product development are important for	13	0	-3	0.5	3.5	11	7
3	Wide discussions in our company on the relative position and importance of product development are important for	5	-2	-3.5	-1	2.5	5	8
1	Wide discussions in our company on the relative position and importance of product development are important for	8	0	-3.75	0	3.75	8	7.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Results and analysis

The results characterising routine practices in terms of the organisational information requirements framework are shown in Table 23. Only one product development practice seems to have been categorised similarly in this table. This practice has been defined as: "a broad range of technological capabilities is important for..". This question originates from interview data with an industrial expert on product development, Dr. Yrjö Neuvo from Nokia (February 1999). The background data of this question is shown below in the form of interview response from Dr. Neuvo:

24. "We don't mix together research and product development activities. We have been thinking about this question a lot. This means that the necessary sharing and transfer of information from research to product

development has to be fluid and seamless. And if you approach close enough, near to product development, you can adopt new technologies without too big risks. You should be able to cross that line almost in an unnoticed way, it is important. We plan our product development for a time frame that is less than two years, 0-1½ years is better. Research activities go in very different stages, depending on what goals we are talking about. We have our own research programmes, corporate research, EU research programmes, universities all over the world. We are involved within a wide variety of different research programmes. Our research activities have a very long time frame, the horizon that we are planning for. But ten years in this field is a really long time. Five years is also a very long time. Even if we have these in-depth networks for the refining and development of new information and knowledge, we don't do so much there between 5-10 years in the future. Technological development in our fields is so very fast. (An interview with Dr. Yrjö Neuvo, Nokia Mobile Phones, February/1999, Helsinki)"

→A broad range of technological capabilities is important for ...

This question describes how a variety of both long-and short-term research activities may be needed in order to create technical capabilities for product development. The idea of technological capabilities has then been used as a description of the development practices in the shown question. This question is therefore not based on the interviews with any representatives of the case companies.

Case companies 1, 2, 3 and 5 were similar in that this variable has been categorised as being among the routine practices. It seems that all responses from all these cases have in common that this product development practice has been related with orientation on technological competitiveness. This would support an interpretation where these respondents and their firms may see " a broad range of technological capabilities" as an issue that reflects their firm's technological strengths and competitive capabilities. This kind of observation is also supported by earlier empirical literature on product development (Cooper 1985a, Clark and Fujimoto 1991).

It may be an important issue for the firms that they have a range of technological capabilities. This kind of variable has also been seen as critical success factors for firms' R&D activities (Roussel, Saad and Eriksson 1991).

According to the research framework, a broad range of technological capabilities would be seen as a routine practice. This is the interpretation that can be made with the results from the empirical data. It is not self-evident that this particular variable would have been picked up beforehand from among all the variables. Also, there were no prior hypotheses on this.

Interestingly, this variable has received most emphasis on technological competitiveness in case companies having the longest experience in product development and use of product development processes. Also, cases 1 and 2 represent product divisions from international corporations reflecting the biggest organisations included in this analysis.

An important question is what kind of issues might support the interpretation that these firms may view "a broad range of technological capabilities" as a routine practice in their product development. The related organisational information requirements might be something that are understood and known in the organisation. This is, however, a hypothesis for further inquiries. At this point it can be said that this particular product development practice seems to be related with the perceived antecedents of technological competitiveness in these firms. In this way, it is possible to propose an interpretation here where a practice like "a broad range of technological capabilities" can be seen as a means to address the ends and requirements of technological competitiveness. On the basis of earlier literature, this kind of finding can be seen to support the earlier knowledge on product development practices where technological capabilities have been discussed.

5.1.2 Low equivocality and high uncertainty- characteristics of "engineering practices"

This second element of the organisational information requirements as described by Daft and Lengel (1986) represents another category of analysable but high variety issues concerning the nature of the related issues. A similar data table has been integrated for the analysis of this second set of data, see Table 34. Issues characterised by the original model framework by Daft and Lengel (1986) have been summarised below:

Interpretation guidelines for engineering practices from Daft and Lengel (1986: 563, 557):

"-Many, well-defined problems, managers ask many questions, seek explicit answers, gather new, quantitative data.
-Analysable, High variety (Engineering technology). Structure: a) Media of low richness, b) Large amounts of information to handle frequent exceptions. Examples: Quantitative data bases, plans, schedules, statistical reports, a few meetings"

The previous points suggest that such themes as described by high uncertainty and low equivocality might represent identified questions and themes in an organisation. Things can be planned and analysed with such perspectives. Analytic procedures with data on defined problems can be implemented. In a way, it could be said that these kinds of problems have been identified as important issues for an organisation but there might be also some uncertainty concerning how to carry out activities. It is basically a matter of being able to collect information reflecting the aspects of defined problem situations.

This kind of variable has also been categorised according to a model and analysis approach that has been developed here. The nature of the product development practices analysed in this part may be relatively more uncertain to the organisations than the ones in the first part of the analysis. Next a cross-case analysis will be discussed highlighting the variables found to be common to three or more case organisations, see Table 21.

Table 21. Engineering practices (Low equivocality and high uncertainty, cross-case data) tables

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Case	Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
1	Company-wide efforts for "design chain integration" in product development activities are important for	8	0.5	-2.25	1.75	4	8	6
3	Company-wide efforts for "design chain integration" in product development activities are important for	5	2	0	2.5	2.5	5	7
4	Company-wide efforts for "design chain integration" in product development activities are important for	4	0	0	2.25	2.25	4	3.5
2	Cross-functional product development teams are important for	13	3	0	3	3	11	6
4	Cross-functional product development teams are important for	4	0	-3	0	3	4	4
1	Customer specific product development projects are important for	8	2.5	0	4.75	4.75	8	6.5
2	Development of product and technology platforms first from low-end towards high-end price segments is important for	11	0	-2	0	2	11	5
1	Making authorized technology choices on behalf of our customers is important for	8	-1.5	-4.75	0	4.75	8	6
4	Making authorized technology choices on behalf of our customers is important for	4	0	-0.75	0	0.75	4	3
5	Our company evaluates and measures its product development activities specially for the development of	6	0	-1.25	3	4.25	6	5
5	Our company's own sales and distrubution network is important for	6	3.5	1.5	4	2.5	6	5
5	Our concepts for products and technologies are important for	6	0	-0.75	3.75	4.5	6	5
3	Prioritisation of time based results over cost issues is important for	5	2	1	3.5	2.5	5	7
1	Product development engineers in our company are best motivated with goals for the improvement of	8	-4.5	-5.75	-2.25	3.5	8	6.5
2	Project specific strategies for supplier involvement in product development are important for	11	0	0	2	2	11	4
4	Project specific strategies for supplier involvement in product development are important for	4	0	-1.5	0	1.5	4	1.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.

IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 21. Continued...

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Case	Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
1	Real benefits from the internationalisation of product development work are important for	8	-1.5	-4.75	0	4.75	8	5.5
2	Real benefits from the internationalisation of product development work are important for	11	-3	-3	0	3	10	5.5
3	Real benefits from the internationalisation of product development work are important for	5	0	0	2.5	2.5	5	6
5	Real benefits from the internationalisation of product development work are important for	6	0	-1.5	1.25	2.75	6	3.5
5	Separation of technology development projects and product development projects is important for	6	0	0	0.25	0.25	6	5
1	Synergies from common technical functionalities between products are important for	8	5	4	5	1	8	6.5
1	Synergies from technological discontinuities are important for	7	-3	-4	0	4	7	5
4	Synergies from technological discontinuities are important for	4	-1	-4.25	0	4.25	4	4
2	Top management of our company is typically prioritizing	13	-3	-3.5	-1	2.5	11	6
5	Top management of our company is typically prioritizing	6	4	0	4.25	4.25	6	5
4	Wide discussions in our company on the relative position and importance of product development are important for	4	0	0	1.5	1.5	4	1.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Results and analysis

This second data set describes here product development practices that can be a little more uncertain than the first data set. Variable 27 describes issues related with internationalisation of product development work. Four case companies (1, 2, 3 and 5) out of five were categorised similarly with this specific variable. Both big and small sized companies were represented in this group. This specific question has been developed from the interview of the managing director of case company 1. See the citation excerpt below:

27. "So product development is no longer a challenge for one company? No, we are internationalising our product development with a quite fast pace. There is a tremendous change there, I think that we have not really yet understood that what this change is about. But it is now moving on, quite rapidly into the direction like we have planned. And the impact of the process is increasing, too. (An interview with the CEO from Case 1, October/1998, Finland) "

→Real benefits from the internationalisation of product development work are important for ...

The question here for the interpretation from engineering practice perspective is related with the internationalisation of product development work. Firstly, it is posssible to state that all five case companies were international in their business, so the presence of foreign markets and international operations was familiar to them. These bigger companies have also been practising product development and R&D operations in an internationalised context. R&D work and product development projects have been conducted in co-operation between companies divisions in different countries.

There are two types of issues that can be concluded from the data, regarding the orientation and emphasis related with technological competitiveness and product development performance. Two case companies (1 and 2) have given more emphasis here to the role of internationalisation of product development work as a way to emphasise technological competitiveness. Two other companies are also different in this respect. From the background of these four companies we can find some information that could be discussed here. Companies 1 and 2 are the two biggest companies here among our cases. Both of them have also a clear role and position in global and international markets. This is also related with the fact that these companies also have activities in different countries and markets. To some extent their product development and R&D work has also been done on an international basis. But this does not necessarily explain why both firms have emphasised internationalisation of product development work as a way to perhaps benefit more from technological competitiveness impacts than product development performance. Perhaps one explanation could be that internationalisation of product development work is not as easily perceived to be beneficial to more efficient product development than it could be for increased technological strength. This kind of conclusion would be somehow supported by the literature where DeMeyer (1989) has argued that internationalisation of R&D work may improve a firm's technical learning and respective capabilities. On the other hand, it could also be very relevant to see whether internationalisation of product development work could similarly be an obstacle or an enabling factor for product development performance. In summary, an interpretation can be proposed here where these larger case companies 1 and 2 might see internationalisation of product development activities as a means to address the goals of technological competitiveness.

The smaller firms (case companies 3 and 5) also have different characteristics in this issue. Company 3 which is more experienced in product development, sees internationalisation as a little more related with product development performance than company 5, which has given a little more emphasis to balance and technological competitiveness. Experience from internationalisation in these two medium sized case companies in this question seemed to have put more emphasis on balance or on product development performance.

It is interesting to analyse why internationalisation of product development activities can mean different things for different companies. These two examples show that for some companies internationalisation could be seen as a way to manage a balance between technological competitiveness and product development performance. Considering then that this kind of balance can be an important type of goal for product development activities, it brings up a question: in what ways can internationalisation of product development activities be a means to achieve more balance between technological competitiveness or product development performance? It may be a matter of focus and use of resources of a firm. Larger firms can choose different ways to enter foreign markets. Small and medium sized firms have more limited resources, with respect to both their marketing and product development activities.

Another variable, "real benefits from the internationalisation of product development work are important for" is more related to technological competitiveness, but also received different responses in different firms. These differences can also be discussed. Case 3 might be more focused on channel sales and the company relies on resellers and distributor networks in the sales. Case 5 is more focused on key customers and their needs in longer-term supplier relationships. Even these differences between the companies do not make it really possible to make very clear interpretations.

One additional perspective is to compare these results with the findings on the internationalisation strategies of small and medium sized enterprises (SME's). Ahokangas (1997) has argued that the internationalisation of SME's can be seen largely as a firm specific process, where both firm and inter-firm issues may lead to different paths in internationalisation. Interestingly, Ahokangas (1997) has also identified different types of internationalisation strategies of SME's in Scandinavia. Among others, two examples discussed by Ahokangas can be related with our case studies. Firstly, it can be argued that case 3 can represent an example where the company's internationalisation strategy could be described as product development and marketing based internationalisation, which is one of the internationalisation strategies discussed by Ahokangas (1997). Secondly, case 5 can be argued to represent more a situation where the internationalisation strategy of the company might be based on domestic networking and customer-selection based internationalisation. These examples can give us some additional ideas in interpreting the internationalisation of product development activities. Different types of business and internationalisation strategies can impact also on the firm's product development. In summary, it can be suggested that the internationalisation of product development activities also represents some "engineering challenges" for the companies. On the basis of these results internationalisation is no routine practice in product development, it requires planning.

5.1.3 High equivocality and low uncertainty-characteristics of "craft practices"

We can again start this analysis by showing some citations from Daft and Lengel (1986) who have illustrated some ideas about the characteristics of the information requirements in terms of high equivocality and low uncertainty.

Interpretation guidelines from Daft and Lengel (1986):

-High equivocality, low uncertainty: Occasional ambiguous, unclear events, managers define questions, develop common grammar, gather opinions. (Daft and Lengel 1986:557)
-Unanalyzable, Low variety (Craft technology), Structure: a) Rich media to resolve unanalysable issues, b) Small amounts of information; Examples: Occasional face-to-face and scheduled meetings, planning, telephone (Daft and Lengel 1986:563)

This third data set provides us with a selected element from the model of the Daft and Lengel (1986) where high level of equivocality is related with low level of uncertainty. This change from low equivocality to higher levels of equivocality means that the described aspects of information requirements are more ambiguous and even unclear if compared with the issues of lower equivocality. The nature of the organisational information requirements in this part of the model could be characterised with examples like: "these things may happen, but we are not really sure about this, it is necessary to delve deeper in this problem etc". Interpretation of the related practices will be analysed here as craft practices.

The results of our categorisation show that there are four variables that are comparatively similar here in four firms. These four variables have again been selected as descriptive variables enabling us to perform a cross case comparison with the data available to us. See Table 22 on the next page showing the data.

Table 22. Craft practices (High equivocality and low uncertainty, cross-case data tables)

		Statoment rosponses					Confidonco responses	
		N	Median*	Percontiles		IQR	N	Median
Cases	Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
4	A broad range of technological capabilities is important for	4	-1	-2.75	2.25	5	4	5
3	Achieving "critical mass effect" is important for	5	0	-1.5	4	5.5	4	8
1	Building and use of performance measurement systems is important for	8	3	0	5.75	5.75	8	7 5
2	Building and use of performance measurement systems is important for	13	3	-0.5	4.5	5	11	8
2	Company-wide efforts for "design chain integration" product development activities are important for	12	0	-1.5	3	4.5	11	7
1	Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	8	-1	-6.75	3.75	10.5	8	8
3	Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	5	-2	-2	2.5	4.5	5	8
4	Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	4	-3	-5.5	1.75	7.25	4	6
5	Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	6	-1	-4.5	4.75	9.25	6	7
1	Cross-functional product development teams are important for	8	0	-3.75	5.75	9.5	8	7
3	Cross-functional product development teams are important for	5	2	-1.5	4	5.5	5	8
3	Customer specific product development projects are important for	5	-3	-5	2.5	7.5	5	8
5	Customer specific product development projects are important for	6	3 5	-2 25	4.5	6.75	6	7
1	Flexibility of the external subcontractors for product development activities is important for	8	2	-2.25	4	6.25	8	7
3	Flexibility of the external subcontractors for product development activities is important for	5	2	-3.5	4.5	8	5	8
5	Flexibility of the external subcontractors for product development activities is important for	6	1.5	-6	4	10	6	7.5
2	Integrated timing and scheduling for internationally distributed product development teams is important for	12	3.5	0.5	5.75	5 25	11	7
3	Integrated timing and scheduling for internationally distributed product development teams is important for	5	5	0	5	5	5	8
3	Making authorized technology choices on behalf of our customers is important for	5	-2	-4.5	1	5.5	5	8

→Elaboration of the table: * Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 22. Continued ..

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Cases	Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
3	Management of the whole R&D project portfolio is important for	5	0	-2	1	3	5	8
5	Management of the whole R&D project portfolio is important for	6	3.5	-0.25	6	6 25	6	6.5
2	Our company evaluates and measures its product development activities specially for the development of	13	2	-1.5	4.5	6	11	7
3	Our company evaluates and measures its product development activities specially for the development of	5	1	-1	5.5	6.5	5	8
1	Our company's own sales and distribution network is important for	7	5	-3	6	9	7	7
3	Our company's own sales and distribution network is important for	5	-2	-4.5	0	4.5	5	8
3	Our concepts for products and technologies are important for	5	-3	-4.5	-1.5	3	5	8
1	Pilot projects with selected customers are important for	8	0	-4.25	2.5	6.75	8	7
2	Pilot projects with selected customers are important for	13	0	-5	4	9	11	8
3	Pilot projects with selected customers are important for	5	-5	-6	2	8	5	8
5	Pilot projects with selected customers are important for	6	-1.5	-5.25	1.25	6.5	6	7
2	Prioritisation of time based results over cost issues is important for	13	1	-5	3	8	11	7
1	Product development engineers in our company have a strong task orientation for	8	1.5	-5.25	3.75	9	8	7
2	Product development engineers in our company have a strong task orientation for	13	0	-3.5	2	5.5	11	7
4	Product development engineers in our company have a strong task orientation for	4	-2.5	-3	2.5	5.5	4	6
5	Product development engineers in our company have a strong task orientation for	6	-3	-5.25	2.5	7.75	6	7
2	Product development engineers in our company are best motivated with goals for the improvement of	13	-3	-4.5	2.5	7	11	8
3	Product development engineers in our company are best motivated with goals for the improvement of	5	-4	-5	-2	3	5	8
4	Product development engineers in our company are best motivated with goals for the improvement of	4	-2	-5.75	-0.5	5.25	4	5
5	Product development engineers in our company are best motivated with goals for the improvement of	6	0	-6.25	3	9.25	6	7.5
1	Prototyping and testing principles in our organisation are based on	8	1.5	-1.5	5	6.5	8	7
2	Prototyping and testing principles in our organisation are based on	13	0	-3	3	6	11	7
2	Separation of technology development projects and product development projects is important for	12	0	-3	3	6	11	7
3	Separation of technology development projects and product development projects is important for	5	1	-1	3.5	4.5	5	8

→Elaboration of the table: * Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 22. Continued ..

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Cases	Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
1	Situations where we can use new technologies for existing or traditional kind of products are important for	7	2	-3	5	8	7	7
2	Situations where we can use new technologies for existing or traditional kind of products are important for	13	-2	-4.5	0	4.5	11	7
4	Situations where we can use new technologies for existing or traditional kind of products are important for	4	0.5	-2	3.75	5.75	4	6.5
2	Some long term customer relationships are important for	12	0	-3 5	3.5	7	11	7
2	Synergies from common technical functionalities between products are important for	13	3	-1	5	8	11	7
4	Synergies from common technical functionalities between products are important for	4	3.5	-1.5	4 75	6.25	4	6
3	Synergies from technological discontinuities are important for	5	-2	-3	1	4	5	8
2	Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	12	1	-3	5	8	11	8
3	Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	5	0	0	3	3	5	8
4	Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	4	1	-1.5	4.25	5 75	4	8.5
3	The business we are in requires that we can compete with	5	-3	-5	-1	4	5	8
5	The business we are in requires that we can compete with	6	-2	-4	3.75	7.75	6	6.5
3	This product development organisaton where we are working is often described as oriented towards	5	-4	-5	-1.5	3.5	5	8
3	Top management of our company is typically prioritizing	5	-2	-3	0	3	5	8
4	Top management of our company is typically prioritizing	4	1	-3	4.25	7.25	4	5 5
2	Use of selected key technologies in product development is important for	13	-4	-5	0	5	11	8
3	Use of selected key technologies in product development is important for	5	-5	-6	2	8	5	8
4	Use of selected key technologies in product development is important for	4	-2.5	-5	1.5	6.5	4	8
5	Use of selected key technologies in product development is important for	6	4	-1.5	5.25	6.75	6	8.5
5	Wide discussions in our company on the relative position and importance of product development are important for	6	3.5	-0.75	5.5	6.25	6	7.5

→Elaboration of the table: * Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Analysis and results

Four variables have been categorised similarly here. These will be discussed separately. The first variable concerns the use of new technologies and computerised approaches in product development methods used by companies. The idea for the question came up from the analysis of the results from an interview with Mr. Pekka Malinen from MET/FIMET on the synergies between technological competitiveness and product development performance. See below an excerpt from the interview and how the question was then formulated:

10. "Generally you might probably say that if you have a good technological competitiveness, then you have also very good possibilities to improve product development performance. Because performance is improved, besides with the process competence, with these new technological tools like virtual prototyping. Both process competencies and advanced tools require high level of know-how. If you don't have high-level know-how, then you are probably having troubles in both areas, on process improvement and development tools. Improvement of product development performance is just pretty much about these high level know-how questions. New opportunities cannot be adopted nor used if the company does not have the know-how required, or if the company is not trying to increase its know-how. So there is a correlation. Sometimes you might be in such a lucky position that inefficient product development leads to a high technology product. Competitive situation can be easy; you don't have to be in a hurry. Then product development may work inefficiently but still the outcome is good. But this may be quite rare these days. (An interview with Mr. Pekka Malinen, FIMET, Helsinki, May /1998)."

