A process innovation model at Company ABC R&D

Developing an innovation model for explorative and exploitative process innovations in a manufacturing environment.

UNIVERSITEIT TWENTE.

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Master Thesis

Steven Keuper
s1053949
University of Twente
Business Administration

Supervisory committee
Internal supervisors: Dr. Ir. Klaasjan Visscher & Matthias de Visser Msc.
External supervisor: .. ..

Preface

This thesis is written as the graduation assignment for my masters program Business Administration at the University of Twente. Looking for a company that was able to provide a setting and problem that would enable myself to further broaden my knowledge about innovation management, Company ABC R&D offered this option. In this report the results of a study about the process innovation management at Company ABC R&D is presented.

First of all I would like to thank all employees at Company ABC that have contributed to the end result of this study. In specific I would like to thank Dr. Ir. .. .. for answering all my questions and providing his knowledge about Company ABC and innovation management in the multiple conversations we had during the study. I really enjoyed working in such an innovative environment with colleagues that do not only work on exciting technologies but were also very welcoming.

From the University of Twente I would like to thank Dr. Ir. Klaasjan Visscher and Matthias de Visser Msc for the guidance and useful feedback. Finally I would like to thank my parents, my girlfriend Wenke and roommate Niek for supporting and encouraging me.

Steven Keuper
Enschede, 23 august 2012

Management summary

Innovation is a well studied and described topic in which process innovation is a much less mature topic compared to new product development (NPD). In particular in manufacturing, process development is a key part of the total innovation portfolio. The management and structures of these innovation processes is a well studied topic but again primarily for NPD projects. In this thesis the topic of structuring process innovation projects is researched for Company ABC, and in specific Company ABC R&D.

Company ABC R&D is responsible for both product and process innovation projects of the entire Company ABC organization. For the product innovation projects the R&D organization has a well defined and in use stage-gate model. For the process innovation projects no formal model is in use and the management of R&D questions how such a structure or model should be designed. Therefore this thesis will focus on the question: *"How can Company ABC Research and Development structure his explorative and exploitative process innovation projects effectively?"* In this question the context of the innovation, more explorative or more exploitative, is specifically mentioned because out of NPD theory there can be expected that this context influences the best possible structure for an innovation project.

Process innovations are modeled in theory in multiple different ways aiming on different topic from process innovations in general to process innovations in the production environment of a manufacturing business. This thesis selected seven models that suit the situation at Company ABC best. The topics iterations, sources of process innovation, phases and structure, measurements and targets and, the influence of exploration and exploitation cover the elements that contribute to a successful process innovation model, which is defined as "enables the project to get started" and "perform on time, budget and quality specifications". The central conclusion out of the theoretical framework is that process innovations need a more iterative structure in which production knowledge and measurements are used as input to new innovations. A different set of sources should be considered with, among others, suppliers, NPD projects, measurements, production staff and R&D as main contributors. The phasing of the model is proposed to be slightly different from a NPD model with a focus on connecting the production environment to R&D and excluding a business case phase out of the model. Measurements are a large contributor to new innovation projects and should create the foundation for the target setting of process innovation projects. The influence of exploration and exploitation is a topic that has received limited attention in literature but technology seems to be a major driver in explorative projects in comparison with current production figures for exploitative projects.

The empirical research in this thesis consist out of a innovation portfolio overview that is created by a survey conducted at R&D and a case study of three innovation projects with a large share of process innovation included. For this case study multiple employees involved in the projects are interviewed.

The portfolio overview showed that in comparison with NPD projects, process innovations perform lower on the parameters "performing on budget" and "performing on schedule" but achieved a similar, high performance on "overall performance" and "projects meets quality specs". Exploitative innovations underperform in comparison with explorative innovations on all constructs but in particular on "performing on budget". About the innovation portfolio in general can be stated that in the last six

years, the number of projects increases, the average size decreases, the number of process innovations obviously is lower than the number of product innovations and is still decreasing.

The cases studied gave some very useful insights in the current structures and management of process innovation projects at R&D. Currently no structures are in place to get current production information and knowledge back to R&D as a source of new process developments. This absence of production feedback creates a very reactive approach to process innovations. Competences on a specific field are found to be the most important source of new innovations ideas. With regard to structure, hybrid projects are expected to perform better when separated in a product and a process innovation project. Currently process innovation is the responsibility of multiple parts of Company ABC which hampers the sharing of knowledge and best-practices. Target setting is currently limited or in the grid of a NPD model which potentially obstructs in particularly explorative process innovations to continue. Overall the picture emerges that currently very little room is available to perform really explorative projects. This observation is probably closely related to the target setting which is currently always quantitative and time driven from the start of project. Secondly it can be concluded that Company ABC as an organization has a lot of knowledge on multiple production process but this knowledge is often scattered through the organization. This situation contributes to the fact the projects that should be highly exploitative to Company ABC as an complete organization are highly explorative to the departments or employees involved because not all knowledge in the organization is combined.

Based on the existing theory on this topic, the portfolio overview and the case studies the following recommendations are created:

1. Ensure that knowledge gained during production returns to R&D to potentially initiate new process developments and to share innovations and best-practices to other operating companies.

2. Idea generation should be more structured and be based on different sources when compared to product innovation. Measurements of the current processes and, knowledge and competences are important sources. R&D can have a more proactive role in this phase.

3. Target setting is best be done in two steps. First for boundary setting reasons to enable the feasibility check. Secondly, after feasibility and risk are mapped, targets covering KPI improvement or product requirements can be set.

4. Central coordination of process innovations. To ensure the spread of best practices and to prevent that an existing process in one operating company is going to be developed / improved again in another operating company. R&D should be in the lead because of the available knowledge and competences, potentially supported by ABCD.

5. The setting of the innovation, being more exploitative or explorative in nature, should be assessed upfront. The setting of a process innovations give reason for some adjustments to the model concerning phasing, sourcing and target setting.

Based on these recommendations a visual reflection of the constructed "innovation model for process innovation" can be presented.

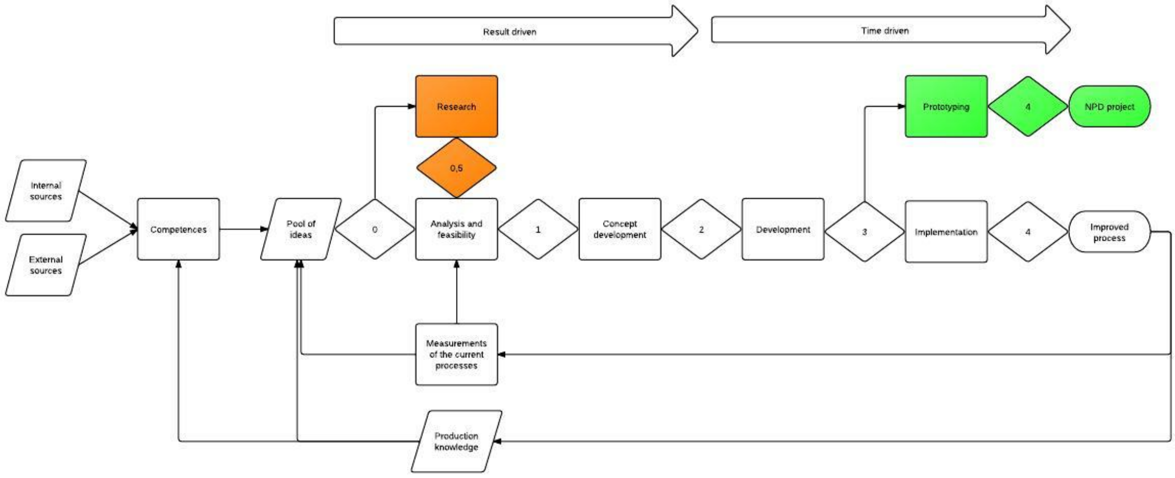

Figure 1: Process Innovation model for Company ABC R&D

The proposed model has a core of four phases and five gates and a extra phase and gate for more explorative projects. Another extra phase and gate is created for process innovations that serve as input to a NPD project. The model is completed with an iterative loop of production measurements and knowledge that serve as input to the competences and pool of ideas at R&D.

This thesis provides a process innovation model that combines special features for process innovation with a basic structure that is similar to the classic stage-gate model. This setup can create leads for scholars in order to create models that are suitable for specific situation (e.g. process innovations) and at the same time are easy to implemented for businesses. Another implications for theory can be found in fact that this thesis distinguished and researched the differences in innovation modeling between exploitative and explorative process innovations. This was not yet done in theory and can give leads for scholars to research these differences in more projects and other types of businesses.

Based on all of the above, the answer to the research question must be: by implementing the model constructed in this thesis and applying the recommendations, Company ABC R&D is prepared to bring the topic of process innovations to a new level and by this means bring the Company ABC organization as a whole to a better position in innovation in the production environment.

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1. Introduction

The company of interest in this research is Company ABC NV and particularly the department Research and Development located in Location XYZ. (N.V. Company ABC, 2011)

The department Research and Development(R&D) is part of the business unit Marketing and Technology, employs over .. people and has as core responsibilities and competences: product development, process development, material knowledge, laboratory services, patent and trademark services, marketing know-how and the application, standardization and certification of new products. (R.D. Company ABC, 2011)

Company ABC R&D is covering both product and process innovation projects and has a well documented and in use stage-gate model, as shown in Figure 2. This model is primarily used for the product innovation projects while process innovation projects follow a less structured approach. A product innovation is here defined (Oslo Manual, 3rd edition, 2005) as the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. An example of a product innovation within Company ABC R&D are …. A process innovation can be defined (Oslo Manual, 3rd edition, 2005) as the implementation of a new or significantly improved production or delivery method. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products. An example of a process innovation within Company ABC R&D is the technical enabling of using recycled plastics in the production of new products.

Figure 2: Stage-gate model of Company ABC R&D

Out of a preliminary research in which all innovation projects of the last five years are categorized can be concluded that about 18% of the innovations projects within Company ABC R&D can be described as an process innovations to at least a large extent. All of these process innovations are currently developed as part of an New Product Development project or without the use of any formal structure. Besides this relative low amount of process innovations the management of Company ABC R&D considers the innovation process as not enough structured and controlled. Practice shows that this low amount of control gives problems in multiple areas. First process innovations are initiated at multiple places and are not the responsibility of a department or function. Secondly it is not clear who is responsible for the overall project and decision making which can potentially result in stagnation of the process. Thirdly the execution of process innovation projects is not always clearly assigned. Finally the steps or activities that should be part of a process innovation are not defined which potentially can result in executing useless activities or missing key steps in the process. Combining the potential threats of this current way of managing process innovations creates the urgency at the management of Company ABC R&D to achieve more structure and control in this part of the innovation portfolio.

Reducing costs and increasing production efficiency is a recognized point of focus for the management of Company ABC. Increasing the number and effectiveness of process innovations is therefore one of the points of focus for the R&D department. Combining the threats of the unstructured innovation process and the current focus on increasing the number and effectiveness of process innovations are the main reasons to start this research.

When exploring the innovation management literature one particular topic stands out on both the amount of discussion as relevance to the topic of interest in this research. This discussion states that explorative projects (new products/processes/markets whereby the feasibility and market potential is uncertain (March,1991)) and exploitative projects (serving by extending/modifying existing services and/or products (March,1991)) are distinct types with specific characteristics that should be taken into account when organized for, especially when both types should be combined (Cooper, Edgett and Kleinschmidt, 2002; Phillips, Noke, Bessant and Lamming , 2004). In order to create an as complete as possible overview, exploration and exploitation are taken into account as variants on process innovation.

In summary this research only focuses on process innovations and takes both explorative as exploitative settings into account. To visualize the scope of this research an matrix is created (Figure 3) in which grey indicates the parts that are within the scope of the research.

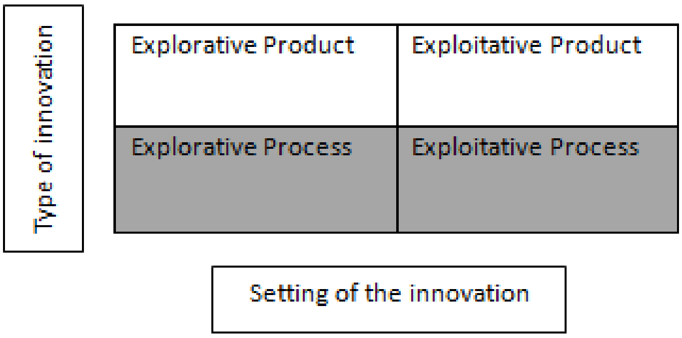


Figure 3: Scope of this research

Researching the innovation model needed to effectively manage process innovations, both explorative and exploitative of nature, has a practical and a scientific relevance. In literature much attention has been paid on the different organizational set-ups required for more explorative vs. more exploitative settings (Phillips et al, 2004; Birkinshaw and Gibson, 2004; Jansen, van den Bosch and Volberda, 2005) but very little research had been done on the same topics for process innovations. Besides this specific gap overall can be stated that very little attention is paid on innovation models specifically suited to process innovations. Although much less literature is present about this topic, according to Ettlie and Reza (1992) “every year, billions of dollars are spent on process innovation in manufacturing” and according to Simonetti, Archibugi and Evangelista (1995), depending on the definition up to 72% of all innovations can be defined as process innovations. This important role of process innovations in the total innovation portfolio of a company combined with the lack of theory creates an opportunity to contribute to this topic. Besides the contribution that can be made to the general literature about innovation models for process innovations we will try to explore a topic that is not covered by current innovation literature, that of the differences in innovations models required for explorative process innovations vs. exploitative process innovations. This topic is well studied for product innovation but very little research is done on the same issues in the area of process innovations.

2. Research design

2.1. Objective

The goal of this research is to give more insights in how an innovation model for process innovation should be structured based on theoretical debates and the current practices within Company ABC R&D. The research will focus on how process innovations, both explorative and exploitative, can be structured to ensure effective project management. When the thesis is completed Company ABC R&D should have a newly constructed innovation model to manage process innovations.

To further clarify to structure of this research a conceptual model (Figure 4) is constructed. For this conceptual model the variant of van Aken van, Berends and van der Bij (2007) is used. In the right-hand box of the model the subject of analysis, the innovation model for process innovations, is represented. In the left-hand box the set of theoretical perspectives required to study the problem are stated. Confronting those two gives the deliverables of the research, at the bottom of the model. The confrontation in this research can be described as combining theory and practical insights from the field of research. The deliverables of this research can be described as an analysis of theory and current practices and secondly as bringing back the outcomes of the analysis as changes to the model.

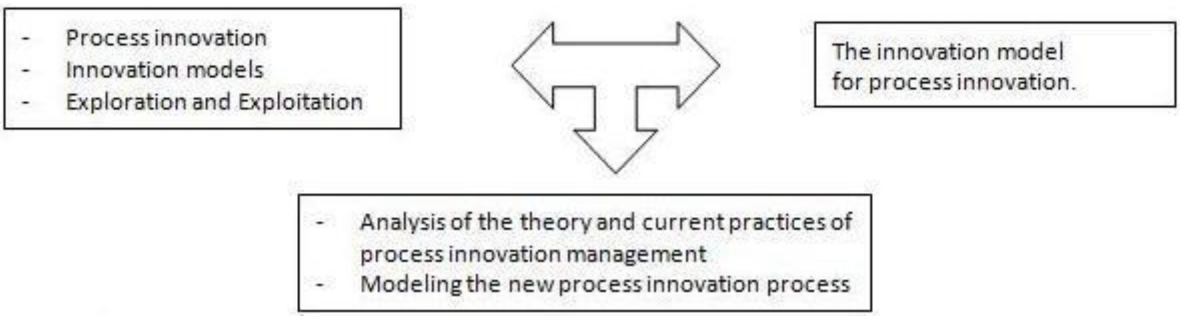


Figure 4: Conceptual model, adapted from Aken van et al. (2007)

2.2. Research questions

Based on the above mentioned objective and conceptual model the following research question can be stated:

"How can Company ABC Research and Development structure his explorative and exploitative process innovation projects effectively?"

In above stated research question, "structure effectively" is defined as: structured in such a manner that it enables process innovation projects to get started and achieve overall project goals.

In order to bring more structure to this thesis, a number of sub questions will be used. The first two sub questions aim at covering theory that debates about innovation models for process innovations and the differences between process innovations in explorative and exploitative settings. Goal of the first sub question can be defined as modeling the innovation process for process innovations, finding the most important factors and determine how these, based on literature, should be structured. To achieve this the first sub questions is stated as:

- *"What are the most important factors in an innovation model for process innovations and how is such a model ideally structured?"*

In order to cover the large differences that exist according to literature between innovation projects in more explorative and more exploitative settings the second sub question is stated:

- *"What are the main differences for explorative process innovations vs. exploitative process innovations?"*

The theoretical foundation that will be created in the first two sub questions gives focus in the second part of the research. This part analyzes the current processes within Company ABC R&D and defines the problem area's in the innovation process. To achieve this overview and analyze it the following sub questions will be used:

- *"How are process innovation projects currently managed within Company ABC R&D?"*
- *"What are the main problem area's in the current innovation process at Company ABC R&D?"*

Based on the theoretical insights and the analysis of the current practices at Company ABC R&D the final two sub questions give recommendations on how the innovation process can be structured to fit with the specific needs of process innovations. Differences in explorative and exploitative settings will be taken into account. In the final question the recommendations will be converted to changes to the model that is defined in the first sub question. To achieve this the following questions are stated:

- *"How can Company ABC R&D improve their innovation process for process innovations?"*
- *"How should the process innovation model look like for Company ABC specifically, based on these improvements?"*

3. Theoretical framework

3.1. Defining process innovations

This first section of the theoretical framework will define the main topic of this research; process innovations. Before creating this definition, the greater construct, “innovation”, will be specified. Garcia and Calantone (2002) have created a definition that is based on the 1991 OECD study on technological innovation which states that “innovation is an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention”.

Zooming in from this general definition to the field of process innovation gives multiple perspectives. Continuing with Garcia and Calantone (2002), they state that a production process is the system of process equipment, work force, task specification, material inputs, work and information flows, and so forth that are employed to produce a product or service. Followed by this definition is the statement that “the primary focus of process innovations is the efficiency improvement of the production process for product innovations”. This is definition is relative broadly stated if compared with e.g. the definition of Rochina-Barrachina, Manez and Sanchis-Llopis (2008) which defines process innovations as “important modifications of the productive process which can be materialized by the introduction of new machines, introduction of new organization methods for production, or both”. Where the first definition also takes work force and information flows into consideration this second definition specifies process innovation only as improvements to machines or organization methods for production.

Besides a discussion about the scope of process innovations there is also no consensus about the main goal of process innovations. Where Garcia and Calantone (2002) define “the efficiency improvement of the production process” as the primary goal, Reichstein and Salter (2006) state that process innovations have the aim of “achieving lower costs and/or higher product quality. The definition used in this article is based on multiple other scholars and specifies process innovation as “new elements introduced into an organization’s production or service operations – input materials, task specifications, work and information flow mechanisms, and equipment used to produce a product or render a service – with the aim of achieving lower costs and/or higher product quality”.

Finally it should be clarified if a process innovations only can influence the manufacturing process, as above mentioned definitions imply, or also cover the broader perspective of business processes. This second view is used in the definition of Papinniemi (1999) who states that “process innovation means performing a work activity in a radically new way. Process innovation is generally a discrete initiative and it also implies the use of specific change tools and technology for enterprise engineering and transformation of business processes.”

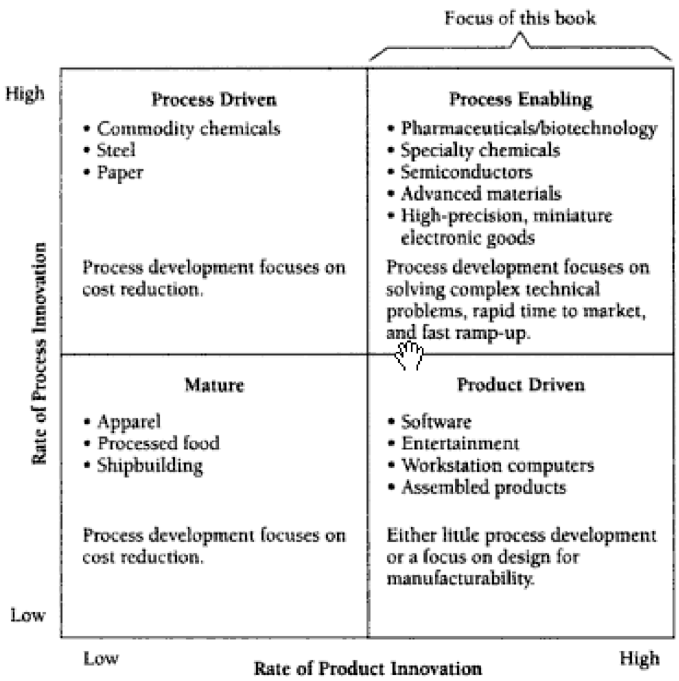


Figure 5: Relationship between product and process innovation by Pisano (1997)

Besides the discussion on what defines a process innovation, Pisano (1997) does also discuss the goal of process innovations in different types of industries, as shown in Figure 5. Depending on the rate of product innovation and the rate of process innovation the innovation focus and composition of innovation portfolio should, ideally, be differently shaped. In mature (low product, low process) and process driven (low product, high process) process innovations are primarily focused on cost reduction. In product driven (high product, low process) process development is low or focused on designing for manufacturability. In the case of high process and high product innovation (process enabling industries) process development is focused on solving complex technical problems, rapid time to market and fast ramp-up. Process innovations in these quadrant are ideally very tightly coupled with the new product development (NPD) process. As for every quadrant the goal of process innovations is different this potentially influences the structure or model that is used for process innovations projects.