→Continuous increase in know-how for advanced technologies and computerised tools for product development methodologies is important for ...

Mr. Malinen commented nicely on the necessity to be capable both in process competence and development tools. The survey performed in the case companies did not contain questions comparing the relative level of uses of new advanced tools in product development. But it can be said that some of the case companies' product development processes represent environments where they have good experience on the use of new information technology applications. Additional information on these questions is however quite proprietary to the companies, because of its criticality. Both small and large firms in our sample did use new information technology solutions. Perhaps the difference also in product development methodologies between these types of companies is that bigger firms have more need to integrate and institutionalise new systems and development practices in perhaps a more systematic manner. The range of applications can grow alongside as the organisations grow and become more internationally networked. In small and medium sized companies product development methodologies can be more often described via basic needs for communications solutions like the Internet and e-mail and engineering design tools. In summary, the issue that emerges from this question might be the emphasis that advanced product development methods are relatively challenging issues for product development organisations.

In terms of the empirical results, case companies 1,3,4 and 5 are similar in the ways in which this specific variable has been categorised. The four cases show that specific product development practice ("continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for") has been related with technological competitiveness. This is an interesting point. The related interpretation on the basis of the research framework is that continuous increase in advanced tools and methods might be seen as as a means to address technological competitiveness. Advanced tools and methods have not been related with the product development performance, or improved efficiency and effectiveness in development activities.

There are bigger (Case 1) and smaller companies (3, 4 and 5) included in this part of the analysis. This specific practice is no longer a routine. The idea of high equivocality and low uncertainty highlights the ambiguity and problems. It can become more problematic also to estimate whether the shown emphasis on technological competitiveness or product development performance can be reliably made. The interpretation is descriptive, and it is important also to acknowledge this. What can be said is that the understanding of this product development practice may be more complicated or difficult as in the case of more routine practices. The idea of continuous increase in emphasis on new methods and tools perhaps also describes perhaps also the imperative to learn continuously, and to be adaptive to new tools like simulation and experimentation in development (Thomke 1997, 1998).

It is also interesting to probe what kind of hypothesis or analysis ideas could be drawn from this for future studies. These will be addressed in the summary and conclusions of this chapter.

The next question is related with pilot projects and customers, and their roles in the product development process. The idea for this question came up in an interview in case company 2.

11. "We have continuously many field tests underway. Co-operation with our customers and demanding lead users is critical for that. In those cases we may deliver very new technology for customers, but they know that there may be some problems to that. It can be a good learning experience for both parties. What you asked about, yes we actually know very precisely who are the core lead users of our products. We almost know them better by their locations than the companies or corporations they are part of. (An interview with the managing director from case 2, April/1999, Finland)"

→Pilot projects with selected customers are important for ...

Experiences from the interviews resulted in conclusions where the role of pilot projects was observed to be quite important for these companies developing new technologies and products for industrial applications. Pilot projects were found to be similarly challenging in four out of five case companies. Case companies 1,2,3 and 5 were similar in this respect, as their responses were categorised as representing high equivocality and low uncertainty for the management teams.

Here the smaller companies (cases 3 and 5) have given more emphasis to technological competitiveness regarding the described product development practice defined through the role of pilot projects with selected customers. The conclusion from this kind of example would then be that for small companies it can be important to get involved with pilot projects with customers in order to carry out development activities supporting the technological competitiveness of a firm. The bigger companies (1,2) would seem to view the product development practice of pilot projects with selected customers as an approach somewhat more balanced between technological competitiveness and product development performance.

The interpretation of these results suggests that in the case companies pilot projects with selected customers can be seen as craft practices, not routines. Pilot projects with selected customers represent advanced practices where a firm has an opportunity to collaborate with the lead users of new technology (von Hippel 1988). Insights gained from early use experiences in pilot projects can bring invaluable information for the development process of a new product or technology. It is also critical to understand that customer-supplier relationships in these kinds of business situations are highly confidential, and often beneficial to both parties. Pilot projects have a definitive role in product development where different issues can be studied. It does not have to be always related with technological solutions only; questions can be broader and more complex, too. But the results from the survey method used here suggest that pilot projects are somehow associated with aims to use pilot projects as a practice emphasising technological competitiveness. This is in one sense a similar type of conclusion to that given in the literature on the role of lead users for product development, as a source of critical information on new innovations (von Hippel 1988).

The next variables actually form a pair of issues that are related with the orientation and motivation of product development engineers. The idea for this question was picked up from an interview with Dr. Yrjö Neuvo, chief technology officer responsible for new product creation process within Nokia Mobile Phones, Finland. See the citation excerpt below, where the relationship, differences and similarities between technological competitiveness and product development performance was analysed by Dr. Neuvo:

15–16. "I think that technological competitiveness and product development performance are a little bit similar. A good product is good from both perspectives, product development is efficient and competitiveness is good. This is how it goes. You need to have both, and you need to have right balance in that. It is evident, that is sure. If you have a damn good product development but you are working with poor technologies, it will not get you to anything. And the same as opposite. It is very easy for a company to forget the other one of these. I could imagine a situation where a young university based company is operating on the basis of technological competitiveness. While another case, some company that is more established is counting on fast development capabilities. Neither of these previous examples is very good. You need to be good both at technological competitiveness and also in product development performance. Organisations need people who take case of the technological competitiveness, and then they bring it to the product development. But if you look at a highly trimmed product development organisation, they don't have so much time to look around; they don't have time to think too long about which technologies we could use here. It is pretty important, that you can refine and develop your new technologies in your company into a level where they can be adopted, directly into the effective product development. Put it differently, it's like product development train on rails; you can throw in bits of new technologies along the way. (An interview with Dr. Yrjö Neuvo, Nokia Mobile Phones, February/1999, Helsinki, Finland)"

→Product development engineers in our company have a strong task orientation for …
→Product development engineers in our company are best motivated with goals for the improvement of …

Firstly, the practice of "product development engineers in our company have a strong task orientation for" has been categorised similarly in case companies 1,2,4, and 5. Bigger firms were a little different in this question. Company 1 has given a little more emphasis to product development performance. Company 2, on the other hand, seems to be more oriented towards the balance between technological competitiveness and product development performance, regarding the task orientation of the engineers. Smaller companies 4 and 5 have emphasised more technological competitiveness, in the case of this variable.

Task orientation is an important variable in the development activities (Norrman 1971). Interpretation of task orientation on the basis of these results shows that both technological competitiveness and development performance can be seen as possible types of orientation. This kind of conclusion is also dependent on the ways whereby this instrument has been built. Estimating a balance between technological competitiveness and product development performance is a compromise in the representation of task environment in the product development process of a firm, as has been described in the earlier discussion. Orientation is also not a clear-cut development practice, but it represents more a conception of the views and ideas typically being adopted in the companies.

The role of individual orientation has also been used as one of the critical elements in this present study. The results provide variance and responses in ways that have led this specific variable to be categorised as a craft practice.

Secondly, another product development practice defined as "Product development engineers in our company are best motivated with goals for the improvement of ", has been categorised in similar ways in case companies 2, 3, 4 and 5. The role of technological competitiveness seems to be more typical in the case of this variable. Particularly companies 2 and 3 represent examples where the improvement of technological competitiveness seemed to be emphasised. Both questions concerning the task orientation and motivation of engineers are quite important, and these issues also represent main themes being addressed with the research framework and survey instrument discussed here. Both variables deal with management issues of product development practices.

Finally, there is a variable defined, as "use of selected key technologies in product development is important for..". This question has been adopted from an expert interview. The interview with Mr. Kari Rintala from TEKES conveniently depicted some core themes related with the use of key technologies in a firm's product development. In one part of the interview, performance of the main technologies of a firm was discussed. See an excerpt from the interview below:

4. "This is a question of how you are progressing in your product development. Stepwise, phased work. And on the other hand it is also about strategic management. Has the company identified its technology needs? Does this increase the efficiency of product development? A company should know in what technologies it should use partnerships, what to buy, when to co-operate with universities etc. Some big companies and a part of the medium sized companies know how to build technological portfolios. *If product development performance is good then the performance of main technologies is good.* (An interview with Mr. Kari Rintala, Finnish Technology Development Centre Office, Seinäjoki, Finland)"

→Use of selected key technologies in product development is important for...

Four of five case companies were categorised similarly with this variable. Case companies 2,3,4 and 5 were characterised similarly with this product development practice. There are a number of important issues here. The first thing is that key technologies can be related with emphasis on both technological competitiveness and also for product development performance, but in different firms. There is some variety in these results, as this practice was also classified as a craft practice that is not a routine for these companies.

From the interpretation perspective this variable seems to offer evidence to propose a conclusion where use of selected key technologies in product development is one means to address the goals of technological competitiveness and product development performance. Companies 2 and 3 may have actually utilised more technology management ideas and practices in their product development. The role of key technologies can be one of these kinds of areas. This is one part of the differences between companies, and of the important differences in their product development. As Henderson (1996) has argued, these kinds of findings can be important. Use of selected key technologies in product development actually includes different types of activities, both the selection of key technologies, and the ability to use them effectively in product development.

It is also interesting to ask why it is that use of key technologies in a firm is a matter that can be also seen as a bit of equivocal, craft practice. The data used for this survey is from project managers and process management teams. Sometimes it might be that selection of key technologies has been organised and carried out by different people working on the R&D management and development management rather than those project managers responsible for the running of the product development process and development operations. The results from this study would seem to support a conclusion where use of key technologies in product development is not really an engineering problem, but more of a matter of craft practice. This difference is subtle, but as such it also offers ways to explain and describe the differences in engineering and craft practices.

5.1.4 High equivocality, high uncertainty-characteristics of "non-routine practices"

The last phase here covers the aspects of the Daft and Lengel (1986) model where both uncertainty and equivocality are high. Some text excerpts can be shown here first in order to describe the characteristics of the issues depicted to be highly uncertain and equivocal. The role of these examples is also important because they are helpful in the analysis of the empirical data. See prescriptive citations from Daft and Lengel (1986: 557, 563) below:

Interpretation guidelines from Daft and Lengel (1986) on non-routine practices:

-High equivocality, high uncertainty: Many ambiguous, unclear events, managers define questions, also seek answers, gather objective data and exchange opinions.
-Unanalyzable, High variety (Non-Routine technology): Structure: a) Rich media to resolve unanalysable issues b) Large amounts of information to handle exceptions. Examples: Frequent face-to-face and group meetings, unscheduled meetings, special studies and reports.

Essentially the point in the above examples might be that non-routine technology like issues can be quite complex in terms of the organisational information requirements. Then it is also critical that companies can apply different product development practices in ways that could match the underlying requirements. According to Daft and Lengel (1986) it is also probable that special organisational information processing mechanisms like group meetings can be required in order to be able to resolve the problem solving requirements. The data collected from the case companies can reflect this theme particularly well. Being able to compare the findings from different management groups in different companies can help us to analyse how these groups can reflect on a set of important issues related with product development practices. The analysis framework we have developed here results in a way to a synthesis describing what kinds of problems can be difficult in different companies.

Product development practices classified here as highly equivocal and uncertain varies again across companies. There is only one variable that can be appropriately used for the cross-case analysis. This one is analysed here in more detail. The variable "achieving 'critical mass effect' is important for", has been interpreted here to be perceived as a highly equivocal and a highly uncertain issue in four of our five case companies. This variable is then common to case companies 2, 3, 4 and 5. The results concerning the nature of this particular product development practice would seem to be such that a notion of critical mass effect was perceived to be related with emphasis on product development performance. Company 2 where the respondent group was biggest seems to view this issue in a little more balanced way.

See Table 23 on next page describing the data.

Table 23. Non-routine practices (High equivocality and high uncertainty, cross-case data tables)

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Cases	Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
1	Achieving "critical mass effect" is important for	8	-3	-4.75	1.5	6.25	8	6
2	Achieving "critical mass effect" is important for	12	0.5	-3	4	7	11	6
4	Achieving "critical mass effect" is important for	3	3	0	7	7	3	4
5	Achieving "critical mass effect" is important for	6	2	-1.25	4	5.25	6	6
5	Cross-functional product development teams are important for	6	1.5	-0.5	4.75	5.25	6	5.5
4	Customer specific product development projects are important for	4	2	0	6.25	6.25	4	4.5
1	Development of product and technology platforms first from low-end towards high-end price segments is important for	8	1.5	-2.25	5.25	7.5	8	6
5	Development of product and technology platforms first from low-end towards high-end price segments is important for	6	3.5	-3	5	8	6	5
1	Integrated timing and scheduling for internationally distributed product development teams is important for	8	5	0	6	6	8	6.5
4	Integrated timing and scheduling for internationally distributed product development teams is important for	4	2.5	0.5	5.25	4.75	4	4.5
5	Making authorized technology choices on behalf of our customers is important for	6	-4	-5.25	1.25	6.5	6	5.5
4	Our company evaluates and measures its product development activities specially for the development of	4	1.5	-2.25	4.5	6.75	4	4
2	Our company's own sales and distribution network is important for	13	0	-3	2	5	11	6
4	Pilot projects with selected customers are important for	4	-2.5	-4.5	1	5.5	4	4.5
5	Prioritisation of time based results over cost issues is important for	6	2.5	-0.25	6	6.25	6	6

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Table 23. Continued…

		Statement responses					Confidence responses	
		N	Median*	Percentiles		IQR	N	Median
Cases	Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
1	Project specific strategies for supplier involvement in product development are important for	8	-2	-4	1.5	5.5	8	6
3	Project specific strategies for supplier involvement in product development are important for	5	2	-1	4	5	5	7
5	Project specific strategies for supplier involvement in product development are important for	6	0	-2.75	4	6.75	6	5
5	Prototyping and testing principles in our organisation are based on	6	-1	-6.25	2.25	8.5	6	5.5
4	Real benefits from the internationalisation of product development work are important for	4	-3	-5.5	1.75	7.25	4	3
4	Separation of technology development projects and product development projects is important for	4	-1	-5	3	8	4	4.5
1	Separation of technology development projects and product development projects is important for	8	0	-3.75	3.75	7.5	8	6.5
1	Some long term customer relationships are important for	8	3.5	-2.75	5	7.75	8	6
5	Some long term customer relationships are important for	6	1.5	-1	4.25	5.25	6	6
5	Synergies from common technical functionalities between products are important for	6	0	-3.5	6	9.5	6	6
2	Synergies from technological discontinuities are important for	11	-2	-5	1	6	11	5
1	This product development organisaton where we are working is often described as oriented towards	8	2	-5	4.75	9.75	8	6.5
4	This product development organisaton where we are working is often described as oriented towards	4	0.5	-2.25	3.25	5.5	4	4
1	Top management of our company is typically prioritizing	8	-2	-4.75	4	8.75	8	6.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

There is only one product development practice that has been categorised as a non-routine practice similarly in four of the five case companies. This practice has been defined as "Achieving a critical mass effect is important for..". The idea for this specific question has been based on the interview with the managing director of case company 2. In the interview, the managing director was describing the differences and synergy between technological competitiveness and product development performance, when the theme of critical mass came up as a way to develop some approaches to manage this issue in product development. It is a type of technology strategy approach to the analysis of similarities and differences between technological competitiveness and product development performance. See the original citation below:

6. "I think you have to focus for critical mass issues, if you are doing something important. Technology, important product, or anything, you have to solve the problem of critical mass. There are so many technologies in our field of business. You have to classify those into key technologies, support technologies, and what is something you can buy totally from suppliers. This classification process is beneficial, because if you do it carefully it helps in focusing. (An interview with managing director of Case 2, April 1999, Finland)"

→Achieving "critical mass effect" is important for...

This result has been categorised similarly in case companies 1, 2, 4 and 5. Two types of information can be found by analysing the data table. The first is that according to the interpretation it is possible to conclude that achieving critical mass effect is a non-routine practice when analysed from the organisational information requirements perspective. Secondly, it can be concluded that this specific practice seems to have received a little more emphasis on product development performance. It can be therefore argued that on the basis of these results it would be possible to argue that "achieving critical mass effect.." is a means to address product development performance, although the difference in empirical data is subtle.

The notion of achieving critical mass mass effect might be an attractive way to describe how the leverage from product development is linked to the output and efficiency of development activities. The nature of this practice (achieving critical mass effect...) is quite complex. Perhaps the best way to describe the findings from this study is that it can represent a management decision (Harrison and Pelletier 2000) that addresses the concerns described in the interview of the managing director of case company 2. Depending on the situation and the firm's capabilities, management may define goals of critical mass in different ways. Achieving critical mass effect is a non-routine practice to manage the balance and focus in the scope of the firm's product development activities.

5.2 Conclusions from the cross-case analysis

This cross-case analysis has been focused on the analysis of the data patterns arising from the survey, only analysing those variables in more detail where some commonality between the cases seems to be showing. This is the purpose of the cross-case comparison, too. Now once we have first shown the data in its raw form, we can also discuss some issues related with the analysis of the results. The presentation of the results so far has been carried out in order to make explicit how the field observations and the survey methods developed here can be used with the data from the empirical interviews. Also the classification procedure developed here for the quantification of equivocality and uncertainty of responses has been addressed. Our model framework also offers additional points to be discussed. The overall relevance and meaning of the dualistic balancing between overlapping goals of technological competitiveness and product development performance can be elaborated. One major point that we have not yet discussed very much is that the role of the model framework also needs to be elaborated here.

Empirical data from the industrial electronics sector of the Finnish electronics industry

The responses in this present study are all from companies operating in a similar type of business environment, that of industrial electronics. Technological competitiveness is a critical success factor for the companies in their business. However, in general it is important to underline that, relatively speaking, the industrial electronics business is not a pioneer in all technical areas. Some experts have suggested that in fact industrial electronics is a follower and application developer for the innovations originating from sectors like the consumer electronics industry. Companies involved in product development and business in industrial electronics can be, however, similarly competing with technical superiority in product applications and technological areas. Both technology development and product development are practised in distinct areas within industrial electronics and consumer electronics. The inclusion of five case companies from the same industry represents an effort to maintain focus on similar type of business environment, where the firm's product development practices evolve and are being used.

Overview of the results

It has been argued that there there are no specific ways to choose a best product development method (Souder 1978). This limitation is also a good point to remember. The results shown here emphasise that there are different types of product development practices, in terms of the differences between the organisational information requirements of different practices (Daft and Lengel 1986). These results may also offer some ideas to make sense (Daft and Weick 1984) of the interpretation perspective of product development practices.