The focus in this research will be on innovations that aim on the manufacturing process in particular. Although the manufacturing process is the key focus in this research, insights from other topics such as business process reengineering (BPR) will be used. BPR focuses on the broader perspective of “business processes” but the models used in this scientific discussion will be used to create a better model for manufacturing innovations. Although a distinction can be made between organizational process innovations and technological process innovations, this distinction is “difficult to sustain in practice as many process innovations involve both organizational and technological changes” (Reichstein and Salter, 2006). Therefore, in this study, there will be no distinction made between those two types of process innovations. Because of the type of organization that is the subject of this research, technological process innovations have the most relevance.

3.2. Modeling process innovations

After defining process innovations in the first section of the theoretical framework this, second, section discusses multiple scholars that have described a model specifically tailored for process innovations.

These scholars will be completed with other literature about the important factors in structuring a process innovation project.

The first perspective used for the modeling of a innovation model for process innovations is the knowledge-based view of Gopalakrishnan, Bierly and Kessler (1999). This knowledge-based view states that the characteristics of knowledge associated with an innovation determines its tacitness, autonomy and complexity and therefore also its strategic implications. Foundation of this perspective is that product and process innovations are associated with knowledge that may be stored in equipment, tools, organizational systems, operating procedures, routines and individual operators. All knowledge is assumed to be initially created by individuals and only becomes organizational knowledge if transferred though-out the organization.

The most important findings out of the knowledge-based view that should be taken into granted for an innovation model for process innovations are: process innovations tend to be significantly more systemic, and more complex than product innovations; process innovations are often more internally sourced, are more costly (particularly in large firms), and are perceived more effective.

One of the few models that specifically focus on process innovations and that also is specifically applicable to manufacturing process is the model of Papinniemi (1999). In his article he aims at "proposing a basic model of process innovation to support assessment of process innovation initiatives and projects". The model is shown in Figure 6. The model consist of a top-down flow which represents the workflow of reengineering and a left to right flow which describes the basic relations between the core elements in the model. The top-down model aims at analyzing the effects of innovation candidates on business and manufacturing processes and their performance whereas the left-right flow aims at actually transforming initiatives to a completed innovation.

The top-down flow consist of three phases being the background, process and outcome element. The first element, background, can be described by three elements. (1) Policy is taken as a fact and directs the development activities in a manufacturing system. (2) Analysis of current state is performed for the selected product line and process sequence. The goal of this step is to specify internal shortages. (3) The current product/process performance, which can be described by analytical process matrices, is used as a source pool for innovation candidates. The second element of the top-down flow (workflow of reengineering) is the (4) process element of reengineering and describes the elements of change in the process. The third element is the outcome of the workflow and consist of (5) the new and improved process concept and (2) the improved product/process performance.

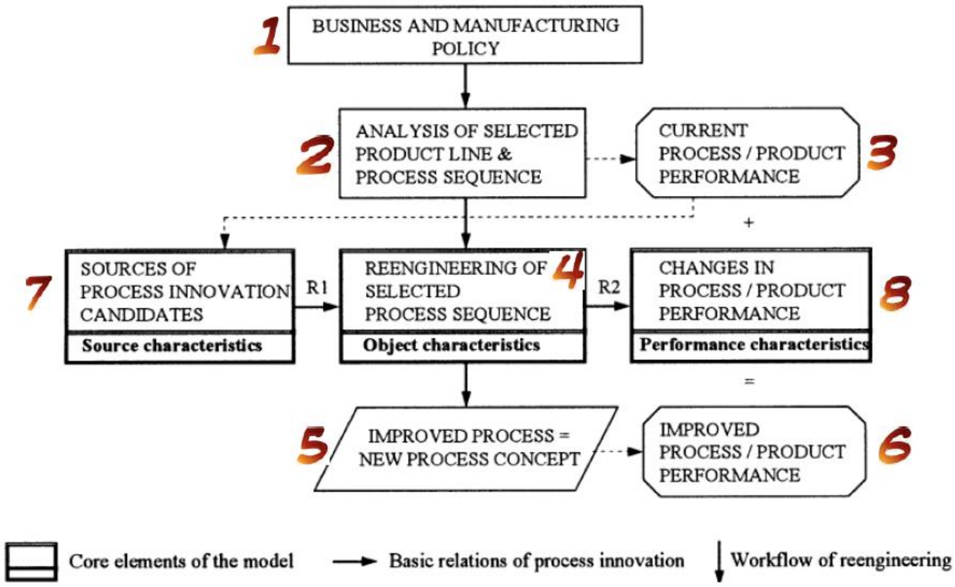


Figure 6: The basic model of process innovation from Papinniemi (1999)

The left-right flow of the model, which contains the core elements of the model, exist out of three phases. The first step is (7) determining the sources of process innovation candidates which can be found in 1) technological enablers such as set-up time reduction or integration of processes, 2) lack of performance in processes or products by comparing current performance with competitors or own progress, or thirdly 3) by resource opportunities which consists of the human and financial resource base that are controlled. In the second step (4) the actual changes to the objects are carried out. These objects can be: change in process type, change in product structure, change in management and control, etc. The nature of the changes can be both value-adding or cost-reducing. The third and final step of the model are (8) the changes in performance which should be measured by “a proper set of performance characteristics for assessing innovation initiatives” that can exist of quantitative measures or non-measurable performance indicators such as difficulty of manufacturing.

The second model that will be discussed here is the seven-step process improvement method of Harbour (1994). The model is created for the broader scope of business process reengineering (BPR) but during this research it will be applied on the specific situation of manufacturing process innovations. According to Khan (2000) the model of Harbour “is easy to use and provides key ingredients for indentifying the weak points and improvement areas and selecting and implementing a....opriate improvement strategy needed for successful reengineering”. To further understand the model, all seven steps will be elaborated on. The model expects the user to already have chosen which process will be reengineered and starts at this point.

In the first step the boundaries of the process are defined, the input and output of the process are identified and the a....opriate metric (e.g. time) is defined. The second step is the observation of the process. To support this phase a flow chart of the process can be constructed with process step information for recording. In the third step the “quantitative relevant data such as time and number of people are collected to support observations”. After selecting, observation and collecting data, this data is analyzed in the fourth step. To analyze the collected data, tools such as “process cycle times” can be used. In the fifth step the potential improvement area’s are identified. In the sixth step the actual improvements are developed which can exists out of eliminating steps, making a linear process parallel, etc. In the final, seventh, step the improvements are implemented and monitored. In summary the seven-step process improvement method consists of:

1. Defining process boundaries
2. Observing process steps
3. Collecting process-related data
4. Analyzing collected data
5. Identifying improvement data
6. Developing improvements
7. Implementing and monitoring improvements

The seven-step process improvement method of Harbour (1994) has some similarities with the DMAIC Improvement process that is used to drive Six Sigma projects. This methods uses Define, Measure, Analyze, Improve and Control as a five step system to improve processes.

Jensen and Westcott (1992) have created a process innovation model based on the relationship between the manufacturing strategy of a company and the selection of process innovation projects. The innovation model they propose is based on a process innovation cycle (Figure 7) that is iterative and has the manufacturing strategy of a company as starting point. This paper states that a firm should work towards a “process concept”, “a concept that defines and describes what the manufacturing system should look like in terms of processes at some point in the future”. The actual model that should promote a structural and systematic approach for establishing this process concept is shown in Figure 8.

It goes beyond the scope of this theoretical framework to describe al 14 steps and the matrices used but the most important flows and steps are discussed. Jensen and Westcott (1992) state that the manufacturing process is build up out of three parts being process technology, people in the process and process integration. The model contains multiple iterations starting with defining the process concept. This iteration of completing matrices and finding process innovation candidates should be repeated until the process concept is detailed enough to allow for the development of a tactical plan for implementation of a process innovation (step 4 in Figure 8). When this first iteration is activated it contains a another iteration within it. After finding process innovation candidates (step 5-8) the selection and researching of these candidates (step 9-11) is also iterative. The model can only be taken to the next step until the following four criteria are taken into granted: 1) Is the process innovation required? Is there no simpler mean to solve to problem? 2) Cost/benefit of process innovation? Which resources are required? 3) Critical needs to be met? Are both short- and long-term needs met? And 4) What are the interrelationships and interdependencies of process innovation candidates?

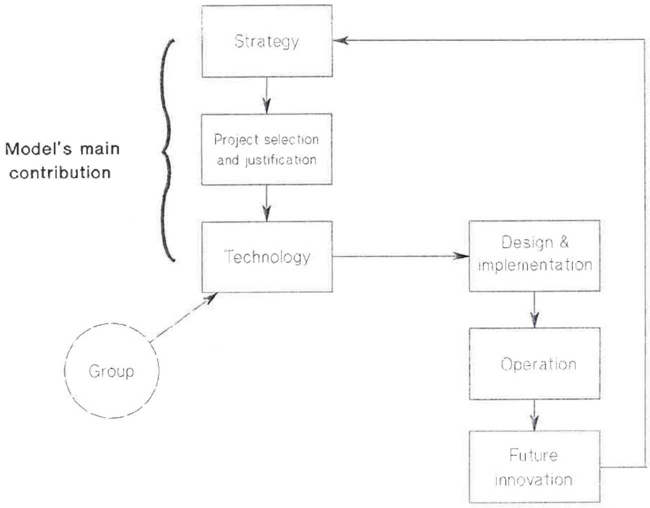


Figure 7: The process innovation cycle from Jensen and Westcott (1992)