The ideas being addressed in the cross-case analysis show that it may be possible to categorise product development practices in ways that are based on the theoretical model of organisational information requirements (Daft and Lengel 1986). Earlier literature review of theory and empirical findings on product development practices would suggest that different integration and problem resolution mechanisms could be used in order to match problem characteristics different ways of organizing the development work. One implication of this would be that product development practices could be used differently in different companies (Maffin et al. 1997).

Development orientation and process performance

In the empirical interviews for this study it has been observed that individual differences in orientation and interests may explain some aspects of the interdependencies between technological competitiveness and product development performance. This previous point needs to be considered together with the analysis of these results.

Earlier literature on product development processes and development practices has often been based on the information processing theory of organisations as problem solving entities. In a deeper sense, it can be argued that orientation of both individuals and groups may be a factor that underlies problem solving in development work. Orientation may also be seen to precede problem-solving activities, which can bring up the information requirements perspective. Empirical studies of product development activities have shown how problem-solving processes have been used as an interpretation and resolution mechanism. The ideas of the Daft and Lengel (1986) framework then brings up the question of what problem-solving requirements can be anticipated, and moreover, what kind of generic problem-solving models could there be. One example is a design structure matrix, as described by Steward (1981) and Eppinger et al. (1994). Design structure matrix type of presentations of product development activities underline the flow of information in terms of the problem-solving tasks. Different kinds of task dependencies and relationships can be analysed in this way (Ulrich and Eppinger 2000).

Often the discussion and analysis of product development practices is based on a background context or situation where some specific problem is being solved, or some development performance goal is being improved. It is also possible that different product development practices may drive information requirements in different projects and situations. A key idea is that the effectiveness of some product development practices has often been analysed in terms of the achieved improvements in designated goals, like the reduction of time-to-market.

In this study an attempt has been made to maintain a quite generic background situation, underlying the use of development practices. This is also a point where we may need to make a differentiation between a practice and a project. Product development project can be used for the depiction of development task goals, in terms of specific time, quality and cost constraints and resources. A practice is more a matter of doing some particular activity in development process with a selected approach. One example could be that companies can use different mechanisms to manage the relationship of technologies and their interactions in different projects and products. Practices can be argued to represent a way to approach the transformation issues (various forms of input-output processes) in development processes, to find an alternative approach that could complement the project level focus. Process performance then deals with this need of organisations to be able to adjust the uses of development practices in different development tasks.

Process performance can include various means ends relationships, also conceivable as integration models with varying focus and types of fit between task-technology relationships. Different types of task-technology, technology-information processing relationships and their terms of fit are conditioned by some important factors. This can be perhaps argued with the examples where perceived individual and group level orientations and uncertainty can have some impact on the information processing. Therefore perceived uncertainty and orientation can be examined as a source of information on the antecedents of organisational information requirements. This gives us some possibilities to use that kind of approach as a way to deal with the information available to us from the empirical research.

The survey methods we have developed and used in this research are based on this kind of analysis of the orientation and perceived uncertainty of the match of product development practices with the need to achieve critical focus or balance in a product development process. In the research the idea of process performance has been accomplished with relating the use of product development practices (means) with the "ends" of product development process: a managed balancing between technological competitiveness and product development performance, through contingent use of product development practices for these goals. This enables us to utilise also the organisational interpretation perspective in the analysis of the development practices as ways to address some particular types of goals and performance objectives.

The results of this cross-case analysis have shown that it may be possible to analyse the differences in information requirements of product development practices between companies. However, data from a few cases cannot be generalised to a great extent, which should be remembered. But as a whole the pattern and variety of uncertainty and equivocality as analysed here presents an interesting range of challenges concerning the implementation of product development practices. Next we will present a summary of the common findings between the case companies. Comparing the differences in routine, engineering, craft and non-routine practices has carried this out.

Interpretation of the empirical data

The differences between the suggested categories of organisational practices are described with the empirical results obtained here. An overview of the practices is shown in the Tables 24 and 25 on next pages.

Starting here with a variable from the Table 25: "A broad range of technological capabilities is important for the technological competitiveness" has been categorised here as a routine practice in four out of five case companies. It would seem possible to argue that this represents a view in these organisations where the importance of different types of technological capabilities can be important. But this is just a matter of orientation. Individuals and groups in different organisations seem to be similar in this practice.

Next there is another product development practice that has been categorised as an engineering practice. This practice has been defined as "the real benefits from the internationalisation of the product development work are important for..". This practice has been related with both technological competitiveness and the balance between technological competitiveness and product development performance. It would seem that the benefits from internationalisation of product development work represents issues for these organisations where they need to make plans and collect quite a lot of new information. The idea of internationalisation itself may not be so difficult, or it can be said that these companies are working in order to manage the internationalisation of their product development, with related opportunities and difficulties.

Routine practices -"Clear, well-defined situation, managers need few answers, gather routine objective data." Or, -"Analysable, Low variety (Routine Technology), Structure: a) Media of low richness, b) Small amounts of information. Examples: Rules, standard procedures, standard information system reports, memos, bulletins..
Engineering practices -"-Many, well-defined problems, managers ask many questions, seek explicit answers, gather new, quantitative data. -Analysable, High variety (Engineering technology). Structure: a) Media of low richness, b) Large amounts of information to handle frequent exceptions. Examples: Quantitative data bases, plans, schedules, statistical reports, a few meetings"
Craft practices -High equivocality, low uncertainty: Occasional ambiguous, unclear events, managers define questions, develop common grammar, gather opinions. (Daft and Lengel 1986:557) -Unanalyzable, Low variety (Craft technology), Structure: a) Rich media to resolve unanalysable issues, b) Small amounts of information; Examples: Occasional face-to-face and scheduled meetings, planning, telephone (Daft and Lengel 1986:563)
Non-routine practices -High equivocality, high uncertainty: Many ambiguous, unclear events, managers define questions, also seek answers, gather objective data and exchange opinions. -Unanalyzable, High variety (Non-Routine technology): Structure: a) Rich media to resolve unanalysable issues b) Large amounts of information to handle exceptions. Examples: Frequent face-to-face and group meetings, unscheduled meetings, special studies and reports.

Table 24. Practice characteristics according to Daft and Lengel (1986: 557-563)

Table 25. Results of the empirical cross-case study

Categories of different practices	Product development practices
Routine practices (Low equivocality, low uncertainty)	A broad range of technological capabilities is important for...
Engineering practices (Low equivocality, high uncertainty)	Real benefits from the internationalisation of product development work are important for...
Craft practices (High equivocality, low uncertainty)	Continuous increase in know-how for advanced technologies and computerized tools for product development methodologies are important for...
same as above	Pilot projects with selected customers are important for..
same as above	Product development engineers in our company have a strong task orientation for..
same as above	Product development engineers in our company are best motivated with goals for the improvement of..
same as above	Use of selected key technologies in product development is important for...
Non-routine practices (High equivocality, high uncertainty)	Achieving "critical mass effect" is important for...

Then there are a larger number of practices that have been categorised as craft practices. These represent more equivocal situations than the routine and engineering practices. Craft practices are also practices and challenges that may not be yet ready for analysis and planning. It is more a matter of finding the questions and answers to problems that have characteristically a more multi-sided nature than in the case of routine issues. Craft practices are also issues where opinions are discussed and common concepts being sought.

Finally there is non-routine practice. The variable has been categorised as: "achieving a critical mass effect is important for product development performance", and this could be stated as an interpretation of the results presented in Table 23. It would seem possible to interpret this result in a way where the goal of critical mass is an objective that may enable effective results in terms of product development performance. It can also be a goal of product development management to build a critical mass of resources in order to be strategically capable in some specified ways. But the notion of critical mass effect can also be a problem when this kind of performance is not being achieved, and there can be some performance gaps in the organisation. Critical mass is a matter of business and technology strategies, giving guidance and paths for the product development of a firm. It is a management challenge.

Some questions may be also mentioned as ideas for future studies. Are there significant differences between routine practices and other practices, in terms of their impact on development performance? What kind of real differences can there be between routine and non-routine practices, are these differences related with the development capabilities and competitiveness of a firm?

6. DISCUSSION

6.1 Research gap and the findings from this study

This present study has been carried out in order to find ways to benefit from the inherent uncertainty and equivocality of development activities. The main goal has been to advance our understanding on the following questions.

1) How might the technological and competitive settings of a firm impact the uses of product development practices within a product development process?
2) How could we analyse different types of product development practices and their implementation in the product development process of a firm?

The first question has been addressed in the literature review, and thus a perspective has then been chosen for the more detailed analysis of the second question. Regarding the first question, earlier studies on product development performance in the electronics industries have shown that the nature of product development process performance is dependent on the nature of the competition and the market environment of a firm (Loch, Terwiesch and Stein 1996). This means that the particular type of performance dimensions may be achieved only by using certain related product development practices that may support the achievement of such goals. This kind of means ends approach has been selected as an approach that has been used in this research.

In the present study we have attempted to take a look at product development process as an environment where development practices are being used. Regarding the second question, a particular type of analysis approach has been adopted where product development practices and their implementation in the product development process of a firm has been modelled by using the ideas of means and ends. The idea of means and ends perspective is that product development practices may have characteristically related information requirements that are associated with the ways in which product development practices can be implemented in the context of the product development process of a firm. Earlier literature on this area has led to conclusions where it has been argued that effective product development processes seem to be both balanced and focused (Cusumano and Nobeoka 1996). Notions of balance and focus have then been selected here as characteristics that can be related with the development orientations, also argued to be an important enabling factor of successful product development activities (Norrmann 1971).

On the basis of earlier literature, it may then be possible to argue that product development orientation underlies the understanding of the use of product development practices as means to achieve selected objectives. Obviously organisations may have different means to accomplish their goals. Individuals and groups may have different orientations. In the context of industrial product development processes it can be important to be able to align the peoples' orientation towards development goals and tasks. Orientation to development practices is also a matter of learning and experience. People can be very different, but when they work together for a joint goal in a product development process their specific and general ideas of different product development practices can be negotiated and analysed by the teams. This is a source of variance that we have tried to tap into with this study.

Earlier in the literature analysis, we have also referred to Koufteros et al. (2001, 2002) who have argued that new research is needed in the area of product development practices and relationships between them. Koufteros et al. (2001,2002) have also suggested that analysis of development practices should focus on the competitive capabilities being related with the development activities.

In this present study, the idea of linkages between competitive capabilities and product development practices has been approached with the ideas of organisational information requirements. The use of selected product development practices, as means to achieve some selected goals is a way to conceive how the development orientation may be related with the use of different practices. The product development orientation discussed here is a bridging concept between earlier studies on technology and market orientation. For example, Cooper (1985a) has discussed how companies should try to balance and focus their activities in order to find ways to integrate technical and market based issues. These questions are also based on the importance of strategic orientations in product development (Gatignon and Xuereb 1997; Madhavan and Grover 1998, Iansiti 1995b). Some other examples can also be mentioned where the middle management level perspective on the product development practices can be critically important for the success of product development (Barclay 1992b).

On the basis of the literature analysis it was possible to conclude that competitive capabilities are natural attributes of the information requirements of the product development practices. The second key finding was that these information requirements might also be associated with the underlying development orientation of both individuals and groups conducting product development tasks. On these bases, it was then possible to pursue the modelling of the use of development practices.

6.2 Characteristics of the empirical study

Organisational theories often represent a perspective to a firm's activities where one single practice or method does not necessarily suffice for the description and elaboration of important issues. More often organisational theories represent several complementary constructs like organic or mechanic structures (Burns and Stalker 1961), or single and double loop learning (Argyris and Schön 1996). Organisational practices related with product development may also be related with a number of complementary issues like shared knowledge base, communication and co-ordination activities within the organisation (Hoopes and Postrel 1999). In this present study we have also analysed a number of different product development practices. The idea has been rather to delve deeper into the realms of product development, than to focus on one specific method or tool used in product development.

The ideas of organisational information requirements also represent a relatively broad approach to the associations between information and organisations (Simon 1957, Nadler and Tushman 1978, Daft and Weick 1984, Daft and Lengel 1986). Having performed a literature review on these issues the framework of Daft and Lengel (1986) was adopted as an underlying guideline in the modelling of product development practices. This was because the ideas in selected problem types, alternative levels of complexity and uncertainty seemed to offer a convenient way to address the elements of information and organisations. Information processing theory based perspectives on organisations have also been used earlier in studies and the modelling of product development activities (Gales et al 1992, Sicotte and Langley 2000).

One limitation of this study is that the role of organisation has not been addressed in a very comprehensive manner. Still the empirical analysis of the material discussed in this research has been collected from several companies. The purpose of such data collection has been to analyse product development processes and practices in a number of different firms operating in the industrial electronics industry. The ideas of information requirements have been applied in a way where the product development orientation underlying management of a product development process of a firm has been studied. This issue has been studied through group meeting type contexts where the firm's product development management teams can try to resolve the task requirements of the ongoing development activities. Development orientation is also related to issues like how companies think about risk taking and performance requirements.

6.3 Contributions of this study

The goal of this study has been to analyse different types of product development practices and their implementation in the product development process of a firm. This research task has been approached from the perspective of organisational information requirements. Ideas from both literature and empirical interviews have been used in the analysis, and a new type of conceptual construction and survey instrument has been developed. Next follows a short discussion in order to review the contribution of the study.

The level of analysis in this research has been the product development process of a firm. To put this in perspective it can be argued that this study has analysed the business process of a firm, not the firm as a whole. This limitation is important, and the results of this study do not try to explain the success of a firm. Neither have we sought to explain the product development success in terms of the new product success factors for a firm. The focus in this study has been in the business process level perspective related with the analysis of the product development practices.

Focus on product development process means that a range of different development practices or development activities used in the product development process was analysed. The analysis approach used in the study has been based on the development orientation related with the practices. The modelling of product development practice and its use has been conducted in a manner where company level best practices have been used in the building of a conceptual framework that attempts to measure aspects of the development orientation of individuals and groups. This is important because in this way the earlier knowledge on firm level issues has been utilised in the analysis of the business process level use of development practices[7]. The ideas of modelling in this way are examined here because it shows the traces of how the ideas and frameworks utilised have been developed. It also helps to describe the areas of contribution. The idea that product development work is often carried out under different constraints and imperatives has been discussed in earlier literature. Aspects of product development performance have also been conceived as development imperatives (Schilling and Hill 1998; Wheelwright and Clark 1992, Clark and Fujimoto 1991). Such performance dimensions are versatile and often contingent to the original new product and development programme strategies of a firm (Cooper 1984, 1985a, 1993).

[7] Existing literature on development performance has often underlined the criticality of being able to match and integrate technology development with product development in balanced and focused ways (Clark and Fujimoto 1991, Cusumano 1992). This comment may clarify the analysis of technological competitiveness and product development performance in the conceptual framework of this study.

The question may arise of why we should analyse the implementation of the product development practices. Specifically in this study it can be an important question. Earlier literature on product development practices and development activities has often examined the conduct of practical development tasks as their performance is analysed with the project level goals for time, quality and costs. On the other hand, company level analysis of product development performance suggests that effective development operations are often balanced and focused. These two examples show different perspectives on the product development process of a firm. Product development practices are dependent on both of these, project level and firm level issues. Questions like these have pointed us towards the analysis of how product development processes are actually being managed and operated. This is the level of analysis that explains the need to analyse product development practices and their implementation.

The research framework and ideas used in this research give possibilities to separate five related issues in the analysis of product development practices. Empirical modelling covers three of these issues, and the underlying theoretical perspective describes the fourth and fifth aspects. These issues are discussed here in the following manner, addressing the following questions:

–What kinds of product development practices might be seen as means to be related with the development orientation towards technological competitiveness?

–What kinds of product development practices might be seen as means to be related with the development orientation towards product development performance?

–What kinds of product development practices might be seen as means to be related with the development orientation to balance technological competitiveness and product development performance?

–How does the underlying perspective on organisational information requirements enable us to examine the questions shown above?

–What kinds of conclusions might then be drawn on the basis of the used approach and results achieved?

Empirical issues addressed in the analysis:

i) Product development practices related with the development orientation towards technological competitiveness.

ii) Product development practices related with the development orientation towards product development performance.

iii) Product development practices related with the development orientation to balance technological competitiveness and product development performance.

In this study, we have applied the concepts of technological competitiveness at the company level product development processes. Appendices 6,7,8 and 9 show examples of how different product development practices have been related with the orientation towards technological competitiveness. These results are descriptive, case company level results with some common issues between cases. There are also differences.

One implication from the study is that practitioners in product development may perceive technological competitiveness and/or product development performance itself as a goal or priority, besides the more practical terms like development lead time, productivity and total product quality (Clark and Fujimoto 1991). Performance goals have quite strong impacts on the product development processes. This may even be so important as to justify saying that for some companies technological competitiveness is a competitive priority for their product development processes.

The set of practices used here represents a summary of practices describing the relationship between technological competitiveness and product development performance, on the basis of this material analysed in the present thesis. Here in the study balance has been conceived as a type of management team orientation, as analysed through the responses of a management team.

Fundamentally, the balancing between technological competitiveness and product development performance is a matter of timing between different development activities. One primary issue is that we need to discuss how the role of product development performance, technological competitiveness and balance between them has been analysed in the course of this research. In a basic sense the study has presented a method of categorising product development practices in terms of the underlying product development orientation of the management team participants.

Ideally, a balanced and focused product development process then integrates all these mixed goals with organisational capabilities in order to ensure optimum deployment of competencies and insights for product innovation activities. How to achieve this kind of optimum processes is an important challenge of product development management. Theoretically we might be able to propose a synthesis over the previous perspectives in a form of management variable of *development orientation*, as a characteristic of both individual and group level attribute of organisational information requirements. Various situations can represent the context where this kind of balancing can be necessary. In real-life the balancing takes place via different mechanisms and processes. Orientation of both individual and group can have an important role in the background of the "balancing" process.

How does the underlying perspective on organisational information requirements enable us to examine the questions shown above?

Earlier empirical research has shown us that there are many types of performance dimensions related to the product development process of a firm. Deeper analysis of dimensions or product development performance has also shown that issues like total product quality are strategic issue categories to firms that can actually be also seen as drivers of many underlying performance areas also critical to product development (Clark and Fujimoto 1991). The point is to be able to make sense of the performances improving the product development function of a firm and competitiveness as a whole. From the perspective of this research, it becomes important to find an appropriate way to address the research questions. Here the key finding has been that product development practices can be related with multiple performance dimensions. And as we have already discussed, it is important to be able to have an appropriate development orientation that can help companies manage the complex challenges in product development processes (Norrmann 1971).

The modelling approach used in this research is built on an idea where fit between development practice and its use as a means to address competitive capabilities of technological competitiveness and/or product development performance has been examined. The approach attempts to capture the product development orientation of the management team running a company level product development process. The ideas of uncertainty and equivocality are analytical perspectives used for the analysis of the empirical data representing information requirements underlying a descriptive problem used in the modelling of a product development process. Product development practices have been classified into four different categories reflecting the variation in the responses. For example, product development practices characterised by highly consistent and converging development orientations coupled with low levels of uncertainty have been classified as routine practices reflecting low levels of equivocality and uncertainty as suggested in the ideas of Daft and Lengel (1986).

Accordingly, different product development practices have been analysed in terms of their information requirements characteristics for routine, engineering, craft and non-routine practices as proposed in the model of Daft and Lengel (1986). This classification into four types of different practices gives deeper and complementary perspectives for the analysis of the research questions. The use of the organisational information requirements perspective has enabled a building of an interpretation framework that addresses many of the issues mentioned as parts of the research gap by Koufteros et al. (2002).

What kinds of conclusions might then be drawn on the basis of the used approach and results achieved?

Results show that different product development practices may have different information requirements. In practice this means that different types of product development practices seem to receive different types of responses on the basis of the management team orientation. In some practices the responses of the groups converged quite much and in other cases they were also quite divergent. Some practices can be seen as very much related with technological competitiveness while some others are more related to product development performance. Perhaps no one best type of "balance" can be picked up through this type of research approach. What we can say here is that various responses concerning different product development practices seem to vary from low uncertainty and low equivocality to those of higher levels of uncertainty and equivocality. This is the analysis logic and perspective used here.

Some practices may be more familiar and routine like in companies, especially if we are speaking about a specific product development practice that has been very much discussed in a firm. We cannot argue here whether the issues with low uncertainty and low equivocality can be better used for balancing between technological competitiveness and product development performance than those with higher perceived levels of uncertainty, for example. Rather, the point we can argue here is a broader question of what kind of information requirements could be in the first place be seen as characteristic of technological competitiveness or product development performance. This is a way to delve into the realms of the development orientation of individuals and groups participating in the management of the product development process.

Theory and literature on organisational information requirements have been used here to build a base for the analysis in terms of organisational interpretation (Daft and Weick 1984). The interpretation achieved with the used framework can be described. Daft and Lengel (1986) have provided alternative ways to interpret the information requirements. One perspective of their model suggests that routine issues can be dealt with with reports and performance data collection, while non-routine issues may require frequent face-to-face discussions and problem solving (rich media). Different types of information requirement categories may therefore require respectively different choices and approaches in the resolution mechanisms.

The theoretical framework utilised here offers a way to analyse organisational practices, and to make a systematic interpretation of the differences between product development practices. From this perspective, the measurement instrument and related questions describing product development practices have enabled us to build a way to analyse product development activities with the ideas suggested by Daft and Lengel (1986). The nature of the measurement approach is not very simple, but it seems to be possible to utilise the data in ways that provide analysis results for analytical inquiry.

Some selected questions could be highlighted. Categorisation of the practices into different groups gives us possibilities to analyse the differences and similarities between product development practices. This is an issue that has been recently discussed by Koufteros et al. (2002) as an area that may benefit from new research results. Secondly, the categorisation approach shown here has resulted in empirically grounded new hypothesis for further research. This kind of hypothesis might be given in the following form: is it possible to verify the differences between routine and non-routine practices in the implementation of product development practices in the product development process of a firm? In addition to this hypotheses it can also be argued that new means ends hypothesis can be developed on the basis of product development practices being better or worse in supporting ends like technological competitiveness.

The basic result of this study is to provide new perspectives and improved understanding on issues like what kinds of product development practices might be seen to be complementary with each other to address a goal like the technological competitiveness of a firm and its products. This also represents a way to address the need to achieve new research results on the organisational interpretation perspective in product development activities with the ideas of Daft and Lengel (1986). Achieving this is also one way to focus on the research gap in innovation projects as discussed by Gales et al (1992).

6.4 Summary

The results from this study may be unique in that the role of product development practices has been problematised in terms of the contingent use of the practices to address the relationships between a practice and its use as means to address the purpose for which it is being used. The purpose implied with the uses of the practices has been modelled as a need to balance or focus on different imperatives like technological competitiveness and product development performance. The framework utilised in the research has been a compromise and synthesis over a range of success factors for effective product development processes. Specifically we can argue that the type of product development practice level approach we have used in the empirical survey represents a method or tool kind of collection of various product development practices, giving us a cross-disciplinary view over a product development process.

In this model, a list of 33 contemporary product development practices has been built into a structured survey instrument. These practices and related excerpts from interviews present in-depth insights into the management issues of product development activities in some companies from the electronics industry. In many cases the interviews used for the analysis of the chosen 33 practices have been made with the managing directors of the companies. These practices can also be used and analysed in future studies. The linkage between questionnaire and these development practices does offer ways to use these as a new type of survey tool for the analysis of development activities. This survey tool has been tested in five companies with empirical group interviews of the management teams of these firm's product development processes. The data has been analysed via a cross-case analysis against the ideas of the underlying organisational information requirements framework of Daft and Lengel (1986).

Data from a cross-case analysis have been used for the comparison and analysis of the similarities and differences between the companies in terms of the responses to the survey questions.

In this way the practices and analysis methods bring new empirically based information on the use of product development practices in the electronics industry. The fact that these practices have been gathered from companies in the electronics industry may be important because this industry is by nature international. So even when this study is empirically limited to Finnish companies in the industrial electronics industry, it is grounded on practices used in internationally operating companies.

We have approached product development processes with a two-stage research process. First we have collected a number of observations from qualitative interview material in the industry. Then these findings were synthesised into a set of statements concerning product development management. A response scale was also designed that was used in the analysis of the derived statements. This questionnaire tool is an essential part of the contribution of the study. We have developed, tested and refined the main findings into a hypothesis for further research work. The set of 33 statements represents different perspectives to product development process performance. This list of items is seen as another contribution of the study. These items may be used and replicated in further studies concerning product development process performance, regardless of the response scale being used in the study. We have sought to keep the framework quite simple in order to keep it flexible enough for the analysis and interpretation of different kinds of product development processes. The premise here is that whatever the needs and reasons might be for more detailed use of the model framework, it is necessary to limit the focus to a specific approach required for the analysis. We can use the model framework as such, or the set of questions associated with the model as such, in separate roles.

7. LIMITATIONS OF THE STUDY AND FUTURE RESEARCH

7.1 Limitations of the research results

We may start here with critical limitations of the study. A primary risk in the study may be that concepts have been used that describe both internal and external issues related to product development. Traditionally, competitiveness may have been seen as an external parameter related to success in business and operations. We have used a concept of technological competitiveness as perceived by the management groups of product development processes. That is one major limitation of the study, as it has not been verified externally how important technological competitiveness really may be for the business performance of the companies included in the sample. This limitation also concerns also product development performance. This study has been an attempt to operationalise product development orientation with these previous concepts.

Product development activities have mostly been studied by analysing product development projects. Product development process level analysis on product development is little different in its scope. A process-based approach may cover different issues and topics concerning the environment and practices of product development in a broader way. This research has combined some elements of both project and process level approaches to product development processes. Here we will discuss the questions on validity and reliability in the context of the present study. The justification and role of cases is also considered. There are both qualitative and quantitative issues to validity that we need to cover here.

7.1.1 Validity

This study has sought to utilise product development orientation as an underlying level of observations used in the analysis of product development process performance.

According to the results, the methods used have shown such results where this issue of orientation has been found in the empirical analysis.

Major issues of validity and reliability are critical to all research activities (Kirk and Miller 1986). Product development process performance has been found to vary in different industries (Loch, Terweisch and Stein 1996; Terwiesch, Loch and Niederkofler 1998; MacCormack 1998). This notion of the theoretical nature of product development process performance may also be used for the justification of the selected case studies, in that they are all from the industrial electronics industry. Also, the basic nature of the concept of process performance is related with issues of how well we have operationalised it, a major issue on the validity of a study. We will discuss validity here in terms of content, construct and criteria related perspectives to the study.

We have developed a model of product development process performance with two main concepts used in the operationalisation of the model. By doing so used concepts of technological competitiveness and product development performance have been used as major characteristics of product development process performance. Then the issue of content validity can include questions of how well these concepts and their definitions are sufficient for requirements like Sekaran has described: *content validity ensures that the measure includes an adequate and representative set of items that would tap the concept* (Sekaran (1992:171). Together these concepts of technological competitiveness and product development performance cover a broad overview of product development processes. Definitions of the concepts have been discussed already earlier, in the part of our text addressing the development of the survey tool questionnaire.

Here we might also add that results from the use of the concepts in empirical interviews captured quite well the critical issues related with product development process performance. In order to argue that the operationalisation of process performance here has been careful, the following could be stated: the approach of this study has tapped into a plurality of performance dimensions that are associated with dynamic needs for strategic decision-making (Eisenhardt 1989b) in a tight paced environment like the product development process of a firm. The utilisation of the mentioned concepts has also been based on an approach where information is collected via responses on individual subjective performance measures that may be useful in examining relative performance within an industry (Dess and Robinson 1984:271).

Secondly, Sekaran (1992:173) has argued that discriminant validity can be seen as an element of construct validity, *that testifies how well the results obtained from the use of the measure fits the theories around which the test is designed.* Also, DeVellis (1991: 46) wrote: *it is the extent to which a measure "behaves" the way that the construct it purports to measure should behave with regard to established measures of other constructs.* This requirement for construct validity through discriminant validity requires that we specify the nature of the relationships we want to test with our two selected performance dimensions. Product development process performance is a construct that we have tried to model here through two dimensions that can either converge towards balance between them, or diverge to their own distinct directions. These concepts are somehow overlapping.

Such a "bipolar mode" means here that the balance between technological competitiveness and product development performance was expected to behave like a sort of contingency variable. In practice, this balance was constructed into the form of response scale that could measure how individuals perceived technological competitiveness or product development performance for a given statement, or did they see the item more as a matter of emphasis on balance between those ends. This is a simple trade-off model. Therefore, our measurement model of the product development process performance does not imply issues associated with company performance.

Instead, we have been looking for deeper insights and descriptions of the nature of technological competitiveness and product development performance, at the level of product development processes. Overall, it is argued that the model framework is a potential approach for the development of new, theoretically sound contingency theory framework for the study of product development process performance. The approach in this study on the balance between technological competitiveness and product development performance in terms of different product development practices discriminates individual and group responses. Therefore we can argue that this aspect of construct validity has been covered.

Thirdly, the survey questionnaire contained 33 item statements derived from qualitative research material. The face validity of these items was considered in a series of pre-test interviews with the questionnaire. Still we need to find out that whether they can be seen as relevant criteria for an empirical survey. *Criterion-related validity is established when the measure differentiates individuals on a criterion it is expected to predict* (Sekaran 1992: 172). Moreover, we may argue that broad variance over the responses is a sign of the match of the measurement model against the theories of individual behaviour within the context of innovation related processes (Burns and Stalker 1961). Therefore we may argue that the approach here can show evidence for criterion–related concurrent validity (Sekaran 1992:172).

But we cannot show evidence for predictive validity with the data. That would become more relevant in future studies with adjusted goals for the use of dependent variables, etc. We can summarise here that the model framework used has been characterised here through some validity considerations.

Interpretations of the results achieved by the use of the model are dependent on the scores for different items studied with this kind of response scale (Sekaran 1992). In this way, our interpretation of the causality and relationships between different variables can be also be addressed theoretically, by explicitly showing the nature of the role of contingencies associated with particular variables (Ginsberg and Venkatraman 1985).

Moreover, we have restricted the analysis to selected case companies that to some extent were known from earlier engagements in research interviews. It is also possible for us to argue that construct validity can be shown by known-group validation. DeVellis (1991) wrote: *known-groups validation is another example of a procedure that can be classified* *either as construct or criterion-related validity, depending on the investigator's intent.* We have shown here in this study how we can find company specific differences with the approach used. We cannot predict these differences, not at least with the small amount of data gathered.

7.1.2 Reliability

We have used response scales where it was possible to mark estimated confidence right next to the score given on the basic response scale. These confidence estimates thus cover our response scale from one end to another. There is variance in the given confidence estimates. Despite this, we can say that the response scale for technological competitiveness versus product development performance received both high and low levels of confidence with different variables. As intended, this response scale succeeded in showing that different individuals might see different question items in a different way.

The reliability of a measure indicated the stability and consistency with which the instrument is measuring the concept and helps to assess the goodness of a measure (Sekaran 1992:173).

We have tried to achieve the objectives of reliability here with the systematic nature of the research process. There are different parts to it that we have already covered in the previous chapters. For instance, development of the questionnaire and its anchored response scale has been discussed in detail in the description of the research process. Our premise for reliability has been to develop a formal research process that can be replicated. New studies can also bring additional experience for the evaluation of the validity and generalizability of the developed research framework (Hubbard, Vetter and Little 1998). There are some shortcomings in the reliability of the study. We will discuss them here in order to show that they also areas that we can work in future studies.

A key issue on the reliability of the study is that we argue that we have shown evidence where technological competitiveness and product development performance can be studied in the context of product development processes. Thus this result is also a point that we want to generalise in further studies. In this present study, the results may be seen as a new middle-range theory or sort of substantial theory developed from grounded empirical work.

Shortcomings of the study can also be addressed. The study has not shown the stability of the measures through test-retest reliability (Sekaran 1992). We expect that in the future there are possibilities to perform annual or bi-annual test-retest with the survey tool used. This kind of data is needed for the evaluation of the stability of the approach. Moreover, we did not perform Cronbach's alpha tests for the analysis of inter-item correlation. We saw that the role of correlation or regression analysis was not so important at this stage of the research. We need bigger data sets for the analysis of such associations.

Ontological questions are based on capabilities in product development performance (Clark and Fujimoto 1991). Product development capabilities may contribute to the competitiveness of a firm through different mechanisms, especially by the proper management of product development processes (MacCormack 1998, De-Weerd Nederhof 1998, Loch, Stein and Terwiesch 1996, Nishiguchi 1996, Cooper 1993, Clark and Fujimoto 1991). The strategic context of the business has many implications for competitiveness. A study by Hambrick and Lei (1985) illustrated that technical change is only a subordinate variable besides many other important contingency variables in business strategy research. With regard to the question of strategy, this study is more about the implementation of strategies than strategic planning (Ansoff 1984).

Eisenhardt and Brown (1995) associated process performance in product development to variables like use of suppliers, team composition, and team organization of work, team group process and senior management role. These variables are important for product development performance (Clark and Fujimoto 1991). These kinds of variables have also been represented among the question items used in this research.

Questions of competitiveness through product development processes are perhaps more related to issues like organisational learning than to product development project specific problems. This is a strategic dilemma. The literature suggests that effectiveness in either processes or projects depends on different things. Project specific goals need to be different from the goals of a process, in a sufficient way. For process performance, we find it important to focus on process based performance results.

We have used here a specific definition of a product development process in order to study product development empirically in a particular way. The definition used is as follows: *product development process is the sequence of steps that a firm employs to conceive, design and commercialise a product* (Ulrich and Eppinger 2000). What are the implications of this specific definition for questions of product development process performance? Notions of sequential conceptions of development process are quite common. Also, this kind of sequence-based orientation might be argued to be in logical relationship with the ways in which we have studied product development processes through means ends based analysis. Information processing activities often occur in sequences. We argue that this may be a natural result from the capacity centric thinking in manufacturing and operations management. Production capacity is often built in specific sequences. Product development processes are more fragmented in their nature, but it is also possible to find very rigid and sequential descriptions of product development processes. Perhaps this is also a question of semantics. Naturally product development processes, or any processes seen in a very operational manner, seem to be sequential and systematic. The difference lies in the ways we have chosen to approach the performance of a product development process through an overall model framework.

We suggest here that the analysis and description of product development processes through sequences of steps in development work are associated with requirements for process innovations, often in a continuous state of flux between facets of more integrated work environments (Cooper 1994, Nihtilä 1996, Nihtilä 1999). After all, we need innovations in both new product and process development (Wheelwright and Clark 1993).

We need also to be also careful in the attempt to properly address the product development process of a firm, and development process performance from the project specific information requirements. Therefore we need also to answer the question of what it means in the context of a product development process to find a match or fit between technologies and information processing requirements, not limited to project specific issues. Product development processes are coupled with the realities of uncertainty and equivocality, more often we can also say that these attributes characterise product development orientation of individuals and groups.

Definition of the concepts

The survey method developed and used in this study may also have some limitations, especially the definition of the key concepts used: technological competitiveness, product development performance and product development process. The conceptual definitions used in the study may have their strenghts and weaknesses. Only the definition of product development process has been adopted directly from the earlier literature. This definition and its use link this study to earlier literature on product development process where similar types of definitions have been used. New definitions for other key concepts have been developed and this is part of the research effort. The exact definition of a concept like product development performance is a good example. The definition used here has been developed as a synthesis from the results of the expert interviews. Conceptual definitions always have their limitations. In this present study the interpretation of the results has been based on analysis of empirical responses from the survey. Quantitative data has helped us to focus on in-depth analysis of the results. Then the role of product development performance as one of the main concept of this study has been to provide a basis for analysis of different product development practices. On the basis of the results achieved, it can be summarised that the used concept definitions have been operational and sufficiently differentiable, which has enabled their use in the building of the interpretation based analysis framework.

7.1.3 Reliability and validity aspects of the new questionnaire

This study has presented results that are based on the use of a new survey instrument. Data collection procedures have been systematic and structured, which may support the reliability of the technical conduction of the survey. The meaning of validity is also important, as the concepts and purposes being measured with the questionnaire are conceptual. We have performed a statistical check of the differences between the survey instruments used here. This provides a way to assess the validity of the survey instrument developed. The approach used has been based on the comparison of rank order correlations between the response scales and related answers on the estimated confidence levels to the questions. Each survey question included in the instrument has also been complemented with this kind of respective estimation of the perceived confidence level for each question. Spearman's rank order correlation can be calculated from variables that are based on the ordinal response scale (Cramer 1998, Vasama-Vartia 1971). Analysis of the correlations between responses to questions and related confidence levels of these answers provides a way to analyse the validity of the questions.

Examination of the differences between the traditional survey questions and the new type of survey questions offers us a way to estimate the validity of the new survey instrument. Two types of statistical runs have been performed to analyse these issues: firstly at the level of the case companies and then also at the level of the whole sample of five companies. Case companies 1 and 2 were selected for this test as in these cases the number of respondents was biggest (8 and 13 people). In the light of these results it would seem that the validity of the results provided with by new survey instruments is not as good as that which can be achieved with the traditional Likert-type survey. There is evidence, however, that the new instrument can also provide validity comparable with the traditional approach. Detailed results of the analysis of rank order correlations with both types of response scales are shown in Appendices 15 and 16.

The conclusion that can be drawn is that the new survey instrument and its related response scale do not seem to provide as good validity as that which can be achieved with the traditional response scale. However, there are examples where the new survey instrument also reaches comparable levels of correlations. Specifically, for each variable Appendices 15 and 16 show the values of Spearman rank correlation analysis where each question has been analysed with bivariate correlations related with the substantial questions. These pairwise correlations provide estimates on the validity of the measurement instrument.

The new instrument seems to provide results with weaker validity than the traditional approach. This question level analysis of validity does not yet give answers to the validity issues related with the categorisation approach carried out according to the ideas of Daft and Lengel (1986). The conclusion here is that when the questions used in the building of the framework may have some limitations or risks of varying levels of validity, this also causes some doubts on the nature of the results of the categorisation process. In conclusion, it can be summarised that the validity of the new instrument could be improved by specifying the questions concerning product development practices in concrete ways. One additional point is also that the traditional survey instrument provided results with mainly positive rank order correlations, while the new instrument provided both positive and negative significant correlations. The double-ended response scale may be a reason why these kinds of differences in the results have been observed. One additional issue is that the sample size may have an impact on the rank order correlations, in both the new and traditional survey instruments. Hence it might be necessary to carry out this kind of survey with larger sample sizes. The validity of the overall approach might improve if larger samples are used instead of small groups. The implication seems to be that the developed research approach on the organisational information requirements of product development practices needs to be studied also at company level with larger sample sizes of more than 30 respondents. This would then lead to a conclusion where new company specific cases studied with improved survey instruments could be seen as an area that may warrant further research with the ideas and methods developed in this study. Broader empirical perspectives may thus be needed.