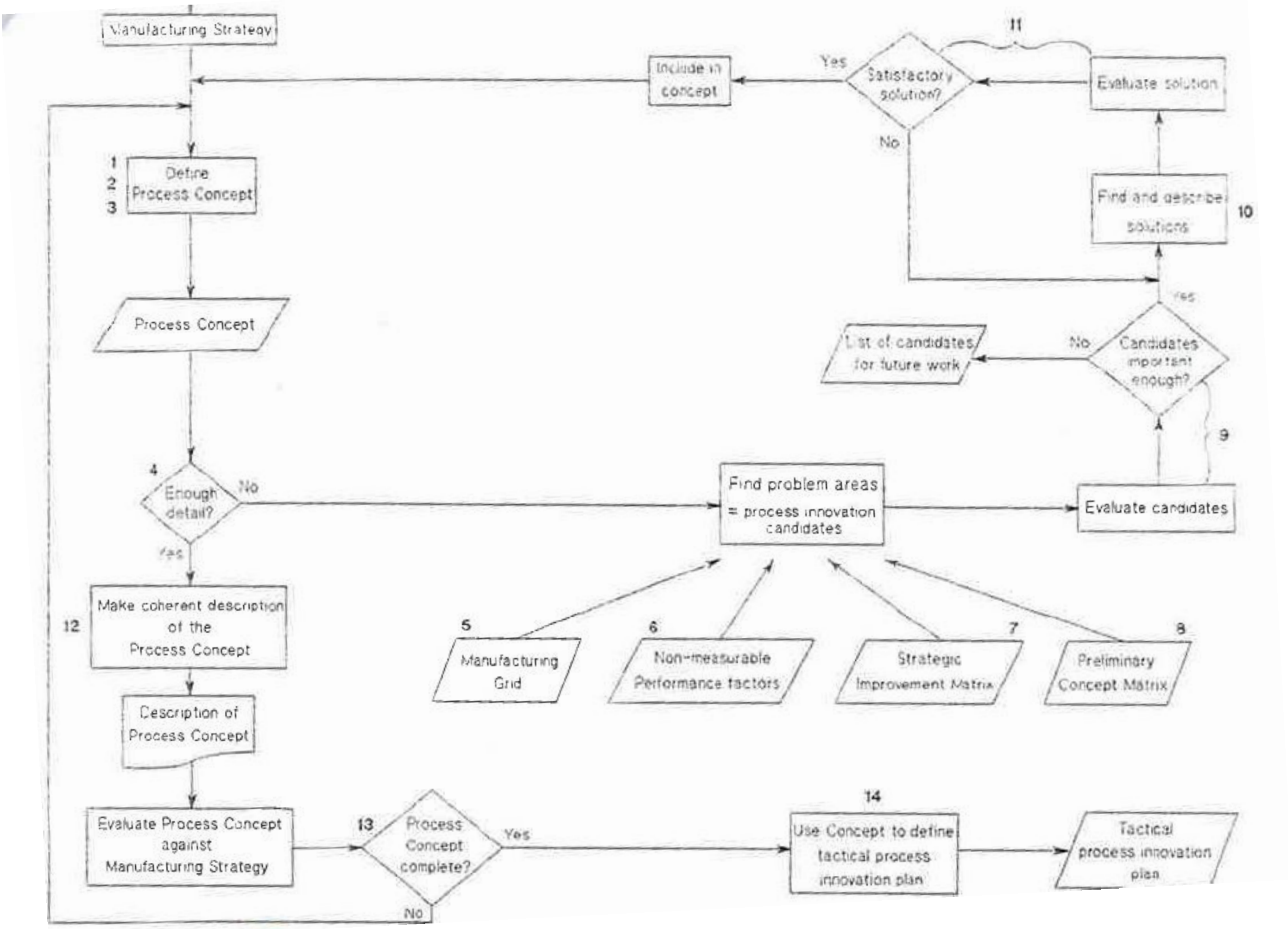


Figure 8: The process concept cycle from Jensen and Westcott (1992)

The fourth model that is used in this comparison of models for process innovations is used by Wu (2002) in their article about implementing BPR. In the article reengineering of processes is placed in a broad view that includes corporate strategies and strategic paths with IT application but for the use of this theoretical framework the third step "implement BPR" will be used. For this third step Wu (2002) uses an adapted version of the composite framework of Kettinger, Teng and Guha (1997). The model, shown in Figure 9, is not completely applicable for the situation at hand in this study but the structure of stages and activities can be of value to this research. The model of Wu (2002) is not iterative and uses a sequential approach.

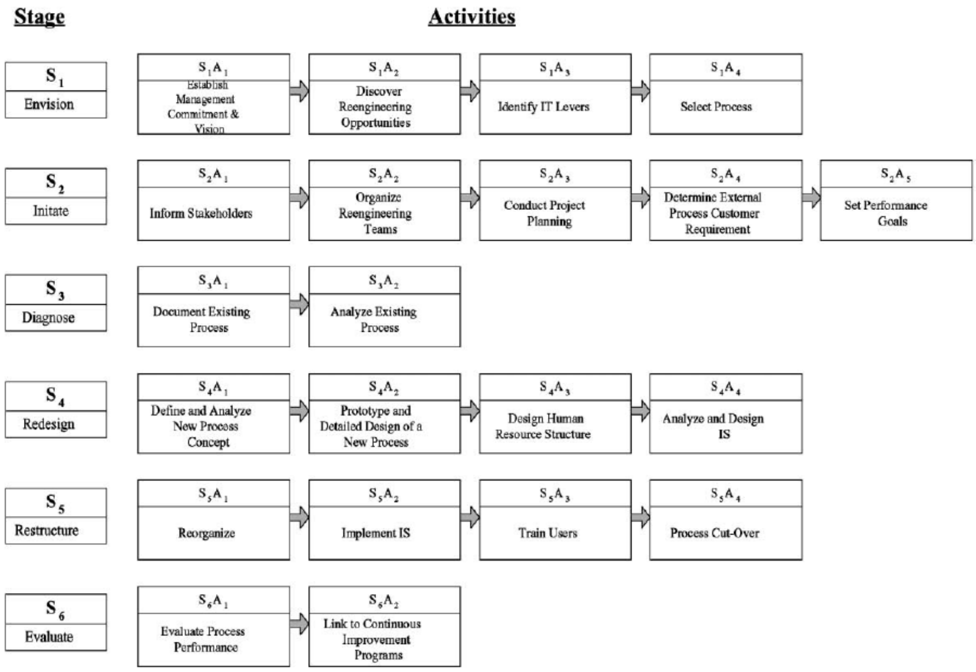


Figure 9: The BPR implementation model from Wu (2002)

In contradiction with above mentioned model of Wu (2002), the BPR framework of Ackermann, Walls, van der Meer and Borman (1999) is iterative and uses two feedback loops. The model is shown in Figure 10 and uses organizational learning and "feedback of progress upon the original design" as important features.

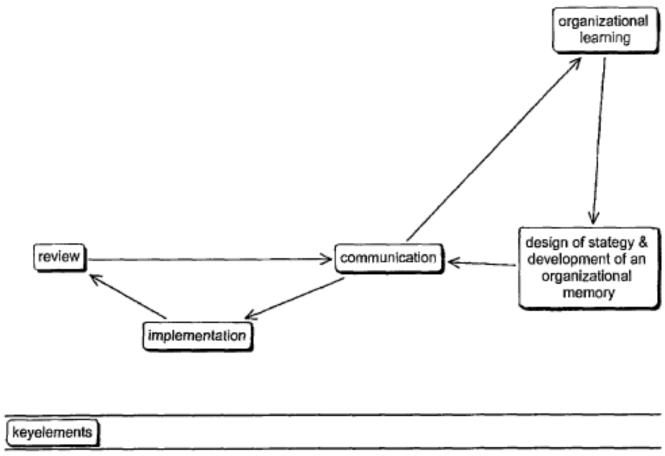


Figure 10: The BPR framework of Ackermann et al. (1999)

In the model of Painniemi (1999) the potential sources of process innovation are specified but on a relative high level of abstraction. The study of Reichstein and Salter (2006) have further elaborated on the topic of sources of process innovation. Using suppliers as a source of information and knowledge was proven to be associated with process innovation but other external sources such as customers and consultants decrease the change of being a process innovator. An cost-focus strategy is also associated with process innovation just as collaboration with other enterprises or institutions.

To further accentuate the process innovation model the study of Lager and Hörte (2002) is used. In this paper success factors for improvement and innovation of process technology are defined. As the most important factor “The company has a good and stimulating climate for process development work” is found, followed by “The development organization is good at generating new ideas and formulating interesting new process development projects” and thirdly “The development organization includes individuals with suitable personal qualifications for process development work”. To complete the five most important factors “Good and well-functioning networks are available for research and technical development” and “There are good incentives and driving forces for process development” are stated.

Based on experiences from leading corporate companies Cooper et al. (2002) have developed a stage-gate variant that is specifically tailored to the needs of technology development projects, shown in Figure 11. Steps that are part of an traditional stage-gate model, such as “undertake a competitive analysis, do voice of customer work and define the product benefits to the user” are not useful in technology development projects. Also deliverables such as “a business case or a commercialization plan” are not included anymore. The adapted stage-gate model is an smaller three-stage model and should be the input to the traditional NPD stage-gate process. One of differences is the discovery phase which has much different types of input such as scientist, technical people or scenario generation.

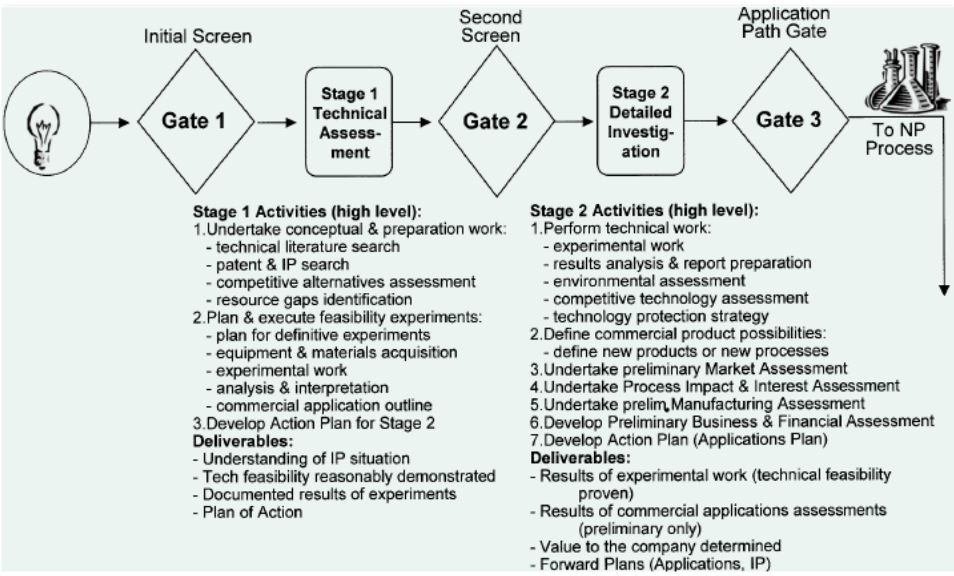


Figure 11: The stage-gate model for a technology development process from Cooper et al. (2002)

A final paper used in this thesis is the paper of Pisano (1997) which covers the topic of process development. Based on the integral view on process development he proposes, “a capabilities-based perspective on process development” (Figure 12). In this model, process development projects are defined as attempts to create new process architectures, rather than to achieve incremental improvements in existing technology. Process development focuses on solving problems that may arise in actual production, problem-solving activities that take place before actual production, referred to as “learning before doing”. Improvements that are made by operators/technicians while the new production process is already operating is referred to as “learning by doing”. New knowledge acquired in learning by doing activities should contribute to the process development capabilities of the firm which can be tapped in for future process development projects. Firms should seek to a balance between costly learning before doing projects through process R&D and high amounts of learning by doing attempts potentially resulting in low production efficiency in the first period of production.