7.2. Managerial implications

7.2.1 Overview of product development processes

Earlier literature has addressed how uncertainty and complexities can be analysed and solved in terms of specific product development projects. Companies' development processes may also have deeper impacts on the organisation's activities. In a way, when previous literature on development activities in terms of projects has focused on constraints and resources for a given project, we have developed a different type of approach. With the model framework of this study we use product development process as a sort of resolution mechanism to reduce the uncertainties critical to a firm's development activities. Sources of such uncertainty can be grouped into respectively similar or different complex issues as perceived by the managers. Issues underlying a team's work in product development can be studied by analysing how such teams perceive uncertainties and equivocality in their work environment regarding the used work practices and pursued goals. Our approach to the analysis of product development process performance addresses how the management teams enact their goals and projects within the environment provided for them by the company and its organisation. More practical concretisation of this is could also be given. For instance, there can be situations where some goals need to be balanced against the requirements of effective enactment and deployment. A key issue is then to ensure that product development practices can be used in development processes in ways that would achieve effective enactment of goals.

Product development problems should be relatively reduced and refined. When managing a product development process from a firm perspective we need therefore to be able to resolve many types of problems and issues. One related issue is that often it is senior management participation in the product development that can enhance strategic links between projects and companies strategies (Englund and Graham 1999, Bart 1999). Li and Calantone (1998) argue that top management's competence in market knowledge may be their core competence areas regarding new product development. In this way product development processes also mix experience and competencies together. Besides projects, processes are also used for the improvement of focus on key goals of the product development management. Focus is also required for progress in product development work. A practical side of focus is that it is built from diversity. Horwitch and Thietart (1987) studied how business management challenges vary according to the different levels of R&D intensity in various business units. They wrote: "*again, we repeat: technological diversity is at least as demanding for the setting of strategy as business diversity* (Horwitch and Thietart 1987:193). Product development processes are very sensitive to different competencies (Winterscheid 1994). Product development competencies may be related to different products and processes.

Perhaps the point is that we need to build different kinds of learning models for different purposes like, technology integration (Iansiti 1995a), systemic development processes (Verganti 1997), modularity of information structures (Galvin 1999) or cultural and social learning (Boisot 1995). At least we can say that performance measures need to be developed for different kinds of objectives in product development (Iansiti 1998). Product development processes integrate all these previous aspects and also other issues into the development activities. Product development processes are created and used for the needs of company specific product development activities.

We may sometimes make a mistake and assume that something like the product development process is the same thing for all companies. However, the reality is that there are big differences in the spending on R&D and product development between companies. Even the basic positioning of product development in companies may vary according to their strategies. What we may perhaps say is that companies increase or decrease their efforts in product development processes according to how their business is going. If we assume a growing company, their concerns about the product development process are likely to be different from a company facing sales decline. Product development processes are also subject to the constraints and possibilities of resources of a company (Wernerfelt 1984, Lindman 1997, Verona 1999).

Fichman and Kemerer (1997) studied process improvements in the context of software development. We may utilise their findings in the descriptions of the differences between product development processes. Thus product development processes may differ to the extent that they have: a) different scales of activities over which learning impacts can be spread, b) different amounts of existing knowledge related to the focal area of innovation; and c) differences in the diversity of technical knowledge and activities. These reasons may also be associated with the various aspects of improvement and analysis of the product development process performance.

Miller (1995) argued that we should aim to build broader mission assignments for research and development departments. It might also be an important goal in the analysis of product development process performance. It has a lot to do with the strategic intent of a company or a corporation (Prahalad and Hamel 1994). Some people may be more driven by this kind of competitive mindset and some others may look for motivation from their professional growth. This was actually one of the first problems observed from project management. Wilemon and Cicero (1970) suggested that engineering professionals were looking for a dual ladder in their career paths. Starting to work with projects might have meant that engineers would have to give up their functional discipline areas like electronics or software design. Today we can argue that the situation is even more complicated. At least this may be true in product development where the diversity of people's background and education may have become broader. Ancona and Caldwell (1992) propose that product development teams need to be rewarded based upon their own work, and not on a functional basis. Overall, it is important that product development organisations can use different kind of temporary groups in their product development processes (Ellis 1979, Cusumano and Selby 1997).

7.2.2 Management implications of this study

This study may help managers of product development activities to find some new perspectives in the analysis and utilisation of product development practices. Managerial problems addressed with the results of this study could be characterised in the following ways:

–What could we do in order to try to improve the technological competitiveness of our firm?
–What could be done in order to improve the product development performance of our firm?
–How could we better manage the balance between technology development and product development?
–What kind of product development practices might be better known and understood by our organisation, and on the other hand what kind of practices can be more complex?
–How could we analyse the relationships between different kinds of product development practices?

We can also ask what is the significance of the results of this study? An answer to this question needs to be developed from the beginning of the premises behind the study. New interests in product development processes are moving towards goals like strategic flexibility and operational effectiveness (De-Weerd Nederhof 1998). These ideas may help companies to be better prepared for the anticipation of changes in product development processes. As Verganti (1999) argued, flexibility could be planned in order to enhance the responsiveness of the product development projects. There are many things that we plan in product development processes. After all, a major share of product development work is concerned with derivative products (Wheelwright and Clark 1993). Bigger risks are often involved in research and development work (Jolly 1998).

This present study is an attempt to develop new analysis methods for the review of product development process performance. Based on the original idea of Daft and Lengel (1986) on organisational information requirements, we have developed an approach for the analysis of product development process performance. The way we have conceived this research task is built on a finding from earlier literature in that process performance in product development is addressable with means-ends type of models. The model and survey data analysis tool used here is based on the principles of Daft and Lengel (1986) in the categorisation of technology into varying approaches for problems ranging from routine technologies to non-routine technologies.

Different issues impact on the use of product development practices. Earlier studies on product development process performance often address issues like the question of cycle time and lead-time of development activities. The conclusion from many earlier studies is tthat time factors need to be managed strategically in the context of product development processes (see also Ittner and Larcker 1997). Managers need to be capable of making appropriate trade-offs between development speed, product cost, product performance and development program expenses (Smith and Reinertsen 1995, Ali, Krapfel and LaBahn 1995:67). Time-based issues drive many aspects of product development process performance. But timing and speed of development are not necessarily resolved effectively unless the uncertainties can be understood in a deeper manner.

Different issues can be comparable in their uncertainty and complexity, and hence also in terms of the organisational information requirements. A given product development practice can be analysed by how its role is perceived by the practitioners. For example, implementation of technologies can vary between routine and non-routine technologies. A key managerial issue from our results is that for a specific team or group of people, an analysis for some important product development practices can be made in order to gain some additional information on how that particular product development practice could be effectively approached in terms of process performance. In other words, our results can be useful in the analysis of issues prevailing in the implementation of development practices. In our approach a new kind of way to reduce and decompose these kinds of uncertainties in product development process has been developed. Inherent uncertainty and equivocality can be analytically resolved with some modelling frameworks like the organisational information requirement by Daft and Lengel (1986). We have used such a generic modelling framework in the conception of the critical goals of product development for a firm. The need to be technologically competitive and effective in product development is also a way to understand how the competitive premises of development work impact on the product development groups. Ideally, firms should try to maximise their uses of various capabilities in the task areas being pursued. Through our model, the capabilities cannot actually be measured, but the underlying product development orientation reflecting interpretation and perception of development goals can be analysed. And then the related source of variation in the groups and members' perceptions concerning specific product development practices can be categorised according to the ideas of Daft and Lengel (1986). This gives us different ways to study how the competitive premises present in development processes can impact development work. In summary, an analysis method has been developed.

Companies developing products need to be aware of both internal and external situations around a firm and its business environment. Companies are naturally interested in their competitiveness and sustainability of their critical assets. Managers compare both internal and external elements of their firm's performance. New aspects of competitiveness cannot always be perceived beforehand, even in product development. In product development companies are looking to the future and it is necessary to be able to manage development activities. Some kind of rules and heuristics might be used in this kind of management tasks.

The model framework developed in the present research illustrates an analytic gap of performance-competitiveness, and how product development practices might be used to reduce sufficiently uncertainty in the product development process. This kind of framework does not explain how product development activities in the first place are carried out, or how a firm decides on product strategy and development goals. The model characterises the product development process performance targeted when development work has been commenced and launched. It is supposed to be an analytic framework to be used in the analysis of various types of product development practices. Companies for product development activities can use different practices. When a management team is reviewing the practices of a development organisation or working group it is possible to gain some insights into the use of different product development practices. The management with the help of the model developed in this research can therefore study beliefs and assumptions behind an essential set of development practices.

The set of issues included in the model framework should not be seen as a constraint. The methodological approach and analysis used can be applied in different ways. Different problem areas can be formulated into a similar type of analysis procedure reflecting the ideas and possibilities offered by the literature on organisational information requirements (Daft and Lengel 1986). Additional tools could be also used to add complementary perspectives to the analysis or product development processes or other type of business activities. It is in the way any tool is used that has a significant impact on the value of the results and conclusions to be made with it, and in spite of the results shown sometimes, too.

In summary, the ideas and methods discussed in this research may offer some perspectives for the analysis and utilisation of product development practices. These practices may be utilised in the context of the product development process of a firm. The ideas considered here are not necessarily tied to specific types of development projects or process models. Product development process has been seen as an organisational information analysis and processing activity, where the sequential nature of development activities has been underlined (Ulrich and Eppinger 2000). From a management perspective the key questions could be framed in the following way. What could we do in order to improve the technological competitiveness of our firm and its products? This is an important management goal for the product development process of a firm. Correspondingly, the ideas of this research can offer ways to find out what kind of product development practices can be inherently such that they might help management to implement their goals to improve technological competitiveness. Some specific product development practices or also management approaches may work better in this task than some others. Also, if the firm has this kind of goal where they need to be able to improve their technological competitiveness, they may need information on the enabling and constraining factors having impact on the implementation of the different product development practices. In this way, the ideas of routine, engineering, craft and non-routine practices can help firms to find out the differences between the implementation challenges of different practices. For example, a firm can evaluate whether its current product development practices can be seen as routines or not. These questions might need to be probed at the levels of product development organisations and management teams. When this kind of analysis can be carried out as has been described in this research it can be that the differentiation of product development practices in terms of their organisational requirements turns out to be an important tool that can help management.

Given the example of a situation where a firm might need to improve its technological competitiveness, the use of different product development practices may require that correspondingly organising approaches should be used. For this kind of situations the descriptive information available from this kind of analysis could be helpful. In this way, the ideas of Daft and Lengel (1986) can be used for the analysis of the organising and management of different product development practices.

It has to be also argued that the ideas and examples that can be derived from this kind of analysis do not offer a map towards best practices. The managerial value of the information from this kind of analysis is in the analysis of the situation and management challenges. A key question is whether management eventually accepts or supports the ideas and findings from these kinds of results. If management supports the results of this kind of analysis they still need to make careful decisions about whether some product development practices are really being implemented. In terms of the constructive research, it can be said that only the management decisions to use the information and ideas derived from this kind of analysis represent an empirical verification of the ideas and proposals described in this research (Kasanen, Lukka and Siitonen (1991). These kinds of issues are outside the scope of the present study. However, these questions and others may be pursued in future research undertakings. Ideally, future studies can be conducted in different companies and organisations where challenges of technological competitiveness and product development performance need to be addressed and managed in their product development processes.

7.3 Research implications

It would be interesting to study more deeply whether the perceived role of product development practices are related with differences in product development project level performances. A working hypothesis for further studies could be developed where the practices of varying uncertainty and equivocality could be studied in terms of their impact on development performance measures. For instance, do the product development practices classified into routine or non-routine technologies differ in terms of the practices association with development performance? More precisely, can we identify means-ends relationships between different categories of product development practices and their impacts on product development performance? These kinds of results could show the linkages between product development process performance and product development performance. Means-ends relationships between product development practices could be thus compared with performance data available from product development projects. Also, similar analysis could be performed with the various aspects of new product performance, new product success and failure, technical success in projects and the areas of product development process performance. The classification model we have developed here can offer a way to model product development process performance, in terms of the product development orientation. But the implications from this need to be addressed in deeper studies where new data and analysis can be carried out. Additionally, the role of the product development practices can also be studied in terms of the interdependencies between product development practices (correlation analysis). It could be studied whether the associations between different product development practices are really such that they would impact on development performance, or whether it is so that the relationship between product development practices is somehow a spurious relationship emerging from the data analysis and methods. This kind of comparative analysis of the product development practices through categorisations and statistical associations could be used in comparative research on the theme of product development performance, new product performance, and so on. For example, one idea for further studies is that the interactions between information requirements for different product development practices can be studied.

Considering the results of our study, some key variables were quite consistently related with technological competitiveness, and some others also with product development performance. This can be said to represent examples where some specific product development practices can inherently embody a sort of development orientation when such practices are being used in industrial companies. These kinds of results give us some ideas about what kind of things need to be enacted when a management team wants to emphasise improvements in the technological competitiveness of a firm, as an example. An additional perspective for future analysis is also to study that whether there would be new types of synergy or negative effects between different product development practices, which might be analysed through deeper questions concerning the relationsships between different practices (correlation analysis). Empirically we can see this project as a study of the product development processes in the Finnish electronics industry, within the industrial electronics sector. It could be possible to carry out a broader survey among companies in the Finnish and international electronics industry.

New research ideas

i) Multi-variate analysis of the survey results. One idea for further studies might also be to analyse the associations between information requirements between different product development practices. This could be done by a correlation analysis where basic measures of association and significance can be used in the analysis of relationships between different question items. Such a correlation analysis is also best performed with company level data where different management teams working in a specific development environment can be used as an empirical frame of respondent base. This kind of analysis of data from team surveys may also produce some data on the team level group processes in the context of management of a product development process.

ii) A questionnaire survey might be constructed in such a way that it would be possible to analyse the success and failure of new product performance against the model framework and question variables. It would be especially interesting to see whether this kind of use of balanced and double-anchored response scale could produce results that are consistent with the previous findings that product development processes should be balanced and focused (Cooper 1985a, Cooper 1993, Cusumano and Nobeoka 1996).

iii) Basically the classification procedure enabled by this method developed in this research needs to be compared with other similarly oriented approaches to analyse product development practices. One practical idea might be to perform a comparative analysis between the method developed here and a process evaluation tool like a capability and maturity model for software processes. Firstly, aspects like maturity and advances in development capability in software processes can be reviewed with the results of the standardised CMM model. Similar practices originating from the CMM/SPICE model framework could be implemented with the approach that has been developed here. Then a comparative review could be performed by using case studies or quantitative surveys within organisations having carried out the CMM evaluation for many years. Interestingly this kind of study could be also put into a research design where both CMM practitioners and non-practitioners could be included in an overall sample. This kind of broad range analysis might bring new information on the characteristics of software development processes, and organisational information requirements typical of the used practices in such organisations. In more general ways, this kind of study could extend the applicability and rigor of the conclusions that can be made from the analysis we have developed here, in terms of process improvements. Then it might be interesting to argue that future research activities may benefit by covering both product development practices and process improvements in a manner where the means-ends results for continuous improvement might be collectible. And finally, in the spirit advocated scholars like Lewis (2001), these kinds of research approaches are critically needed in the pursuit for more longitudinal studies of new product development activities.

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APPENDICES

Appendix 1. List of theme questions for the expert interviews

BACKGROUND INFORMATION

Name: ______________________________

Profession: ______________________________

Organization: ______________________________

Experience in the field of technology and product development: __________ (years)

Experience in the field of technology and product development related to electronics: __________ (years)

Experience in the field of technology and product development related to industrial electronics: __________ (years)

Areas of related market knowledge (mark where approapriate):

	Excellent				Average		Poor
Finland	7	6	5	4	3	2	1
Scandinavia	7	6	5	4	3	2	1
Europe	7	6	5	4	3	2	1
North-America	7	6	5	4	3	2	1
Asia	7	6	5	4	3	2	1
Global	7	6	5	4	3	2	1
Other__________	7	6	5	4	3	2	1

QUESTIONS

-What kind of elements would constitute a best practise level results from product development for the whole firm (general success factors)?
-What about the previous issues in electronics industry?
-How would you describe the same issues in the industrial electronics industry as compared to the more general points mentioned above (examples of products) ?
-How would you define product development performance, in general and if necessary customized in industrial electronics?
-What would you say is/are the key drivers behind product development performance? [a) firm specific, b) corporate scific, c) partnership specific, d) network specific, when necessary]
-How would you define technological competitiveness at firm level, in general and if necessary customized in industrial electronics? [a) firm specific, b) corporate scific, c) partnership specific, d) network specific, when necessary]
-What would you say is/are the key drivers behind technological competitiveness at firm level, and if necessary in industrial electronics?

-If you would have to compare or categorize major elements of product development performance how would you do that, in general?
-What kind of interdependencies, differencies or similarities do you see between product development performance and technological competitiveness?
-In case there is a firm which has excellent product development performance, what would you say are trademarks of such a firms customers opinions of that firm or its products?
-Another case, if there is a firm which has excellent technological competitiveness, what would you say are trademarks of such a firms customers opinions of that firm or its products?
-How would you describe the role of product development performance and technological competitiveness in the competitiveness of fast growing firms?
-How would you describe the role of product development performance and technological competitiveness in the competitiveness of firms operating in mature markets?
-How would you describe the role of product development performance and technological competitiveness in the competitiveness firms in exports?
-How would describe the role of business transaction complexity (high,medium-high,medium-low,low) on the impact of product development performance or technological competitiveness in the competitiveness of the firms?
-How would describe the role of technological complexity (system delivery, equipment manufacturing, component supplier) on the impact of product development performance or technological competitiveness in the competitiveness of the firms?

Thank you for your co-operation!

Appendix 2. Interview questions for managers in the case companies

1. How would you describe the current stage of your firm in business?
2. Is there something special that has lead to this situation?
3. Where would you say that what you (or the place in organization that you represent) have either done or will most likely do does have an effect on the future success of the firm?
4. What kind of success or contribution did you think in the previous question?
5. How would you see the issue of technological competitiveness in general?
6. How does your firm rate in technological competitiveness?
7. Best drivers of TC, you would see as most important factors?
8. How does it pay off to build strategies for continued technological competitiveness?
9. Regarding the organization in your disposal, which or what factors would you name as the key mechanisms or resources for sustained high performance towards technological competitiveness?
10. Who is the main person or group responsible for technological competitiveness?
11. How would you see the issue of product development performance in general?
12. How does your firm rate in product development performance?
13. Best drivers of PDP that you would see as most important factors?
14. How does it pay off to build strategies for continued product development performance?
15. Regarding the organization in your disposal, which or what factors would you name as the key mechanisms or resources for sustained high performance towards product development performance?
16. Who is the main person or group responsible for product development performance?
17. What kind of advantages or disadvantages would you see in pursuing for synergies between technological competitiveness and product development performance?
18. How and where does your organization best manage the balance between product development performance and technological competitiveness?
19. Is there something that you would like to develop or change in your organization because of issues related to its performance on technological competitiveness or product development performance?
20. How do you believe that your organization is actually manageable towards these kind of objectives?
21. Considering the project xx, introduced by the interviewer, how would you rank it currently based on its impact to competitive position in business in general?
22. Considering the project xx, introduced by the interviewer, how would you rank it currently based on its impact to technological competitiveness targeted by your organization?
23. Considering the project xx, introduced by the interviewer, how would you rank it currently based on its impact to product development performance targeted by your organization?
24. How would you describe the relative position of that project has developed during the course of its conduction from the early stage to this moment?
25. On what terms, would you describe the representativeness of that particular area of product development activities in your organization?
26. On what terms, would you describe the particular area of product development in your organization as missrepresentative?