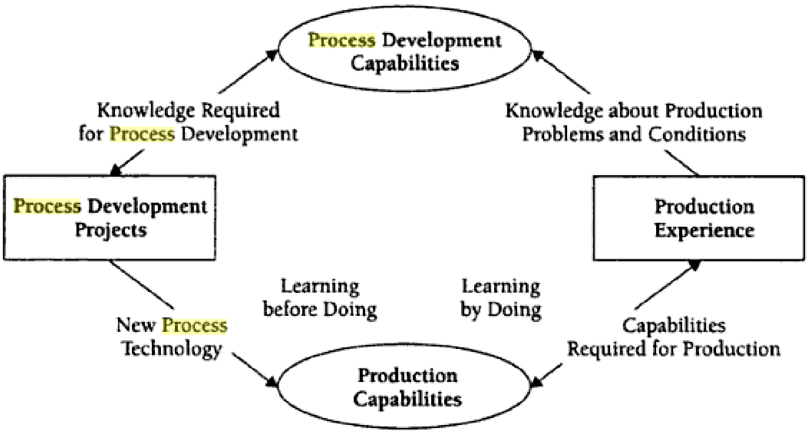


Figure 12: A capabilities-based perspective on process development from Pisano (1997)

Representativeness of Final Production Environment	Locus of Experimentation	Learning Mode
High	Full-scale commercial factory	By Doing
↑	Pilot plant located at production site	↑
	Pilot plant located at development site	
↓	Laboratory	↓
Low	Computer-aided simulation	Before Doing
	Theory, algorithms, heuristics	

Figure 13: The locus of experimentation and representativeness from Pisano (1997)

Based on the amount of uncertainty firms should find a balance between learning before doing approaches such as using theory and computer-aided simulation and more learning by doing methods such as experimenting in a pilot plant located at the production site or experimenting in a full-scale commercial factory.

3.3. Exploration and exploitation in process innovations

In new product development the differences between radical and incremental types of innovations are well recognized and discussed. In process innovation this is a much less discussed topic but Reichstein and Salter (2006) state that multiple scholars (Tushman and Anderson, 1990; Dosi, 1982; Gatignon, Tushman, Smith and Anderson, 2002; Freeman and Perez, 1988) have recognized the differences in types of process innovation. They define incremental process innovations as “a process innovation that is new to the firm but not new to the industry” or “those innovations that improve price/performance at a rate consistent with the current technological trajectory”, a radical process innovation is defined as “those process innovations developed by a firm and those that are also new to the industry” or “advancing the price/performance frontier by much more than the existing rate of progress”. In this part will we will discuss the potential consequences of these differences for a process innovation model. Because very little, or even no, scholars have specifically discussed a model for radical process innovation we will try to learn from articles that cover the broader perspective of an innovation model for radical innovation.

When determining differences between an innovation model for more explorative and more exploitative process innovations the article of King (1992) can be used. In his study King compares two types of innovation model, the more sequential model of Zaltman, Duncan and Holbek (1973) and a more fluid model without a fixed sequence of stages that is created by Schroeder, Van de Ven, Scudder and Polley (1989). Part of his research is dedicated to the suitability of both models in more incremental and more radical innovations. The study suggest that, although not significantly, highly radical innovations proceed in a less orderly step-by-step manner than less radical ones. A more fluid, less sequential model such as that of Schroeder et. al. (1989) was proven to be accurate in highly radical innovations. This findings provide support for modeling a less sequential, more iterative model when it concerns more radical, explorative innovations.

Although focusing on NPD and not process innovations the article of Veryzer (1998) is used to determine major differences in managing radical innovation and incremental innovation. Veryzer (1998) states that "the process that was observed across the sample of firms involved in discontinuous new product development differs from conventional new product development both in terms of sequencing of steps and the focus of the activities that are undertaken". Some differences between continuous and discontinuous NPD are stated of which the first is that "the development of discontinuous products does not seem to proceed in the manner described by either conventional or stage-gate like development systems". Veryzer (1998) emphasizes that although the phases in his model look like discrete events they overlap, especially in the later phases. He also states that where in continuous development market assessment and financial analysis are the decision point for starting development, in discontinuous development the formulation of a product application out of emerging technologies is the starting point. A final important conclusion in this paper is that the discontinuous new product development process, as projected below, can precede or flow into a conventional, potentially stage-gate like, new product development process. In this conventional model, process activities such as a market assessment are carried out after all.

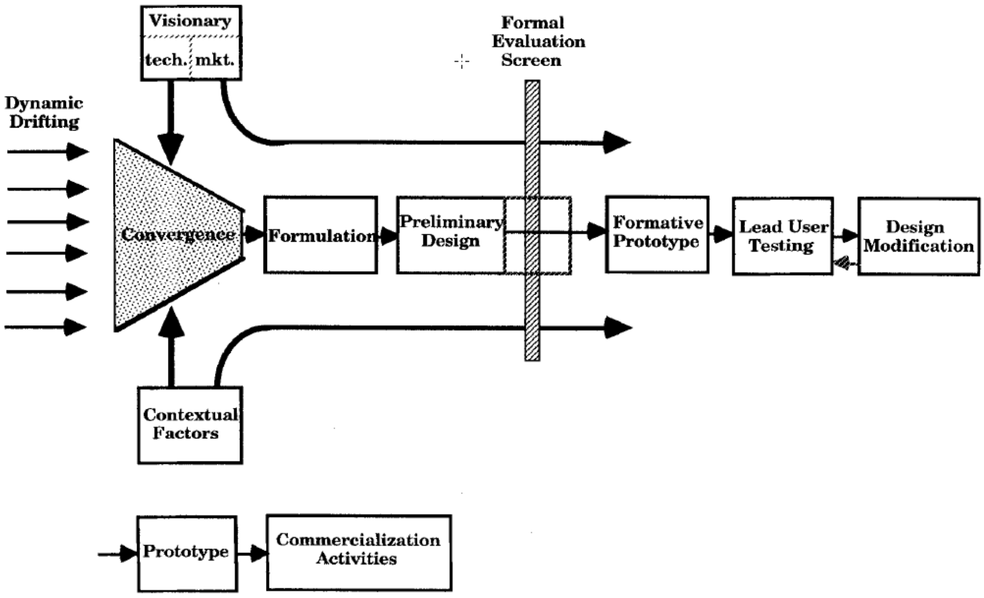


Figure 14: Discontinuous product innovation process from Veryzer (1998)

A final scholar that tries to combine process and product in an attempt to create a model for "managing discontinuous product and process innovation" is Phillips et al. (2004). Based on an empirical study they conclude that "high risk discontinuous innovation projects do not fit well with 'traditional' stage-gate approaches" and created the model below.

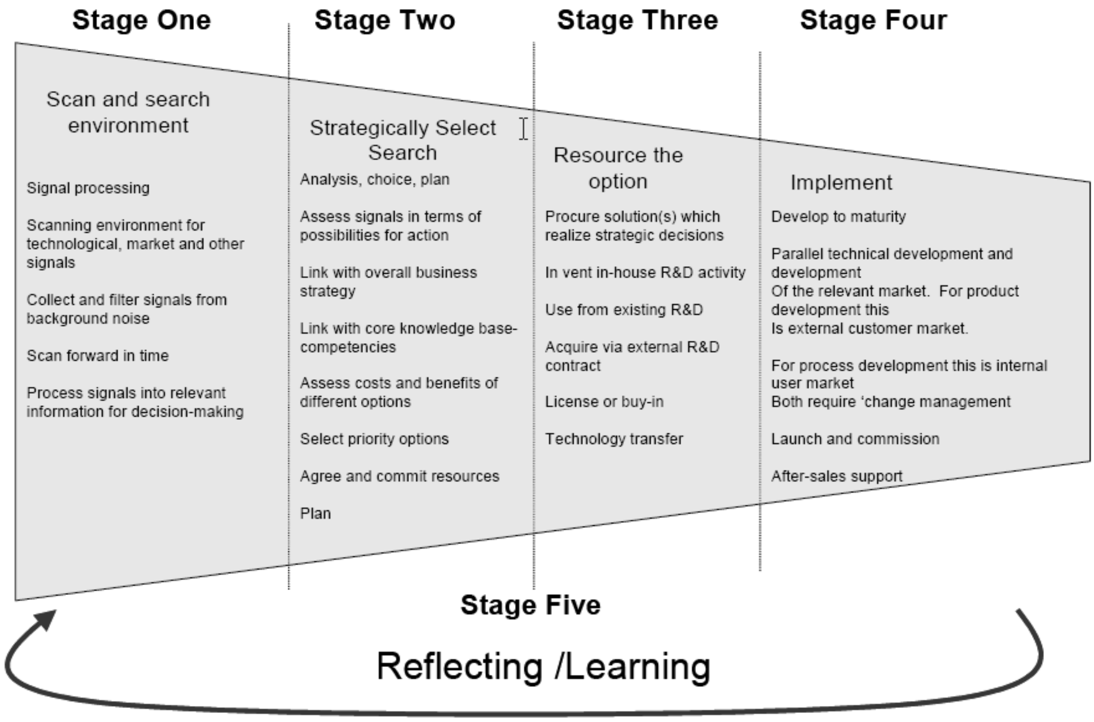


Figure 15: Routines underlying the process of innovation management (Phillips et al., 2004)

Phillips et al. (2004) discuss three main topics that differ from continuous development. The first topic is the management of serendipity. The study discovered that serendipity is critical and should be managed by the creation of conditions that stimulate creative thinking or through an expansive search process. In all cases "the firm undertook a thorough scanning and selection process that involves looking beyond existing boundaries". The second topic, which can be summarized as idea championing, states that both senior management as first line managers have an important role in this process. Individuals should be encouraged to "take a step back from the day job" and adopt an innovative view, which can for example be stimulated by an ideas board where anybody can post ideas. The third topic, working beyond the comfort zone, explains why it can be of use to companies to look beyond the existing borders in both the scanning and selection process but also further in the innovation process. As an example joint ventures , technology exchange agreements with universities and collaborations with other firms are mentioned.

3.4. Effective structure for process innovation projects

In the research design of this thesis is stated that the research is focused on "structuring process innovations effectively". Effectively is here defined as structured in such a manner that it enables process innovation projects to get started and achieve overall project goals. To determine if an model or structure contributes to this "effectiveness" this construct should be elaborated on.

The first part of the definition, "enables process innovation projects to get started" is quite straightforward. The model or structure should support process innovations to get started within the organization. The second part of the definition, "and achieve overall project goals" requires the definition of "overall project goals". Adams, Bessant and Phelps (2006) developed a framework for the measurement of innovation management. This framework list multiple constructs of which project management is one. Project management is separated into four aspects: project efficiency, tools, communication and collaboration. Project efficiency, although not necessary equal to overall project goals, seems like a useful construct to this discussion. In the article of Adams et al. (2006) two measurements of project efficiency are mentioned: costs and speed. Costs are mostly measured in the form of a comparison between budget and actual. Innovation speed can be measured as speed, performance against schedule and duration of the process.

Besides the article of Adams (2006), Hoegl, Weinkauf and Gemuenden (2004) mention three dimensions for the performance of development projects. The dimensions in this article are schedule (time), budget (cost) and quality. Quality refers to certain desired properties of the output produced by the team, budget refers to the costs associated with the team's development activities and schedule refers to an overall sequence of milestones where certain deliverables are expected at predefined times.

This thesis will use the following definition of performance: "enables process innovation projects to get started, and perform on budget, schedule and meets the quality specs".

3.5. Similarities and contradictions in the process innovation model theory

In the second part of this theoretical framework multiple models and theories concerning the management of process innovation are discussed. This paragraph will try to combine and compare the models and highlight the main similarities and contradictions. This paragraph is structured around five main topics that are generated based on the most discussed issues in the articles used for the theoretical framework. Besides discussing the similarities and contradictions for every topic the contradictions with product innovation models will be discussed.

3.5.1. Iterations

When comparing the different models that are discussed it becomes clear that there is no consensus about whether or not a process innovation model should be iterative as a whole, just contain some iterations or not be iterative at all. The model that covers the topic of interest in this study particularly well, that of Papinniemi (1999), does not mention a repetition and states that "it is a significant performance change in processes that indicates the completion of a process innovation". Although the article does not mention an iteration in specific it does state that the current process/product performance should be a major form of input to the list of process innovation candidates which can be interpret as an iterative structure.

A model that leans heavily on iterative cycles is the model of Jensen and Westcott (1992). In their article they state that after the implementation of a process innovation the operation of the process should give input to future innovations. Besides this overall iteration the article emphasizes that a company should go through a number of iterations to establish a "tactical process innovation plan" that is based on the manufacturing strategy, has considered all potential problem areas, has assessed the potential solutions and is detailed enough to be practical feasible.

A third model that supports the idea of an iterative model is that of Pisano (1997) which emphasizes importance of feedback from production (production experience) towards the department that is responsible for the process development projects (process development capabilities). This approach should ensure that knowledge generated in the "learning-by-doing phase" is brought back to R&D to ensure that R&D can initiate new process development projects with complete knowledge.

As counterpart of above mentioned models the stage-gate model for a technology development process from Cooper et al. (2002) does not mention an iteration and instead states that a technology development process can be divided in three phases and then can be coupled to the normal stage-gate model. For this approach there should be noted that the focus in this paper is on technology development projects that are specifically developed as the basis of a new product development project which is a different form of process innovations compared to the form which focuses on reducing costs, improving quality or reducing lead time.

When combining the insights of these models, the following recommendations for a process innovation model can be made. When a process innovation model should cover not only a process innovation related to a NPD project but also process innovation with the aim of reducing costs, improving quality or reducing lead time a somehow iterative process is essential. Only with this approach improving the production process can become a structural part of the innovation strategy of a firm. If such an, iterative, model should also contain multiple iterations within itself to determine the innovations candidates, solutions, etc is still subject of debate and will be decided on after the case studies.

When relating the conclusion of this topic to the performance measures (quality, cost and speed) there can be stated that using an iterative structure for process innovations that are aimed at improving the production process can contribute to quality and speed of these projects. Because of the production knowledge feedback that is generated in this iterative structure new process innovation projects can be started faster and executed in higher speed because of more complete knowledge. The quality of these innovation projects can be improved because the needs of the end user, the production environment, can be better incorporated into the project. The other goal of effective structure, “enables process innovation projects to get started”, is obviously also supported by an iterative structure because it ensures a much closer link to a major pool of ideas, the production environment.

For this topic, iterations, some differences with a NPD model are quite clear. The most discussed and used model for NPD process, the stage-gate model of Cooper (1990), has a clear start and termination point without an iterative or loop-like structure which explicitly differs from most process innovation models discussed in this thesis who use iterative structures. If a NPD process can be overlapping and iterative within a phase does not become clear out of the stage-gate literature but other NPD scholars such as Krishnan, Eppinger and Whitney (1997) and Lin, Chai, Wong and Brombacher (2008) do discuss this option. This aspect of a model for process innovations does not very clearly seem to differ from NPD models.

3.5.2. Sources of process innovation

Based on a number of scholars, such as Reichstein and Salter (2006) who state that "there are a few empirical studies that focus more directly on the sources of process innovation at the firm level and the relationship between product and process innovations", there can be assumed that the initiation phase of a process innovation is shaped different than that of product innovation projects. In the models mentioned in previous part of this theoretical framework a large number of potential sources for process innovation are mentioned. This part will try to converge these sources to a relevant and feasible amount. Based on the articles used for this research the following list of sources for process innovations can be constructed.

External

- External sources of knowledge (Rouvinen, 2002)
- Suppliers (Reichstein and Salter, 2006; Cabagnols and Le Bas, 2002; Von Hippel, 1988)
- Collaboration (Reichstein and Salter, 2006)
- Nonacademic partners (Rouvinen, 2002)

Internal

Measurements

- Performance problems (Papinniemi, 1999; Pisano, 1997)
- Non-measurable performance indicators (Jensen and Westcott, 1992)
- Manufacturing grid (Jensen and Westcott, 1992)
- Preliminary concept matrix (Jensen and Westcott, 1992)

Strategy

- Resource opportunities (Papinniemi, 1999)
- Cost-focus strategy (Reichstein and Salter, 2006)
- Internal knowledge accumulated through problem-solving experience (Pisano, 1997)
- Product innovation projects (Pisano,1997; Kraft, 1990)
- Technological enablers (Papinniemi, 1999)

People

- R&D staff (Cooper, 2002)
- Scientist (Cooper, 2002)
- Production staff (Cooper, 2002)

When examining the list of potential sources that are mentioned in literature a number of distinctions can be made of which the distinction between internal and external sources is most clearly visible. Sources that can be defined as internal are a cost-focused strategy (Reichstein and Salter, 2006), performance problems (Papinniemi, 1999; Pisano, 1997) and measurements such as the manufacturing grid of Jensen and Westcott (1992), personnel input of scientists, R&D staff and production staff (Cooper, 2002), product innovation projects (Pisano, 1997; Kraft, 1990) and internal knowledge accumulated through problem-solving experience (Pisano, 1997). Broadly spoken the internal sources can be divided in three groups: people such as R&D staff and production staff, strategy and measurements such as a manufacturing grid.

Besides these internal sources there are also a variety of external sources identified. Sources that can be defined as external are suppliers (Reichstein and Salter, 2006; Cabagnols and Le Bas, 2002; Von Hippel, 1988), collaboration (Reichstein and Salter, 2006), nonacademic partners (Rouvinen, 2002) and using external sources of knowledge (Rouvinen, 2002).

As this thesis is , also, focusing on the differences between radical and incremental process innovation the article of Reichstein and Salter (2006) is particularly interesting as this article distinguishes between the sources for incremental and radical innovation. They conclude that firms with a high share of sales from products new to the market are more likely to have a high degree of novelty in process innovation. Secondly they conclude that a cost-focus strategy is particularly related to radical process innovation and finally collaboration also increases the probability of being a radical rather than an incremental process innovator.

When converting these potential sources of innovation ideas to input for a process innovation model a couple of statements can be made. When structuring the ideation phase both internal (people, strategy and measurements) and external sources should be included and a broad range of potential sources should be considered as input for a new process innovation project. Additionally, when creating a specific structure for radical process innovations, the potential sources should be reconsidered based on the article of Reichstein and Salter (2006).

When relating the sources of process innovation to the performance measures of this thesis there can be assumed that a suitable structuring of the ideation phase contributes primarily to the first part of this goal, “enables process innovation projects to get started”. Using suitable sources to create input for process innovations most likely contributes to getting more and more valuable process innovation to get started. If using a suitable set of sources for process innovations also contributes to speed, cost and quality of these projects cannot be substantiated.

When comparing these sources with the sources that are mentioned in relation to product innovation a number of sources are different. The following sources are specifically mentioned as being applicable to product innovation and not applicable to process innovation: customers (Reichstein and Salter, 2006), universities and non-profit research organizations (Amara and Landry, 2005; Rouvinen,2002) and consultancy (Reichstein and Salter, 2006).

3.5.3. Phases and structure

The scholars used in this theoretical framework mention a great variety of phases and structures for the process innovation models they propose. Both the model of Papinniemi (1999) and Jensen and Westcott (1992) emphasize the importance of starting the process innovation process based on a manufacturing strategy. Both scholars state that the manufacturing strategy “directs the organization and sets guidelines for the development activities of product lines and process sequences in a manufacturing system”. This emphasize can be interpret as a need for a guiding manufacturing strategy that can steer the selection of process innovation projects and the resource allocation between projects. In contradiction models such as Cooper (2002), Harbour(1994) and Wu (2002) focus only on the improvement of a process leaving a (manufacturing) strategy besides the theory. Generally spoken they assume that a process is already selected when starting a process innovation.

A major phase in most scholars is the selection and analysis of the processes. Papinniemi (1999) mentions these items as phases two and three and the model of Jensen and Westcott (1992) is in fact completely dedicated to the selection, analyzing and solution generation of process innovation projects. Also broader applicable models such as that of Wu (2002) emphasize the importance of selection by the phases "envision" (1) and "diagnose" (3). In contradiction the models of Pisano (1997) and Harbour (1994) do not mention a selection or analysis phase but this can at least partly be attributed to the scope of these models. Harbour (1994) clearly admits in his article that his models focuses on the phases after a problematic process is selected.

Another step that most scholars in this theoretical framework agree on is the "concepting" phase. Wu (2002), Jensen and Westcott (1992) and Harbour (1994) mention a concepting phase before the actual reengineering takes place. In this phase potential areas of improvement are defined and suitable solutions should be considered feasible and agreed on. The model of Papinniemi (1999) does also mention a "new process concept" but states this is the result of a reengineering phase where the other models state it as being the input for the reengineering phase.

When combining the insights of these scholars about the phasing and structuring of a process innovation model we can make the following recommendations. First of all, to ensure fact based project selection and resource allocation a process innovation model should be coupled to the manufacturing strategy of a firm. And based on the literature the model should ideally at least contain a selection and analysis phase. As most models also contain a concepting phase this is ideally also included but the exact place and content will be defined after the case study.

When relating the conclusion about the phasing and structuring of process innovations to the performance measurements of this thesis there can be assumed that phasing the innovation process as described in this paragraph can at least contribute to the cost and speed elements. The cost element can be influenced because of better analysis and risk investigation and a strict procedure for the "gates" in the process. The speed element is assumed to be influenced by the same elements.

When comparing the phases mentioned above with the stage-gate model of Cooper (1990) a number of phases are quite similar such as an ideation phase, a development phase and an implementation phase. Cooper uses two phases, "build business case" and "testing and validation" which are both not mentioned in the process innovation literature. Building a business case is in most cases not applicable to process innovations because the innovation is not directly "sold". A "testing and validation" phase seems useful for process innovations but is not mentioned as so in literature. Papinniemi (1999) and Jensen and Westcott (1992) do give substantial attention to the reengineering and implementation of the process which can be at least to a great extend be considered as covering the "testing and validation" phase.

3.5.4. Measurements and targets

In contradiction with the innovation process for product innovations, measurement of the current, and improved, situation is potentially an important part in managing process innovation projects. Multiple articles use measurements as part of their model but the application and goal of the measurements differs.

For example the model of Jensen and Westcott (1992) uses the "manufacturing grid" to quantify the problem areas of a process. Such a schematic view of an process can be made for any process innovation candidate and the outcome of these matrices become the input of the idea generation phase. Also the article of Papinniemi (1999) emphasizes the importance of measurements in the idea generation phase and states that "the current product/process performance, which can be described by analytical process matrices, is used as a source pool for innovation candidates".