Thank you for your co-operation!

Appendix 3. Observations from theme interviews, qualitative interview transcriptions

FOLLOWING CITATIONS WERE SELECTED AND INCLUDED HERE FROM THE RESEARCH MATERIAL WE ANALYSED IN THE COURSE OF THE RESEARCH. JUSTIFICATION OF EACH CITATION TO BE INCLUDED HERE AS THE BASE MATERIAL FOR THE DEVELOPMENT OF THE QUESTION ITEMS WAS BASED ON AN ANALYSIS OF FOLLOWING QUESTION:

Question: *"What kind of interdependencies, differences or similarities do yousee between product development performance and technological competitiveness?"*

Below here onwards we will report some selected findings associated to the study of this question. "→ " arrow marks our interpretation from the excerpt of text presented above the questions. Each one of the 33 question statements included in the final questionnaire is included and reported here. Origin of the material is also clarified.

1. "A product is an embodiment of technology. Technology is perceived via products. Technologies come first. Products are embodiments of technology. When you develop a product you have hundreds of technology components that might do the job. It is really a quite challenge to be able to do that. *The only way to do that sensibly is that you have guidance from your management.* So you know what business you are into, what to say yes to and what to say no to. And understand what your target market needs and want. And those two things will help you to select which products you are going to do and what enabling technologies are going to be useful in delivering the functionalities of those products. (Telephone interview with Mildred A. Hastbacka, Arthur D. Little, USA, April/1998)"

→Top management of our company is typically prioritising issues which are important for

2. "In industries where product technology is critical to competitive success, then product development performance is also going to be critical. In that sense they would be very closely related. There may, however, be industries where you do not need to have a strong technological competitiveness but you still need good product development performance. For example, if you are in the furniture industry; you might still need excellent product development performance but you might not not need what we would normally consider technological competitiveness. *I would say they are very closely related in industries where technological superiority is important to product development success.* (Telephone interviews with Karl T. Ulrich, Wharton School, University of Pennysylvania, USA, March/1998)"

→The business that we are in requires that we can compete with...

3. "We have a global market network. Our customers come from over hundred different countries. We export daily to tenths of countries. *This delivery channel is very important for us.* And it is also a quite economical delivery chain, because its costs are quite reasonable for the pricing of our products. (An interview with CEO from Case 1, October/1998, Finland)."

→Our company's own sales and distribution network is important for ...

4. "This is a question of how you are progressing in your product development. Stepwise, phased work. And on the other hand it is also about strategic management. Has the company identified its technology needs? Does this increase the efficiency of product development? A company should know in what technologies it should use partnerships, what to buy, when to co-operate with universities etc. Some big companies and a part of the medium sized companies know how to build technological portfolios. *If product development performance is good then the performance of main technologies is good.* (An interview with Mr. Kari Rintala, Finnish Technology Development Centre Office, Seinäjoki, Finland)"

→Use of selected key technologies in product development is important for...

5. "Basically, if you look product development and product development performance. And you would like to increase this factor, then you better not to do anything. Never fall for any new technologies; that is one point of view. Or apply all of the technologies all the time. Because then performance is stuck, due to investments. But this is also short-term thinking. *If you think on medium or long terms issues, you have to switch to new technologies, in order to be competitive, just a very simple problem.* You could still develop the aged product development today, it may make sense on very long term. Today there are much more powerful processors available with which you can have even better performance. But you need to, before you could do all things on hex code, but today even C language might not do it, but you need still higher-level languages. If you need to just have both, then company needs to be a risk taker, in order to analyse what should we do in order to be competitive in the next version. In USA there is a thing, there is, "driven mind", a technology push or technology pull. If you introduce new technologies too early, then you have hard time to get market convinced to buy from you. Because they don't believe that this is a good product. They are not ready to accept the product. (An interview with Prof. Dr. Wolfhard Lawrenz, Fachhochschule Wolfenbüttel, April 1998, Vaasa, Finland)"

→Situations where we can use new technologies for existing or traditional kind of products are important for ...

6. "I think you have to focus for critical mass issues, if you are doing something important. Technology, important product, or anything, you have to solve the problem of critical mass. There are so many technologies in our field of business. You have to classify those into key technologies, support technologies, and what is something you can buy totally from suppliers. This classification process is beneficial, because if you do it carefully it helps in focusing. (An interview with the CEO of Case 2, April 1999, Finland)"

→Achieving "critical mass effect" is important for...

7. "On answer to the question that what product development is, it is an embodiment of technological competitiveness. So, the way that organizations compete, is that they compete with technology in two ways: one is in product development, and one is in process development. The Japanese have been very succesfull in embedding technology into products. And they have been even more succesfull in embedding technology and processes. So, when you look at Toyota and compare it with a Saab or BMW: it is inferior product in terms of the design but it is made in a superior way. What gives Toyota and Japanese advantages is that the product is not superior but the process by which the product is made makes it more valuable. Toyota can make cars in half of the hours than the Mercedes, Saab or Volvo. They take half as many more hours to make a comparable car. So, in terms between product development and technological competitiveness: product is the embodiment of technological competitiveness, but the technological competitiveness is not just only the product but it is also the process. (An interview with Professor William B. Werther Jr. University of Miami, USA, April 1998) "

→Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for ...

8. "For product development performance, I think there are lot of different measures you can use and follow. But performance, if you think it about like an operational issue; we have plans and we follow how well we can meet those plans. Specially time is important, success in timing is critical. Costs are more flexible, we can allow some additional expenses, as well as cheaper solutions. Because we can never know what to expect when we are developing new products. If we would develop just very similar products, we could easily estimate the required costs. (An interview with the CEO of the Case 1, October/1998, Finland)"

→Prioritisation of time based results over cost issues is important for ...

9. "You have to verify the components of the product before making the product design decision. This verification requires sometimes very expensive prototyping. You need to create a functional test environment for the product. The goal is to make sure that we try to eliminate the surprises and potential problems. (An interview with a managing director and one product development manager from a Case 3, April 1999, Finland). "

→Prototyping and testing principles in our organization are based on ...

10. "Generally you might probably say that if you have a good technological competitiveness, then you have also very good possibilities to improve product development performance. Because performance is improved, besides with the process competence, with these new technological tools like virtual prototyping. Both process competences and advanced tools require high level of know-how. If you don't have high level know-how, then you are probably having troubles in both areas, on process improvement and development tools. Improvement of product development performance is just pretty much about these high level know-how questions. New opportunities can not be adopted nor used if the company does not have the know-how required, or if the company is not trying to increase its know-how. So there is a correlation. Sometimes you might be in such a lucky position that inefficient product development leads to a high technology product. Competitive situation can be easy, you don't have to be in a hurry. Then product development may work inefficiently but still the outcome is good. But this may be quite rare these days. (An interview with Mr. Pekka Malinen, FIMET, Helsinki, May /1998)."

→Continuous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for ...

11. "We have continuously many field tests underway. Co-operation with our customers and demanding lead users is critical for that. In those cases we may deliver very new technology for customers, but they know that there may be some problems to that. It can be a good learning experience for both parties. What you asked about, yes we actually know very precisely who are the core lead users of our products. We almost know them better by their locations than the companies or corporations they are part of. (An interview with the managing director from case 2, April/1999, Finland)"

→Pilot projects with selected customers are important for ...

12. "If we accept a customer order where we see difficulties ahead, there will be a conflict. We may forecast that this project is not easy for us. At the particular time, we may not have the right people for the project, we know that the customer is counting on us. And we know that if we allow our competitor to take this project, we may well loose our good relationships with the customer. They might not give us the next project they are going to need. It is very difficult thing to say no to an old customer. (An interview with CEO from the Case 4, April/1999, Finland)"

→Some long term customer relationships are important for ...

13. "For us, technological competitiveness starts from the fact that we are an application oriented company. We don't develop so much any generic technologies. Our competence is more about being fast in choosing the right technologies for customer needs. We do some small scale research work in order to stay informed on technological development in our field. That has been our way to approach this problemacy. It is our competence that we can choose the right technologies. When you are doing that you need contacts to this business environment. But as I said, for our market area, for the applications we do, we have made good choices in picking up the right technologies for our customer needs. (An interview with CEO from the Case 4, April/1999, Finland)"

→Making authorized technology choices on behalf of our customers is important for ...

14. "The balance between technological competitiveness and product development performance, it is manageable, yes but it involves changing the behaviour of individuals. That kind of changes are known to be slow. We can start all kind of working groups and evaluation teams and get some things written on paper. But before someone really changes his/her behaviour, you have to repeat the message for many times. (An interview with CEO from the Case 4, April/1999, Finland)"

→This product development organisation where we are working is often described like that we are oriented towards...

15-16. "I think that technological competitiveness and product development performance are a little bit similar. A good product is good from both perspectives, product development is efficient and competitiveness is good. This is how it goes. You need to have both, and you need to have right balance in that. It is evident, that is sure. If you have a damn good product development but you are working with poor technologies, it will not get you to anything. And the same as opposite. It is very easy for a company to forget the other one of these. I could imagine a situation where a young university based company is operating on the basis of technological competitiveness. While another case, some company that is more established, is counting on fast development capabilities. Neither of these previous examples are very good. You need to be good both at technological competitiveness and also in product development performance. Organizations need people who take case of the technological competitiveness, and then they bring it to the product development. But if you look at a highly trimmed product development organization, they don't have so much time to look around, they don't have time to think too long about which technologies we could use here. It is pretty important, that you can refine and develop your new technologies in your company into a level where they can be adopted, directly into the effective product development. Put it differently, it's like product development train on rails, you can throw in bits of new technologies along the way. (An interview with Dr. Yrjö Neuvo, Nokia Mobile Phones, February/1999, Helsinki, Finland)"

→Product development engineers in our company have a strong task orientation for ...

→Product development engineers in our company are best motivated with goals for the improvement of ...

17. "We have different kind of projects, some of directly for product development. A-projects are like here and now, they are purely product development. B-projects are based on long term objectives. C-projects are mostly about preliminary research or technology studies. Thinking about those (A,B,C) different kinds of projects, balance is a wrong word. Naturally a major share of our projects belong to A-type. C-projects are low at volume or size, but they are important. You need to have enough of those in-the-process, whole time. In that way we are scanning that what is coming up in a next few years. We are conciously trying to add the amount of C-projects we are doing. (An interview with the managing director from Case 2, April/1999, Finland)"

→Management of the whole R&D (research and development) project portfolio is important ..

18. "Product development performance, the first measures are of course money and time, can we meet the schedule as planned, is the original schedule valid. Primary measures for company interests are the sales volume and market share the new products can bring. Do we reach the cash flow that was planned for the specific project. (An interview with Mr. Pekka Malinen, FIMET, Helsinki, May /1998)"

→ Building and use of performance measurement systems is important for ...

19. "For product development performance, first you have these direct measures like development time, predictability of the development time, costs and time, product sales etc. There's a measurement logic, first time-to-market, then time-to-break even and finally market share. (An interview with managing director from case 3, April 1999, Finland)"

→Our company evaluates and measures its product development activities specially for the development of ...

20. "We have centralised our product development, both organisationally and geographically. Even more organisationally. This was done by combining previously scattered product development units under the same umbrella. And we have also networked our product development, quite much actually. A considerable share of product development money goes to our subcontractors. This gives actually a better controllability over the product development. If you want some changes, then it is relatively easier to handle it with subcontractors. When you do everything with your own resources it is not so flexible. (An interview with the managing director from Case 2, April/1999, Finland).

→Flexibility of the external subcontractors for product development activities are important for

21. "This brief summary suggests that the supplier systems in Europe and Japan may help to explain the degree of reliance on black box parts in the Japanese and European projects in the sample, and may play a role in explaining regional differences in development performance. But the issue is complex. There are important firm-to-firm differences in *exercised project* scope within regions, and the regional distributions on the variables underlying scope (supplier involvement, off-the-shelf parts) overlap: some European firms rely more heavily on suppliers for engineering work than some Japanese firms, and they too manage that work through a collaborative relationship. The question is how such variations in scope affect engineering hours and lead time, taking into account regional and product content differences. (Clark 1989: 1252-1253)"

→Project specific strategies for supplier involvement in product development are important for...

22. "Literally design chain integration extends supply chain integration upward towards product development. Product development collaboration can also be seen as a part of supply chain management (Lamming 1993). Design chain integration is one element of design chain management. *Design chain management is the management of participants, both internal and external to a focal firm, that contribute the capabilities (knowledge and expertise) necessary for the design and development of a product which, on completition, will enable full-scale manufacture to commence (Twigg 1997 in Twigg 1998:509).* Design chain integration implies shared challenges in R&D and product development efforts, for instance joint co-specialisation between firms (Dyer 1996). But design chain integration is not a nickname for vertical integration. Lamming (1993) describes challenges for vertical disintegration. Design chain integration is also not restricted to electronic data exchange arrangements, which though should already be a constituent element in subcontracting business. Here design chain integration is approached through sophisticated collaboration between suppliers and customers. More proactive and pre-emptive approaches are emphasised as target costing and supplier certification used often for supply chain integration in manufacturing. The crucial question for strategic supplier involvement in product development is that what sort of competitive impact the customer is eventually trying to achieve through co-operation." (Maunuksela 1999, Maunuksela and Keskinen 1998)"

→Company-wide efforts for "design chain integration" in product development activities are important for...

23. "We have centralized our product development, both organizationally and geographically. Even more organizationally. This was done by combining previously scattered product development units under the same umbrella. And we have also networked our product development, quite much actually. A considerable share of product development money goes to our subcontractors. This gives actually a better controllability over the product development. If you want some changes, then it is relatively easier to handle it with subcontractors. When you do everything with your own resources it is not so flexible. And another thing is that we have taken product development up as a strategic input target for us. And when its relative priority has risen we are also discussing more about it." (An interview with the managing director from Case 2, April/1999, Finland)."

→Wide discussions in our company on the relative position and importance of product development are important for ...

24. "We don't mix together research and product development activities. We have been thinking this question a lot. This means that the necessary sharing and transfer of information from research to product development has to be fluid and seamless. And if you approach close enough, near to product development, you can adopt new technologies without too big risks. You should be able to cross that line almost in an unnoticed way, it is important. We plan our product development for a time frame that is less than two years, 0-1½ years is better. Research activities go in very different stages, depending on what goals we are talking about. We have our own research programmes, corporate research, EU research programmes, universities all over the world. We are involved within a wide variety of different research programmes. Our research activities have a very long time frame, the horizon that we are planning for. But ten years in this field is a really long time. Five years is also very long time. Even if we have these in-depth networks for the refining and development of new information and knowledge, we don't do so much there between 5-10 years in the future. Technological development in our fields is so very fast. (An interview with Dr. Yrjö Neuvo, Nokia Mobile Phones, February/1999, Helsinki)"

→A broad range of technological capabilities is important for ...

25. "It is problematic if you have to develop technology simultaneously with products. I mean before starting product development, before you have really tested and verified the functionality of the technology. It is better to have technology development projects and then separately product development projects. A product development project is a product project. (An interview with the product development manager from Case 3, April/1999, Finland)"

→Separation of technology development projects and product development projects is important for...

26."But I think that the time is the most important thing. That is the thing we are looking at the moment, do we meet the planned schedules. Performance is about doing the planned things within the schedules as agreed upon. And that is all the more important because we are collaborating with product development teams working at different countries. If these teams are working in a different pace, this will be a big problem, everything becomes slow and there is no progress. Of course it is little easier if we are just working here, by ourselves. But we don't have enough capacity to do it here. We have many product development projects distributed among many units in different countries. And you have to integrate all of these into a one big development effort. So it becomes really important to be able to maintain the planned schedules. At least I see this issue as a very important goal for the operational activities. It is really a challenge for us at the moment. (An interview with the CEO from Case 1, October/1998, Finland) "

→Integrated timing and scheduling for internationally distributed product development teams is important for ...

27. "So product development is no longer a challenge for a one company? No, we are internationalising our product development with a quite fast pace. There is a tremendous change there, I think that we have not really yet understood that what this change is about. But it is now moving on, quite rapidly into the direction like we have planned. And the impact of the process is increasing, too. (An interview with the CEO from Case 1, October/1998, Finland) "

→Real benefits from the internationalisation of product development work are important for ...

28."Synergies between technological competitiveness and product development performance. I cannot really say anything on that, if you asked it right now. Technological competitiveness, to me, it is always costs and functionalities. Then again, efficient R&D performance usually means also lower costs. If you are efficient, time is usually the factor, then you are usually working cost efficiently. Yes, it leads to that. Good overall cost efficiency is important, and if you have a cost effective technology and we have cost effective R&D; there we have at least one synergy. A difficult question. (An interview with the CEO from Case 1, October/1998, Finland)"

→Synergies from common technical functionalities between products are important for

29."I have been thinking this conversation mainly on the basis of individual products. Of course products are parts of larger systems, but then you have to understand that the whole system structure is about technology. How do you build the final product variant or a variant of systems to a customer? If you don't succeed in that, it will be a mess and there is going to be lot of inefficiency, involved. If you think it like that, it is really important to be able to build system concepts and modular structures for that. (An interview with the CEO from Case 1, October/1998, Finland)"

→Our concepts for products and technologies are important for ...

30."We are actually combining different technologies. Doing that gives us the next level of technologies. It is the process how you build this modularity from low-end towards the high-end needs. This gives us a big number of different products. We see here actually our core competence as a specific strategy thinking. Where should you focus? What are the balls that you are going to keep in this game. These are most important, for the competition, and also for the long time performance. Other areas can also be covered through different networks, partners and etc. (An interview with the CEO from Case 1, October/1998, Finland)"

→Development of product and technology platforms first from low-end towards high-end price segments is important for ...

31. "You think about concurrent engineering, for instance. It is not the technology that troubles me. We have major challenges in bringing up the new team organizations for product development. Properly applied team organization takes time and pain. My concern is that how can we really reach the benefits of cross-functional product development, all the way through the product development process. And how you build teams in such a way that you can accomplish this. You need to see how product development can take all support and information it needs from the rest of the organization. There is this total picture you have to see before you make any serious moves towards team organization. And when you do that, you may find that the technology is not the worst obstacle. I mean to have real team based concurrent engineering capabilities for product development, you have to develop your product development process through some kind of systematics. (An excerpt from the discussion from the discussion in a pre-test meeting of a questionnaire draft with a product development consultant, June/1999, Finland)"

→Cross-functional product development teams are important for ...

Question: What kind of elements would constitute best practice level results from product development for the whole firm (general success factors)?And how would you describe the same issues in the industrial electronics industry as compared to the more general points mentioned above(examples of products) ?

32. "I think we can apply what we said before on industrial electronics. One thing which is, more or less based prominent on what we are doing, especially, tools and instruments for networking. I think networking has become very much important for industrial electronics in the last five or four years.