The article of Harbour (1994) states that a key step in his process improvement model is that "quantitative relevant data such as time and number of people are collected to support observations". In this article the measurements are much more used to define the problem area(s) of a process that has already been selected to improve. As mentioned before the article of Harbour (1994) does not shed light on the phase of process selection.

When trying to transform these theoretical suggestions to relevant points of concern for constructing a process innovation model two main subjects can be deduced. First, in contradiction with a product innovation ideation phase, the ideation phase of a process model can profit much more from a well established structure of measurements. Measuring core processes can create a good pool of potential process innovation candidates. The second subject are the measurements when a process innovation candidate has already been selected. Because the goals of process innovations are often cost reduction, quality improvement etc. the variables that determine such an construct should be defined and measured before changes, which are only improvements if they can be measured, are made to the process.

The contribution(s) of "measurements and targets" to the performance measurement can primarily be found in "enabling process innovation projects to get started" as this systems can highlight process problems or opportunities and by this means create input to new process innovation projects. Contributions to the cost, speed and quality can be present but cannot be argued.

When comparing the findings in this theoretical framework with these in product innovation literature it becomes clear that in specific measurements of the current process are not applicable to NPD process at all. Where in the process innovation literature multiple authors mention the value of measurements in NPD literature this is not an topic of interest.

3.5.5. The influence of exploration and exploitation

As the topic of radical vs. incremental (or explorative vs. exploitative) process innovations and its implications for innovation management are already discussed in 3.3. this paragraph will only conclude on its implications for constructing a process innovation model. First of all both King (1992) and Veryzer (1998) emphasize the difference in ideal structure between more incremental and more radical (process)-innovations. The ideal model for more radical projects should be less sequential, more iterative and have overlap especially in the later phases.

A second point of interest is the idea generation phase. Veryzer (1998) states that "where in continuous development market assessment and financial analysis are the decision point for starting development, in discontinuous development the formulation of a product application out of emerging technologies is the starting point" and Phillips et al. (2004) also acknowledges that the scanning and selection should be different and look beyond the existing boundaries. These conclusion can affect the first phases of the model as it should possibly broaden their field of search for more radical process innovation and product applications should be extracted out of emerging technologies.

When converging the diverse literature about exploration and exploitation the main implication for a process innovation model will most likely be in the structuring of the process innovation model (less sequential, more overlap, etc.) and the ideation phase of the model (broader search perspective, using technology as starting point instead of the current production figures.

When discussing the contribution of the "exploration vs. exploitation structure" on the performance measurements in this thesis the following can be stated. Adapting the structure of a process innovation to a more exploitative or explorative setting is assumed to potentially contribute to the cost and speed element because a well adapted structure does ask for the right amount of risk investigation and analysis and ensures suitable target setting and "gatekeeping" to prevent budget or schedule exceeding.

On the topic of exploration and exploitation no clear differences can be found between process innovation and product innovation projects. This apparent similar situation can be partly due to the fact that very little research is done on the influence of exploration and exploitation in process innovation projects and therefore most knowledge is gained from product innovation literature.

3.6. Conclusion

In this chapter multiple models and structures for process innovations are discussed and compared on five main topics. These five main topics, "iterations", "sources of process innovation", "phases and structure", "measurements and targets" and, "the influence of exploration and exploitation" are extracted out of the models that are analyzed in this chapter. To discuss the influence of these elements on the performance of a process innovation project the measures for process innovation performance is discussed. This measure is divided in four elements which are: "Enables process innovation to get started", quality, speed and cost.

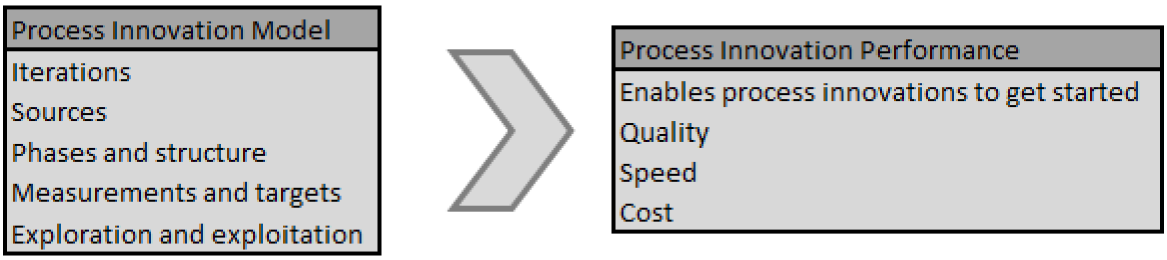


Figure 16: The theoretical model

Iterations

When a process innovation model should cover not only a process innovation related to a NPD project but also process innovation with the aim of reducing costs, improving quality or reducing lead time a somehow iterative process is essential. Only with this approach improving the production process can become a structural part of the innovation strategy of a firm.

Sources of process innovation
When structuring the ideation phase both internal (people, strategy and measurements) and external sources should be included and a broad range of potential sources should be considered as input for an new process innovation project. For explorative process innovations a specific set of sources is applicable of which a cost-focused strategy is one.

Phases and structure
To ensure fact based project selection and resource allocation a process innovation model should be coupled to the manufacturing strategy of a firm. Based on the literature the model should ideally at least contain a selection and analysis phase. As most models also contain a concepting phase this is ideally also included but the exact place and content will be defined after the case study.

When comparing the phases mentioned above with the stage-gate model of Cooper (1990) a number of phases are quite similar such as an ideation phase, a development phase and a implementation phase. Cooper uses two phases, “build business case” and “testing and validation” which are both not mentioned in the process innovation literature.

Measurements and targets
In contradiction with a product innovation ideation phase, the ideation phase of a process model can profit much more from a well established structure of measurements. Measuring core processes can create a good pool of potential process innovation candidates. The second goal of measurements is to support when process innovations candidates have already been selected.. Because the goals of process innovation are often cost reduction, quality improvement etc. the variables that determine such an construct should be defined and measured before changes, which are only improvements if they can be measured, are made to the process.

The influence of exploration and exploitation
When converging the diverse literature about exploration and exploitation the main implication for a process innovation model will most likely be in the structuring of the process innovation model (less sequential, more overlap, etc.) and the ideation phase of the model (broader search perspective, using technology as starting point instead of market potential).

Based on the knowledge gained during this literature review, this paragraph will give a visual representation of the model as it can be deduced from literature. According to Pisano (1997) and other scholars process innovation projects can serve the goal of improving a current process or to create input to an product innovation project.

Because, based on Utterback & Abernathy (1975) there can be expected that product and process innovation are closely related systems a hybrid model is proposed.

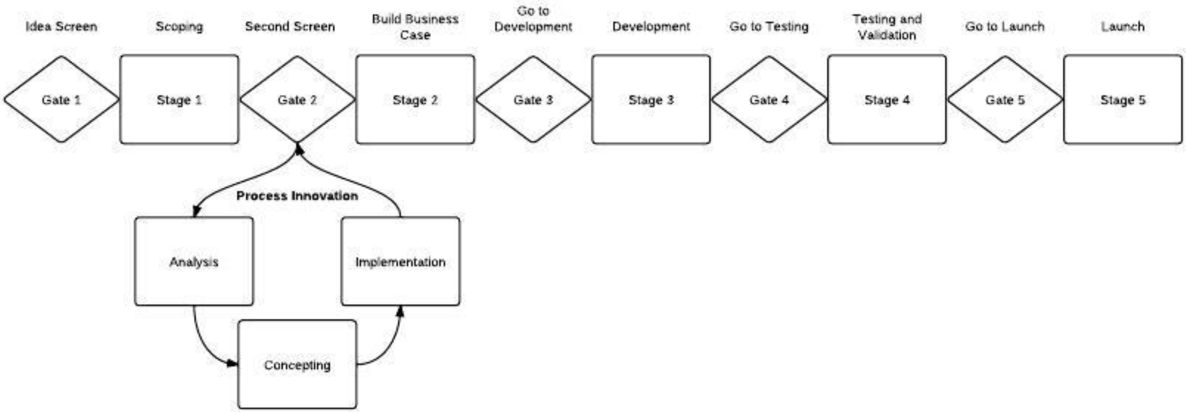


Figure 17: A hybrid model for process innovations

4. Research methodology

4.1. Research methods

In order to answer the research question stated in this report a methodology existing out of three main steps is executed. The chosen methodology starts with the creation of a portfolio overview by means of a survey. Secondly a solid theoretical framework is created to collect the existing knowledge about modelling the management of process innovations. Finally a case study of three process innovation projects at Company ABC should deliver insights in the specific improvement points in the Company ABC methodology. The data for this case study is primarily collected by means of semi-structured interviews.

In this study a combination of qualitative (interviews) and quantitative (survey) data, a mixed method approach, is chosen. By using a mixed method approach the study can incorporate both statistic data and the opinion and attitude of employees about the topic. The quantitative data will be used to create a solid base and clear boundaries to execute a useful qualitative data collection. Qualitative data is used to complement the quantitative data for multiple reasons. First of all qualitative (field) studies are more suitable “for the study of those attitudes and behaviours best understood within their natural setting, as opposed to the somewhat artificial setting of experiments and surveys” which is in line with the goal of the case studies in this research, which tries to extract which structuring is used in the case and even more, if the interviewed employees think this was suitable for the project. The second reason for including qualitative data in the study is the low amount of respondents in some case. This downside of the quantitative part of the research provided for not significant results in some of the statistical tests that are carried out.

4.1.1. Portfolio overview

The start of the project will concern the establishment of an overview of the current situation. This overview will be created by executing a portfolio analysis of all the innovation projects within Company ABC R&D in the past 6,5 years. As there are currently no insight in how process innovations perform the first reason for performing this portfolio analysis can be found in the legitimization and boundary setting of this project. Before starting this study there already was the premonition of underperforming process innovation and unstable management but there was no evidence for these assumptions. The portfolio analysis can underpin these assumption and give direction for the search to points of improvement.

To establish the portfolio analysis a survey will be kept. Out of all the innovation projects in the last 6,5 years an representative sample is selected. For every project multiple employees are invited to respond to the survey. The collected data with the survey will be used to find relations between the performance of innovation projects in different settings and the evolution of the portfolio over time. This information will create the foundation to answer questions like; what are the characteristics of process innovation within Company ABC and which factors could potentially prevent process innovation projects to perform as planned.