Because, using networks means we can shorten the length to actual sensors and actuators. And using network systems with decreasing price elements, like micro-controllers we can have remote intelligence, floor level sensors and actuators. And this of course means, that these intelligent, pre-processing devices need to be networked. And the question is very often, which is the best network for industrial purposes. And this is a very simply to answer, because there are about 257,5 different networks competing. Very often this decision on the best one, is driven by "not invented here". I am never proud of another person's pro-duct, politics, money. For instance, Siemens is pushing Profibus, because they are men of Profibus. If you have a customer who applies Siemens products then for you the answer that which is the best network is very simple; Profibus. From the cost point of view, and the performance point of view, other considerations sometimes have to be taken into account. This leads the interesting thing in this area because, the field bus is like a sea. Sometimes a different wawe coming up, so Profibus coming up, and maybe others going down, or CAN is coming up, and others are falling down. It is politics, money, NIH, protecting market leadership,protecting own company philo-sophies which are driving this technical part. Very interweawed. Very difficult maybe to model. If you plan to establish a simulation, to hypothesise what will happen." (An interview with Prof. Dr. Wolfhard Lawrenz, Fachhochschule Wolfenbüttel, April 1998, Vaasa, Finland)

MB: "In industrial electronics, we see that they are thinking about new standards, new developments, but they have a strategy and strategy of history, they can not throw away all what they have. When they look for open systems, and wait and turn to, new-coming systems if it is good or not, they wait. "
(An interview with Manfred Brustat 4/1998, Vaasa, Finland)

"Technologies come and go. [BiCMOS, RF CMOS, SiGe, GaAs HBT, GaAs HEMT, InP, LTCC, HTCC, SAW, BAW, SMD, CSP, Flip Chip ...]. Each has a role, but only few make a discontinuity. We should develop some technologies on parallel to make the breakthrough. The Successes depends on how well these integrate into other technologies: ICs, packaging, substrates, mechanics, display...etc. Discontinuities mean opportunities." (Excerpts from a presentation of Erkki Kuisma 16.11.1998, Research Manager on Nokia Mobile Phones).

→Synergies from technological discontinuities are important for...

33. " Product development performance is very important for us, it goes even beyond technological competitiveness. Product development performance is part of the customer process, which gives us direct income financing. The more we can make projects with the same group of people, the more we can also increase our production. We gain cash flow. Our strategy has so far been based on the principle that we sell out a product development project for a relatively low price and then we can get its costs back from the production. We measure performance by accuracy of delivery schedules. Small group of people and fast throughput in the processes." (An interview with the CEO from the Case 4 April/1999, Finland)

→Customer specific product development projects are important for ...

Appendix 4. List of academic scholars and experts on product development and technology management

1. **Risto Hienonen**, Senior Research Scientist, VTT Automation/Pro Techno (February 1998)
2. **Kari Rintala**, Senior consultant, Finnish Technology Development Centre, TEKES (April 1998)
3. **Karl T. Ulrich**, Professor, University of Pennysylvania, Wharton School of Business (April 1998)
4. **Pekka Malinen**, Project Manager, Federation of Finnish Metal, Engineering and Electrotechnical Industries, (FIMET), (March 1998)
5. **William B. Werther Jr.**, Professor, University of Miami, USA (April 1998)
6. **Manfred G. Brustat,** CEO, Digalog Gmbh, (April 1998)
7. **Wolfhard E. Lawrenz**, Prof. Dr.-Ing, Fachhochschule Wolfenbuettel (April 1998)
8. **Donald Gerwin**, Professor, University of Carleton, Canada, (May 1998)
9. **Roberto Verganti**, Professor, Politecnico di Milano, Italy, (June 1998)
10. **Mildred A. Hastbacka**, Senior Consultant, Arthur D. Little, USA, (June 1998)
11. **Yrjö Neuvo**, Technology Manager, Nokia Mobile Phones Inc. (February 1999)

Appendix 5. Quantitative survey questionnaire

BACKGROUND INFORMATION

Position:______________________________________ Experience in this current task:__________(years)

Education:______________________________________ Years in the same company:__________(years)

1. How long have you worked within this environment and been involved within its new product development process? ______(years)

2. How do you think that the use of a formal new product development process has improved the performance on the following measures? Please respond to these questions by marking a circle around the alternatives.

1. Improved product success rate and higher customer satisfaction

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10) ____________

2. Product developed at target (meets time, quality and cost objectives)

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10)____________

3. Faster-to-market

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10)____________

4. Improved profit performance (sales and margins)

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10) ____________

5. A learning tool: educate our people

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10) ____________

6. Improved cooperation and coordination among people involved in the projects, e.g. different departments or functions

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10)____________

7. Fewer errors; less recycling; less redesign

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10) ____________

8. Improved communication

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10) ____________

9. Better project control

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10)____________

10. Improved customer acceptance for new products

Strongly disagree Strongly agree — My estimation on the confidence that I could give a reliable answer on this question

0 1 2 3 4 5 6 7 8 9 10 — (0-10)____________

11. Top management of our company is typically prioritizing issues which are important for ….

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

12. The business that we are in requires that we can compete with…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

13. Our company's own sales and distribution network is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

14. Use of selected key technologies in product development is important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

15. Situations where we can use new technologies for existing or traditional kind of products are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

16. Achieving "critical mass effect" is important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

17. Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

18. Prioritisation of time based results over cost issues is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

19. Prototyping and testing principles in our organisation are based on …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

20. Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

21. Pilot projects with selected customers are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

22. Some long term customer relationships are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

23. Making authorized technology choices on behalf of our customers is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

24. This product development organisation where we are working is often described like that we are oriented towards…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

25. Product development engineers in our company have a strong task orientation for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

26. Product development engineers in our company are best motivated with goals for the improvement of…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

27. Management of the whole R&D (research and development) project portfolio is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

28. Building and use of performance measurement systems is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1	0	1 2 3 4 5 6 7	____________

29. Our company evaluates and measures its product development activities specially for the development of …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

30. Flexibility of the external subcontractors for product development activities are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

31. Project specific strategies for supplier involvement in product development are important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

32. Company-wide efforts for "design chain integration" in product development activities are important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

33. Wide discussions in our company on the relative position and importance of product development are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

34. A broad range of technological capabilities is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

35. Separation of technology development projects and product development projects is important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

36. Integrated timing and scheduling for internationally distributed product development teams is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

37. Real benefits from the internationalisation of product development work are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			________

38. Synergies from common technical functionalities between products are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

39. Our concepts for products and technologies are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

40. Development of product and technology platforms first from low-end towards high-end price segments is important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

41. Cross-functional product development teams are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

42. Synergies from technological discontinuities are important for…

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

43. Customer specific product development projects are important for …

Technological Competitiveness	Emphasis on Balancing both	Product development Performance	My estimation on the confidence that I could give a reliable answer on this question (0-10)
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7			____________

Appendix 6. Response profile for case company 2

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
	Valid		25	75		Valid	
Use of selected key technologies in product development is important for	13	-4	-5	0	5	11	8
A broad range of technological capabilities is important for	13	-4	-4	-3	1	11	8
Product development engineers in our company are best motivated with goals for the improvement of	13	-3	-4.5	2.5	7	11	8
Our concepts for products and technologies are important for	13	-3	-4	0	4	11	7
Making authorized technology choices on behalf of our customers is important for	13	-3	-4.5	-2	2.5	11	7
Top management of our company is typically prioritizing	13	-3	-3.5	-1	2.5	11	6
Real benefits from the internationalisation of product development work are important for	11	-3	-3	0	3	10	5.5
This product development organisation where we are working is often described as oriented towards	12	-2.5	-3.75	0	3.75	11	7
Customer specific product development projects are important for	12	-2.5	-3	0	3	11	7
Situations where we can use new technologies for existing or traditional kind of products are important for	13	-2	-4.5	0	4.5	11	7
Synergies from technological discontinuities are important for	11	-2	-5	1	6	11	5
The business we are in requires that we can compete with	13	-1	-3.5	0	3.5	11	7
Pilot projects with selected customers are important for	13	0	-5	4	9	11	8
Some long term customer relationships are important for	12	0	-3.5	3.5	7	11	7
Prototyping and testing principles in our organisation are based on	13	0	-3	3	6	11	7
Separation of technology development projects and product development projects is important for	12	0	-3	3	6	11	7
Product development engineers in our company have a strong task orientation for	13	0	-3.5	2	5.5	11	7
Company-wide efforts for "design chain integration" product development activities are important for	12	0	-1.5	3	4.5	11	7
Our company's own sales and distrubution network is important for	13	0	-3	2	5	11	6
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	13	0	0	3.5	3.5	11	7
Wide discussions in our company on the relative position and importance of product development are important for	13	0	-3	0.5	3.5	11	7
Management of the whole R&D project portfolio is important for	13	0	-3	0	3	11	7
Development of product and technology platforms first from low-end towards high-end price segments is important for	11	0	-2	0	2	11	5
Project specific strategies for supplier involvement in product development are important for	11	0	0	2	2	11	4
Achieving "critical mass effect" is important for	12	0.5	-3	4	7	11	6
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	12	1	-3	5	8	11	8
Prioritisation of time based results over cost issues is important for	13	1	-5	3	8	11	7
Our company evaluates and measures its product development activities specially for the development of	13	2	-1.5	4.5	6	11	7

* Response values range from technological competitiveness (-) to product development performance (+) Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 7. Response profile for case company 3

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
	Valid		25	75		Valid	
Use of selected key technologies in product development is important for	5	-5	-6	2	8	5	8
Pilot projects with selected customers are important for	5	-5	-6	2	8	5	8
This product development organisaton where we are working is often described as oriented towards	5	-4	-5	-1.5	3.5	5	8
Product development engineers in our company are best motivated with goals for the improvement of	5	-4	-5	-2	3	5	8
Situations where we can use new technologies for existing or traditional kind of products are important for	5	-4	-5	-2.5	2.5	4	8
Prototyping and testing principles in our organisation are based on	5	-4	-5	-3	2	5	8
Customer specific product development projects are important for	5	-3	-5	2.5	7.5	5	8
The business we are in requires that we can compete with	5	-3	-5	-1	4	5	8
Our concepts for products and technologies are important for	5	-3	-4.5	-1.5	3	5	8
Product development engineers in our company have a strong task orientation for	5	-3	-5.5	-3	2.5	5	8
A broad range of technological capabilities is important for	5	-3	-3.5	-3	0.5	5	8
Making authorized technology choices on behalf of our customers is important for	5	-2	-4.5	1	5.5	5	8
Our company´s own sales and distrubution network is important for	5	-2	-4.5	0	4.5	5	8
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	5	-2	-2	2.5	4.5	5	8
Synergies from technological discontinuities are important for	5	-2	-3	1	4	5	8
Top management of our company is typically prioritizing	5	-2	-3	0	3	5	8
Wide discussions in our company on the relative position and importance of product development are important for	5	-2	-3.5	-1	2.5	5	8
Achieving "critical mass effect" is important for	5	0	-1.5	4	5.5	4	8
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	5	0	0	3	3	5	8
Management of the whole R&D project portfolio is important for	5	0	-2	1	3	5	8
Some long term customer relationships are important for	5	0	0	2.5	2.5	5	8
Development of product and technology platforms first from low-end towards high-end price segments is important for	5	0	0	1	1	5	8
Real benefits from the internationalisation of product development work are important for	5	0	0	2.5	2.5	5	6
Our company evaluates and measures its product development activities specially for the development of	5	1	-1	5.5	6.5	5	8
Separation of technology development projects and product development projects is important for	5	1	-1	3.5	4.5	5	8
Flexibility of the external subcontractors for product development activities is important for	5	2	-3.5	4.5	8	5	8
Cross-functional product development teams are important for	5	2	-1.5	4	5.5	5	8
Project specific strategies for supplier involvement in product development are important for	5	2	-1	4	5	5	7
Prioritisation of time based results over cost issues is important for	5	2	1	3.5	2.5	5	7
Company-wide efforts for "design chain integration" product development activities are important for	5	2	0	2.5	2.5	5	7
Building and use of performance measurement systems is important for	5	3	1.5	4	2.5	5	8

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.

IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 8. Response profile for case company 4

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
	Valid		25	75		Valid	
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	4	-3	-5.5	1.75	7.25	4	6
Real benefits from the internationalisation of product development work are important for	4	-3	-5.5	1.75	7 25	4	3
Use of selected key technologies in product development is important for	4	-2.5	-5	1.5	6.5	4	6
Product development engineers in our company have a strong task orientation for	4	-2.5	-3	2.5	5.5	4	6
Pilot projects with selected customers are important for	4	-2.5	-4.5	1	5.5	4	4.5
best motivated with goals for the improvement of	4	-2	-5.75	-0.5	5.25	4	5
A broad range of technological capabilities is important for	4	-1	-2.75	2 25	5	4	5
Separation of technology development projects and product development projects is important for	4	-1	-5	3	8	4	4 5
Prototyping and testing principles in our organisation are based on	4	-1	-2.75	1.5	4.25	4	5.5
Synergies from technological discontinuities are important for	4	-1	-4.25	0	4.25	4	4
The business we are in requires that we can compete wi	4	0	-2.25	0	2 25	4	6.5
Our concepts for products and technologies are importa	4	0	-3	1.5	4 5	4	6
Some long term customer relationships are important fo	4	0	0	2.25	2.25	4	6
Our company's own sales and distrubution network is important for	4	0	-1.5	1.5	3	4	4.5
Building and use of performance measurement systems is important for	4	0	0	2.25	2.25	4	4.5
Management of the whole R&D project portfolio is important for	4	0	0	0	0	4	4.5
Cross-functional product development teams are important for	4	0	-3	0	3	4	4
Company-wide efforts for "design chain integration" product development activities are important for	4	0	0	2 25	2.25	4	3.5
Making authorized technology choices on behalf of our customers is important for	4	0	-0.75	0	0.75	4	3
Project specific strategies for supplier involvement in product development are important for	4	0	-1.5	0	1.5	4	1.5
Wide discussions in our company on the relative position	4	0	0	1.5	1.5	4	1.5
Situations where we can use new technologies for existing or traditional kind of products are important for	4	0.5	-2	3.75	5.75	4	6.5
This product development organisaton where we are working is often described as oriented towards	4	0 5	-2.25	3.25	5.5	4	4
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	4	1	-1.5	4.25	5 75	4	6.5
Top management of our company is typically prioritizing	4	1	-3	4.25	7 25	4	5.5
Flexibility of the external subcontractors for product development activities is important for	4	1	0	3.5	3.5	4	6.5
Development of product and technology platforms first from low-end towards high-end price segments is important for	4	1	-1.5	2.75	4.25	4	5.5
Our company evaluates and measures its product development activities specially for the development of	4	1.5	-2.25	4.5	6.75	4	4
Prioritisation of time based results over cost issues is important for	4	1.5	0	3	3	4	5
Customer specific product development projects are important for	4	2	0	6.25	6.25	4	4.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them. IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 9. Raw data from case company 5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
	Valid		25	75		Valid	
Making authorized technology choices on behalf of our customers is important for	6	-4	-5.25	1.25	6.5	6	5.5
Situations where we can use new technologies for existing or traditional kind of products are important for	6	-3.5	-5	-2	3	6	6.5
Product development engineers in our company have a strong task orientation for	6	-3	-5.25	2.5	7.75	6	7
The business we are in requires that we can compete with	6	-2	-4	3.75	7.75	6	6.5
Pilot projects with selected customers are important for	6	-1.5	-5.25	1.25	6.5	6	7
A broad range of technological capabilities is important for	6	-1.5	-4.5	0.5	5	6	6.5
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	6	-1	-4.5	4.75	9.25	6	7
Prototyping and testing principles in our organisation are based on	6	-1	-6.25	2.25	8.5	6	5.5
Product development engineers in our company are best motivated with goals for the improvement of	6	0	-6.25	3	9.25	6	7.5
Synergies from common technical functionalities between products are important for	6	0	-3.5	6	9.5	6	6
Project specific strategies for supplier involvement in product development are important for	6	0	-2.75	4	6.75	6	5
Synergies from technological discontinuities are important for	6	0	-1.25	0.5	1.75	6	6
Our concepts for products and technologies are important for	6	0	-0.75	3.75	4.5	6	5
Our company evaluates and measures its product development activities specially for the development of	6	0	-1.25	3	4.25	6	5
Separation of technology development projects and product development projects is important for	6	0	0	0.25	0.25	6	5
Real benefits from the internationalisation of product development work are important for	6	0	-1.5	1.25	2.75	6	3.5
Company-wide efforts for "design chain integration" product development activities are important for	6	0.5	-1.25	3	4.25	6	5.5
This product development organisaton where we are working is often described as oriented towards	6	1	-0.75	3.5	4.25	6	5.5
Flexibility of the external subcontractors for product development activities is important for	6	1.5	-6	4	10	6	7.5
Some long term customer relationships are important for	6	1.5	-1	4.25	5.25	6	6
Cross-functional product development teams are important for	6	1.5	-0.5	4.75	5.25	6	5.5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	6	1.5	0	3.75	3.75	6	6.5
Achieving "critical mass effect" is important for	6	2	-1.25	4	5.25	6	6
Prioritisation of time based results over cost issues is important for	6	2.5	-0.25	6	6.25	6	6
Wide discussions in our company on the relative position and importance of product development are important for	6	3.5	-0.75	5.5	6.25	6	7.5
Customer specific product development projects are important for	6	3.5	-2.25	4.5	6.75	6	7
Management of the whole R&D project portfolio is important for	6	3.5	-0.25	6	6.25	6	6.5
Development of product and technology platforms first from low-end towards high-end price segments is important for	6	3.5	-3	5	8	6	5
Integrated timing and scheduling for internationally distributed product development teams is important for	6	3.5	1.25	4.25	3	6	7
Our company's own sales and distribution network is important for	6	3.5	1.5	4	2.5	6	5
Use of selected key technologies in product development is important for	6	4	-1.5	5.25	6.75	6	6.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 10. Ordered data sets for case company I

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	8	-1	-6 75	3 75	10 5	8	8
Cross-functional product development teams are important for	8	0	-3 75	5 75	9 5	8	7
Pilot projects with selected customers are important for	8	0	-4 25	2 5	6 75	8	7
Product development engineers in our company have a strong task orientation for	8	1 5	-5 25	3 75	9	8	7
Prototyping and testing principles in our organisation are based on	8	1 5	-1 5	5	6 5	8	7
Situations where we can use new technologies for existing or traditional kind of products are important for	7	2	-3	5	8	7	7
Flexibility of the external subcontractors for product development activities is important for	8	2	-2 25	4	6 25	8	7
Building and use of performance measurement systems is important f	8	3	0	5 75	5.75	8	7 5
Our company's own sales and distrubution network is important for	7	5	-3	6	9	7	7

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Achieving "critical mass effect" is important for	8	-3	-4 75	1 5	6 25	8	6
Top management of our company is typically prioritizing	8	-2	-4 75	4	8 75	8	6 5
Project specific strategies for supplier involvement in product development are important for	8	-2	-4	1 5	5 5	8	6
Separation of technology development projects and product development projects is important for	8	0	-3 75	3 75	7 5	8	6 5
Development of product and technology platforms first from low-end towards high-end price segments is important for	8	1 5	-2 25	5 25	7 5	8	6
This product development organisation where we are working is often described as oriented towards	8	2	-5	4 75	9.75	8	6 5
Some long term customer relationships are important for	8	3 5	-2 75	5	7 75	8	6
Integrated timing and scheduling for internationally distributed product development teams is important for	8	5	0	6	6	8	6 5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		75	75		Valid	
A broad range of technological capabilities is important for	8	-5	-5 75	-0 75	5	8	7
Management of the whole R&D project portfolio is important for	8	0	-2 25	0	2 25	8	8
Wide discussions in our company on the relative position and importance of product development are important for	8	0	-3 75	0	3 75	8	7 5
Use of selected key technologies in product development is important for	8	0	-1 5	1.5	3	0	7
Our concepts for products and technologies are important for	8	0	0	0	0	6	7
The business we are in requires that we can compete with	0	1	0	3 75	3 75	8	7 5
Our company evaluates and measures its product development activities specially for the development of	8	3 5	0 75	5 75	5	8	7 5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc) is important for	8	4	0 75	6	5 25	6	8
Prioritisation of time based results over cost issues is important for	8	4	0 5	5.5	5	0	7

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
Product development engineers in our company are best motivated with goals for the improvement of	8	-4 5	-5 75	-2 25	3 5	8	6 5
Synergies from technological discontinuities are important for	7	-3	-4	0	4	7	5
Making authorized technology choices on behalf of our customers is important for	8	-1 5	-4 75	0	4.75	8	6
Real benefits from the internationalisation of product development work are important for	8	-1 5	-4 75	0	4 75	8	5 5
Company-wide efforts for "design chain integration" product development activities are important for	8	0.5	-2 25	1 75	4	8	6
Customer specific product development projects are important for	8	2.5	0	4 75	4 75	8	6 5
Synergies from common technical functionalities between products are important for	8	5	4	5	1	8	6 5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.

IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 11. Ordered data sets for case company 2

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Use of selected key technologies in product development is important for	13	-4	-5	0	5	11	8
Product development engineers in our company are best motivated with goals for the improvement of	13	-3	-4.5	2.5	7	11	8
Situations where we can use new technologies for existing or traditional kind	13	-2	-4.5	0	4.5	11	7
Pilot projects with selected customers are important for	13	0	-5	4	9	11	8
Some long term customer relationships are important for	12	0	-3.5	3.5	7	11	7
Prototyping and testing principles in our organisation are based on	13	0	-3	3	6	11	7
Separation of technology development projects and product development projects is important for	12	0	-3	3	6	11	7
Product development engineers in our company havea strong task orientation	13	0	-3.5	2	5.5	11	7
Company-wide efforts for "design chain integration" product development activities are important for	12	0	-1.5	3	4.5	11	7
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	12	1	-3	5	8	11	8
Prioritisation of time based results over cost issues is important for	13	1	-5	3	8	11	7
Our company evaluates and measures its product development activities specially for the development of	13	2	-1.5	4.5	6	11	7
Building and use of performance measurement systems is important for	13	3	-0.5	4.5	5	11	8
Synergies from common technical functionalities between products are important for	13	3	-1	5	6	11	7
Integrated timing and scheduling for internationally distributed product development teams is important for	12	3.5	0.5	5.75	5.25	11	7

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Synergies from technological discontinuities are important for	11	-2	-5	1	6	11	5
Our company's own sales and distrubution network is important for	13	0	-3	2	5	11	6
Achieving "critical mass effect" is important for	12	0.5	-3	4	7	11	6

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
A broad range of technological capabilities is important for	13	-4	-4	-3	1	11	8
Our concepts for products and technologies are important for	13	-3	-4	0	4	11	7
Making authorized technology choices on behalf of our customers is important for	13	-3	-4.5	-2	2.5	11	7
This product development organisaton where we are working is often described as oriented towards	12	-2.5	-3.75	0	3.75	11	7
Customer specific product development projects are important for	12	-2.5	-3	0	3	11	7
The business we are in requires that we can compete with	13	-1	-3.5	0	3.5	11	7
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	13	0	0	3.5	3.5	11	7
Wide discussions in our company on the relative position and importance of product development are important for	13	0	-3	0.5	3.5	11	7
Management of the whole R&D project portfolio is important for	13	0	-3	0	3	11	7
Flexibility of the external subcontractors for product development activities is important for	13	3	1	4.5	3.5	11	8

	Statement responses					Confidence responses	
	N	Median	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
Top management of our company is typically prioritizing	13	-3	-3.5	-1	2.5	11	6
Real benefits from the internationalisation of product development work are important for	11	-3	-3	0	3	10	5.5
Development of product and technology platforms first from low-end towards high-end price segments is important for	11	0	-2	0	2	11	5
Project specific strategies for supplier involvement in product development are important for	11	0	0	2	2	11	4
Cross-functional product development teams are important for	13	3	0	3	3	11	6

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 12. Ordered data sets for case company 3

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Use of selected key technologies in product development is important for	5	-5	-6	2	8	5	8
Pilot projects with selected customers are important for	5	-5	-6	2	8	5	0
This product development organisaton where we are working is often described as oriented towards	5	-4	-5	-1.5	3.5	5	0
Product development engineers in our company are best motivated with goals for the improvement of	5	-4	-5	-2	3	5	8
Customer specific product development projects are important for	5	-3	-5	2.5	7.5	5	8
The business we are in requires that we can compete with	5	-3	-5	-1	4	5	8
Our concepts for products and technologies are important for	5	-3	-4.5	-1.5	3	5	8
Making authorized technology choices on behalf of our customers is important for	5	-2	-4.5	1	5.5	5	8
Our company's own sales and distrubution network is important for	5	-2	-4.5	0	4.5	5	8
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	5	-2	-2	2.5	4.5	5	8
Synergies from technological discontinuities are important for	5	-2	-3	1	4	5	8
Top management of our company is typically prioritizing	5	-2	-3	0	3	5	0
Achieving "critical mass effect" is important for	5	0	-1.5	4	5.5	4	8
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	5	0	0	3	3	5	8
Management of the whole R&D project portfolio is important for	5	0	-2	1	3	5	8
Our company evaluates and measures its product development activities specially for the development of	5	1	-1	5.5	6.5	5	8
Separation of technology development projects and product development projects is important for	5	1	-1	3.5	4.5	5	8
Flexibility of the external subcontractors for product development activities is important for	5	2	-3.5	4.5	8	5	8
Cross-functional product development teams are important for	5	2	-1.5	4	5.5	5	8
Integrated timing and scheduling for internationally distributed product development teams is important for	5	5	0	5	5	5	8

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Project specific strategies for supplier involvement in product development are important for	5	2	-1	4	5	5	7

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
Situations where we can use new technologies for existing or traditional kind of products are important for	5	-4	-5	-2.5	2.5	4	8
Prototyping and testing principles in our organisation are based on	5	-4	-5	-3	2	5	8
Product development engineers in our company have a strong task orientation for	5	-3	-5.5	-3	2.5	5	6
A broad range of technological capabilities is important for	5	-3	-3.5	-3	0.5	5	8
Wide discussions in our company on the relative position and importance of product development are important for	5	-2	-3.5	-1	2.5	5	8
Some long term customer relationships are important for	5	0	0	2.5	2.5	5	8
Development of product and technology platforms first from low-end towards high-end price segments is important for	5	0	0	1	1	5	8
Building and use of performance measurement systems is important	5	3	1.5	4	2.5	5	8
Synergies from common technical functionalities between products are important for	5	3	2.5	4	1.5	5	8

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		75	75		Valid	
Real benefits from the internationalisation of product development work are important for	5	0	0	2.5	2.5	5	6
Prioritisation of time based results over cost issues is important for	5	2	1	3.5	2.5	5	7
Company-wide efforts for "design chain integration" product development activities are important for	5	2	0	2.5	2.5	5	7

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them. IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 13. Ordered data sets for case company 4

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Continuous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	4	-3	-5.5	1.75	7.25	4	6
Use of selected key technologies in product development is important for	4	-2.5	-5	1.5	6.5	4	8
Product development engineers in our company have a strong task orientation for	4	-2.5	-3	2.5	5.5	4	6
Product development engineers in our company are best motivated with goals for the improvement of	4	-2	-5.75	-0.5	5.25	4	5
A broad range of technological capabilities is important for	4	-1	-2.75	2.25	5	4	5
Situations where we can use new technologies for existing or traditional kind of products are important for	4	0.5	-2	3.75	5.75	4	6.5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	4	1	-1.5	4.25	5.75	4	6.5
Top management of our company is typically prioritizing	4	1	-3	4.25	7.25	4	5.5
Synergies from common technical functionalities between products are important for	4	3.5	-1.5	4.75	6.25	4	6

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Real benefits from the internationalisation of product development work are important for	4	-3	-5.5	1.75	7.25	4	3
Pilot projects with selected customers are important for	4	-2.5	-4.5	1	5.5	4	4.5
Separation of technology development projects and product development projects is important for	4	-1	-5	3	8	4	4.5
This product development organisaton where we are working is often described as oriented towards	4	0.5	-2.25	3.25	5.5	4	4
Our company evaluates and measures its product development activities specially for the development of	4	1.5	-2.25	4.5	6.75	4	4
Customer specific product development projects are important for	4	2	0	6.25	6.25	4	4.5
Integrated timing and scheduling for internationally distributed product development teams is important for	4	2.5	0.5	5.25	4.75	4	4.5
Achieving "critical mass effect" is important for	3	3	0	7	7	3	4

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
Prototyping and testing principles in our organisation are based on	4	-1	-2.75	1.5	4.25	4	5.5
The business we are in requires that we can compete with	4	0	-2.25	0	2.25	4	6.5
Our concepts for products and technologies are important for	4	0	-3	1.5	4.5	4	6
Some long term customer relationships are important for	4	0	0	2.25	2.25	4	6
Our company's own sales and distrubution network is important for	4	0	-1.5	1.5	3	4	4.5
Building and use of performance measurement systems is important for	4	0	0	2.25	2.25	4	4.5
Management of the whole R&D project portfolio is important for	4	0	0	0	0	4	4.5
Flexibility of the external subcontractors for product development activities is important for	4	1	0	3.5	3.5	4	6.5
Development of product and technology platforms first from low-end towards high-end price segments is important for	4	1	-1.5	2.75	4.25	4	5.5
Prioritisation of time based results over cost issues is important for	4	1.5	0	3	3	4	5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
Synergies from technological discontinuities are important for	4	-1	-4.25	0	4.25	4	4
Cross-functional product development teams are important for	4	0	-3	0	3	4	4
Company-wide efforts for "design chain integration" product development activities are important for	4	0	0	2.25	2.25	4	3.5
Making authorized technology choices on behalf of our customers is important for	4	0	-0.75	0	0.75	4	3
Project specific strategies for supplier involvement in product development are important for	4	0	-1.5	0	1.5	4	1.5
Wide discussions in our company on the relative position and importance of product development are important for	4	0	0	1.5	1.5	4	1.5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale)

Appendix 14. Ordered data sets for case company 5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Craft practices (High equivocality, low uncertainty)	Valid		25	75		Valid	
Product development engineers in our company have a strong task orientation for	6	-3	-5.25	2.5	7.75	6	7
The business we are in requires that we can compete with	6	-2	-4	3.75	7.75	6	6.5
Pilot projects with selected customers are important for	6	-1.5	-5.25	1.25	6.5	6	7
Continous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	6	-1	-4.5	4.75	9.25	6	7
Product development engineers in our company are best motivated with goals for the improvement of	6	0	-6.25	3	9.25	6	7.5
Flexibility of the external subcontractors for product development activities is important for	6	1.5	-6	4	10	6	7.5
Wide discussions in our company on the relative position and importance of product development are important for	6	3.5	-0.75	5.5	6.25	6	7.5
Customer specific product development projects are important for	6	3.5	-2.25	4.5	6.75	6	7
Management of the whole R&D project portfolio is important for	6	3.5	-0.25	6	6.25	6	6.5
Use of selected key technologies in product development is important for	6	4	-1.5	5.25	6.75	6	6.5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Non-routine practices (High equivocality, high uncertainty)	Valid		25	75		Valid	
Making authorized technology choices on behalf of our customers is important for	6	-4	-5.25	1.25	6.5	6	5.5
Prototyping and testing principles in our organisation are based on	6	-1	-6.25	2.25	0.5	6	5.5
Synergies from common technical functionalities between products are important for	6	0	-3.5	6	9.5	6	6
Project specific strategies for supplier involvement in product development are important for	6	0	-2.75	4	6.75	6	5
Some long term customer relationships are important for	6	1.5	-1	4.25	5.25	6	6
Cross-functional product development teams are important for	6	1.5	-0.5	4.75	5.25	6	5.5
Achieving "critical mass effect" is important for	6	2	-1.25	4	5.25	6	6
Prioritisation of time based results over cost issues is important for	6	2.5	-0.25	6	6.25	6	6
Development of product and technology platforms first from low-end towards high-end price segments is important for	6	3.5	-3	5	8	6	5

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Routine practices (Low equivocality, low uncertainty)	Valid		25	75		Valid	
Situations where we can use new technologies for existing or traditional kind of products are important for	6	-3.5	-5	-2	3	6	6.5
A broad range of technological capabilities is important for	6	-1.5	-4.5	0.5	5	6	6.5
Synergies from technological discontinuities are important for	6	0	-1.25	0.5	1.75	6	6
Company-wide efforts for "design chain integration" product development activities are important for	6	0.5	-1.25	3	4.25	6	5.5
This product development organisation where we are working is often described as oriented towards	6	1	-0.75	3.5	4.25	6	5.5
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	6	1.5	0	3.75	3.75	6	6.5
Integrated timing and scheduling for internationally distributed product development teams is important for	6	3.5	1.25	4.25	3	6	7
Building and use of performance measurement systems is important f	6	4.5	2.25	5.5	3.25	6	6

	Statement responses					Confidence responses	
	N	Median*	Percentiles		IQR	N	Median
Engineering practices (Low equivocality, high uncertainty)	Valid		25	75		Valid	
Our concepts for products and technologies are important for	6	0	-0.75	3.75	4.5	6	5
Our company evaluates and measures its product development activities specially for the development of	6	0	-1.25	3	4.25	6	5
Separation of technology development projects and product development projects is important for	6	0	0	0.25	0.25	6	5
Real benefits from the internationalisation of product development work are important for	6	0	-1.5	1.25	2.75	6	3.5
Our company's own sales and distrubution network is important for	6	3.5	1.5	4	2.5	6	5
Top management of our company is typically prioritizing	6	4	0	4.25	4.25	6	5

* Response values range from technological competitiveness (-) to product development performance (+). Zero value (0) marks more emphasis on balance between them.
IQR (Inter quartile range, difference between 75% and 25% quartile values which provides a statistical estimate on the dispersion of data originating from an ordinal response scale.)

Appendix 15. Spearman's rank order correlation statistics on traditional survey variables with Likert-scale

	Case 1			Case 2			All cases (1-5)		
Traditional survey variables with Likert-scale	**Corr.**	**Sign.**	**N**	**Corr.**	**Sign.**	**N**	**Corr.**	**Sign.**	**N**
Improved product success rate and higher customer satisfaction	-0.124	0.77	8	0.576	0.063	11	0.360*	0.043	32
Product developed at target (time, quality and cost objectives)	0.217	0.605	8	0.694*	0.018	11	0.491**	0.004	32
Faster-to-market	-0.336	0.416	8	0.654*	0.029	11	0.215	0.237	32
Improved profit performance (sales and margins)	-0.32	0.94	8	0.434	0.182	11	0.145	0.429	32
A learning tool: educate our people	0.556	0.153	8	0.132	0.735	11	0.486**	0.006	30
Improved cooperations and coordination among people	0.606	0.111	8	0.444	0.172	11	0.559**	0.001	32
Fewer errors; less recycling; less redesign	0.365	0.374	8	0.771**	0.005	11	0.380*	0.032	32
Improved communication	0.354	0.389	8	0.296	0.376	11	0.513**	0.003	32
Better project control	0.817*	0.013	8	0.075	0.828	11	0.386*	0.029	32
Improved customer acceptance for new products	-0.475	0.234	8	0.614*	0.044	11	0.481**	0.005	32

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Appendix 16. Spearman's rank order correlation statistics on new survey variables with new response scale

New survey variables with new response scale	Case 1			Case 2			All cases (1-5)		
	Corr.	Sign.	N	Corr.	Sign.	N	Corr.	Sign.	N
Top management of our company is typically prioritizing	0.475	0.234	8	-0.301	0.369	11	0.014	0.937	34
The business we are in requires that we can compete with	-0.362	0.378	8	0.299	0.373	11	-0.009	0.958	34
Our company's own sales and distribution network is important for	0.33	0.469	7	-0.45	0.165	11	-0.17	0.345	33
Use of selected key technologies in product development is important for	-0.138	0.744	8	-0.226	0.505	11	-0.297	0.088	34
Situations where we can use new technologies for existing or traditional kind of products are important for	-0.217	0.64	7	0.012	0.972	11	-0.212	0.245	32
Achieving "critical mass effect" is important for	-0.212	0.614	8	0.363	0.302	10	0.314	0.086	31
Taking care of both product development and process development (manufacturing, assembly, delivery, distribution etc.) is important for	-0.23	0.585	8	0.314	0.377	10	0.111	0.539	33
Prioritisation of time based results over cost issues is important for	-0.387	0.343	8	0	1	11	0.144	0.417	34
Prototyping and testing principles in our organisation are based on	0.62	0.101	8	-0.32	0.338	11	-0.083	0.643	34
Continuous increase in know-how for advanced technologies and computerized tools for product development methodologies is important for	0.689	0.059	8	0.002	0.994	11	0.055	0.755	34
Pilot projects with selected customers are important for	-0.141	0.739	8	-0.329	0.323	11	-0.184	0.297	34
Some long term customer relationships are important for	-0.454	0.258	8	0.171	0.637	10	-0.139	0.44	33
Making authorized technology choices on behalf of our customers is important for	-0.324	0.434	8	-0.285	0.395	11	-0.454**	0.007	34
This product development organisation where we are working is often described as oriented towards	-0.765*	0.021	8	0.088	0.809	10	-0.354*	0.043	33
Product development engineers in our company have a strong task orientation for	-0.325	0.432	8	-0.333	0.317	11	-0.425*	0.012	34
Product development engineers in our company are best motivated with goals for the improvement of	-0.444	0.271	8	-0.531	0.093	11	-0.557**	0.001	34
Management of the whole R&D project portfolio is important for	0.566	0.143	8	-0.115	0.737	11	0.073	0.682	34
Building and use of performance measurement systems is important for	0.176	0.677	8	0.177	0.602	11	0.106	0.549	34
Our company evaluates and measures its product development activities especially for the development of	0.859**	0.006	8	0.301	0.368	11	0.514**	0.002	34
Flexibility of the external subcontractors for product development activities is important for	0.242	0.564	8	0.748**	0.008	11	0.089	0.616	34
Project specific strategies for supplier involvement in product development are important for	-0.820*	0.013	8	0.307	0.422	9	-0.07	0.705	32
Company-wide efforts for "design chain integration" product development activities are important for	-0.27	0.518	8	0.077	0.832	10	0.025	0.89	33
Wide discussions in our company on the relative position and importance of product development are important for	0.098	0.817	8	0.005	0.988	11	-0.052	0.772	34
A broad range of technological capabilities is important for	-0.872**	0.005	8	-0.096	0.779	11	-0.450**	0.008	34
Separation of technology development projects and product development projects is important for	0.234	0.576	8	0.446	0.197	10	0.193	0.282	33
Integrated timing and scheduling for internationally distributed product development teams is important for	-0.51	0.197	8	0.546	0.103	10	-0.019	0.917	33
Real benefits from the internationalisation of product development work are important for	-0.381	0.351	8	-0.434	0.244	9	-0.342	0.056	32
Synergies from common technical functionalities between products are important for	0.545	0.163	8	0.445	0.17	11	0.376*	0.029	34
Our concepts for products and technologies are important for	0	1	8	0.165	0.627	11	-0.136	0.444	34
Development of product and technology platforms first from low-end towards high-end price segments is important for	0.546	0.162	8	-0.009	0.982	9	0.152	0.405	32
Cross-functional product development teams are important for	-0.101	0.811	8	-0.062	0.857	11	0.211	0.231	34
Synergies from technological discontinuities are important for	-0.715	0.071	7	-0.263	0.484	9	-0.343	0.059	31
Customer specific product development projects are important for	0.217	0.605	8	0.121	0.74	10	0.12	0.507	33

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)