The survey design is cross-sectional, with data collected at one point in time (Babbie, 2010) which suits the goal of the survey which is the evaluation of projects in retro perspective. Investigating changes in projects over time is not considered a primary goal of this study. The survey is a self-administered questionnaire which has the strengths of easily describing the characteristics of a large population, large samples are feasible which makes the results, potentially, statistically significant and standardized questions make measurement more precise by enforcing uniform definitions upon the participants. Weaknesses of this method are the that the researchers must ensure that a large number of the selected sample will reply, it may be hard for participants to recall information or to tell the truth about a controversial question and, as opposed to direct observation, survey research can seldom deal with context. (Writing@CSU, 2012)

Most strengths and weaknesses apply to this study. The weakness of ensuring a large enough number of respondents is not really a problem in this study as all respondents are employees of Company ABC R&D with a high motivation to cooperate, resulting in a response rate of 67%. The number of respondents is by this means ensured but the relative low amount of projects can potentially give significance problems during the statistical analysis but most likely this weakness can be tackled by using non-parametric tests such as a Wilcoxon test. The weakness of recalling information or telling the truth is also a realistic threat to this study. There can be assumed that the respondents tell the truth given the topic but recalling information can be a problem as some projects are between 3-7 years old. This threat will be tempered by supporting the respondents by answering questions personally and providing information about the projects which probably will help to recall the information. The third weakness, the lack of use of context, will be tackled to a large extend by the interviews that will be kept as part of the case study. These interviews are particularly suitable to get more information about context, personal attitudes, etc.

4.1.2. Case studies

The portfolio overview and the literature review should already have defined which elements are of importance in structuring process innovations. In this third part of the study, the case studies, insights are created in how these “elements of importance” should be improved. Because of the qualitative character of this part of the study opinions and attitudes of the different departments and managerial levels of Company ABC can be combined.

Relevant employees involved in each project will be interviewed about why and how projects are initiated, how ideas are found and selected, how the project is structured, managed and controlled and how these points can be improved for the project at hand. This part of the study is structured as a cross-case analysis to find patterns and similarities between the different process innovation projects and strengthens the external validity (Soy, S. K., 1997). This external validity is of importance because when we would like to generalize our findings in these projects to all other process innovation projects at R&D. By studying more than one project we aim at creating a more valid overview of process innovation projects at R&D.

4.2. Case selection and sampling

4.2.1. Portfolio overview

In the years 2005-2011 in total 68 NPD projects have been active during 1 or more years. In total 288.128 hours have been spend on these projects. For 42 projects it was feasible to determine a classification. The composition of these 42 projects in the years 2005-2011, which is defined and accepted as “the total innovation portfolio”, is shown in Table 1. In appendix 5 all 42 projects and their classifications are shown.

Type of project	Number of projects	Percentage of total
Explore	23	55%
Exploit	17	40%
Process	8	19%
Product	33	79%
<10000 hours	31	74%
>10000 hours	11	26%
Total	**42**	**100%**

Type of innovation		
	Explorative Product **19**	Exploitative Product **12**
	Explorative Process **7**	Exploitative Process **1**
	Setting of the innovation	

Table 1: Composition of the innovation portfolio at Company ABC R&D

When classifying the project for product/process and explorative/exploitative the combined results of the survey and the classification of the management of R&D is used. It is important to notice that projects are defined process or product when they score four or five points on the five point scale. Therefore projects can theoretically be both a process and a product innovation or not be a product or a process innovation at all. This explains the fact that the number of process and product innovations, resp. 8 and 33, is less than the total number of projects. When determining the level of exploration and exploitation in a project there cannot be overlap, a project is considered explorative or exploitative. Again a five point scale is used and the score on exploitation is subtracted with the score on exploration. If the result is higher than zero a project is considered exploitative. Because a project can theoretically also end on zero in this approach the total number of explorative and exploitative projects, resp. 23 and 17, is not equal to the total number of projects.

The 68 projects were first evaluated on size and number of involved employees. The hour and employee limits were set in order to exclude projects that were just started or never really developed, because these projects can hardly be described in terms of performance and collaboration. In this first step 10 projects were dropped because the minimum of 100 project hours was not reached. Secondly another 6 projects were dropped because not at least 5 employees worked 10 or more hours on the project.

The remaining 52 projects are discussed with the managing director of Company ABC R&D. All projects were tested on the criteria: not being a collection of multiple small idea's or not a real innovation project but e.g. more technical support for one of the operating companies. 15 projects did not meet the criteria and where eliminated out of survey sample.

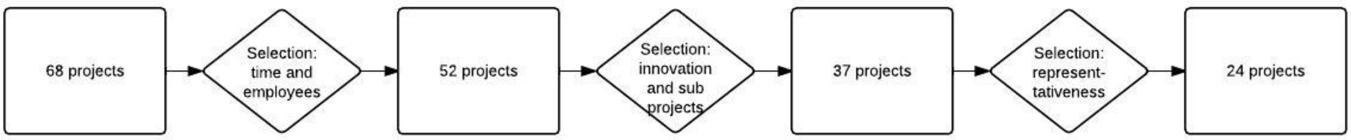


Figure 18: Selection process for portfolio overview

The final goal was to ensure that the sample was representative for the complete innovation portfolio. In order to reach this goal the remaining 37 projects were separated in groups based on size and type of project. Based on the composition of the portfolio for every group of projects one or more projects were randomly excluded out of the sample. After this final step 24 projects remained. The composition of this sample is shown in Table 2. An overview of the selection process is shown in Figure 18.

Type of project	Number of projects	Percentage of total
Explore	16	67%
Exploit	7	29%
Process	5	21%
Product	21	88%
<10000 hours	13	54%
>10000 hours	11	46%
Total	**24**	**100%**

Type of innovation

Explorative Product **14**	Exploitative Product **6**
Explorative Process **4**	Exploitative Process **1**

Setting of the innovation

Table 2: Composition of the sample of innovation projects at Company ABC R&D

Because one of the goals of the survey is to compare performance between groups, a representative sample is necessary to generalize the results to the complete innovation portfolio of Company ABC R&D. When comparing the distribution of the complete portfolio and the distribution of the sample there can be concluded that the distribution of exploitative projects vs. explorative projects is not matching but is approaching the 55/40 distribution in the population. The distribution between product and process innovation is almost completely matching the distribution of the complete portfolio and is therefore very representative on this measure. When comparing the distributions of size there is a difference visible, large projects are absolute and relative more included in the sample in comparison with small projects. This difference is primarily due to the exclusion of small project in the sampling procedures which was done because some of these projects were just started, never really developed or so small that no good evaluation can be made. Although this difference in size, and to a lesser extent exploitation vs. exploration, is recognized there can be concluded that the sample represents the complete portfolio of Company ABC R&D to a great extent.

After selecting the projects, respondents are selected to complete the questionnaire. In theory, a single respondent can evaluate a project assuming perfect memory, no bias and perfect truth. As the variables, in specific memory and bias, are probably not so stable at least three respondents are asked to evaluate a project. According to Babbie (2010) the selection process for individual respondents should be random with each individual in the population having an equal chance to be selected. The selection procedure in this study is not completely random as not all project members had a chance of selection. Project members with very few hours invested in the project, members that are no longer employed at R&D or members that operate in a environment far away from the project structure such as the workshop are excluded. The remaining project members were, if the amount of members allowed it, randomly selected by shuffling the list and choosing every third member. For the use in this study that is assumed to be a random enough sampling of respondents.

Below in Table 3 there is a summary of the respondents and response rate for every project.

Table 3: Overview of respondents and response rate

4.2.2. Case studies

The projects for the case studies, for which interviews are going to be used, will be selected on size and the type of project. The goal is to find a limited set of medium to large sized process innovation projects that give a good insight in how process innovation currently are managed within Company ABC.

According to van Aken et al. (2007) selecting cases for a case study should first of all be based on pragmatic ground, such as the number of cases that are available or the number of cases for which data can be obtained. When multiple cases remain the selection should continue on theoretical grounds.

In theory all process innovations that are executed in the past at R&D can be included in the cross-case analysis but some pragmatic grounds are used to make a selection. Out of the complete list of options, projects are excluded based on being too old, too small or some of the most involved employees were no longer available for data collection. This selection of projects based on pragmatic grounds was done during a discussion with the Managing Director R&D and the ABCD manager Company ABC. It resulted in seven potential case study candidates: Project B (...), Project X (...), Project A (...), Project C (...), Project Y (...), Project D (...) and Project Z (...). Those projects were not necessarily projects which are classified as an process innovation such as defined in the methodology chapter. The projects are projects in which the process innovation part had a clear influence on the results of the project and that fulfilled the above mentioned pragmatic selection criteria.

After a selection based on pragmatic grounds a selection on theoretical grounds followed. Based on van Aken et al. (2007) theoretical grounds can be dependent or independent variables. According to van Aken et al. (2007): “a selection based on one or more independent variables means that case selection is based upon potential causes”. In this study a selection on independent variables is used because there is expected that presence of the stage-gate model as structure of the project influences the success of project management in that project. Based on this assumption three project are selected of which one used the stage-gate model quit strict and two did not used this approach. A selection on dependent variables (operational and overall performance) is not used in this study because this variables can be influenced by much more factors than just “the structure/model of the project”. This combined with the fact that researching a large number of projects is not feasible in this study resulted in selection on independent variables only.

The three cases selected are Project A (1), Project B (2) and Project C (3). The selected projects are all, to a greater or lesser extent, a combination of product and process innovation. The Project B and Project A are primarily process innovations with a small product innovation component, the Project C is primarily a product innovation in which the process development was a smaller, but in retro-perspective very critical, part. The cases seem to suit the theoretical quit good for two main reasons: all project can be defined as a process innovation to a large extent and the project suits the hybrid model of product and process innovation that is proposed in the theoretical framework of this thesis.

A fourth case, Project D (4), is selected to apply the newly created model and insights on. This fourth case is a project that is defined as a "know-how" project which is created to collect projects that are focused on collecting of knowledge on a specific topic without the direct goal to contribute to a product or process innovation.

The following employees are used as respondents in this case study. The current occupation is mentioned.

1. **Project A**

- Project leader / technical expert (Company ABC R&D)
- Quality & innovation manager (Company ABC Department A)
- Engineer (Company ABC Department B)
- European product manager (Company ABC BU H&C)

2. **Project B**

- Senior project leader (Company ABC R&D)
- Technical coordinator (Company ABC ABCD)

3. **Project C**

- Project leader (Company ABC R&D)
- Manager productmanagement (Company ABC GmbH)
- Industrial engineer (Company ABC Country A)
- External consultant (Company ABC R&D)

4. **Project D**

- Project leader (Company ABC R&D)
- ABCD manager (Company ABC ABCD)

4.3. Data collection

For the collection of empirical data two sources are used, a survey and a case study, which will be discussed in this paragraph.

4.3.1. Survey

The survey is composed in close collaboration with M. de Visser Msc, PhD student, who uses the data as input for his PhD research. The survey consist of two parts. In the first part the cognitive style of the respondent is determined and this information is primarily used by the PhD research. In the second part the respondent is asked about the performance, collaboration, type of, current status and individual contribution to the projects he or she has been involved in. For this thesis only a limited, specific part of the survey is used. To determine the setting of the project a question is created to determine the level of exploration and exploitation in a project.

How was the total amount of project time allocated over the next two types of activities?

1) Explorative activities such as fundamental research.	(0-100)	%
2) Exploitative activities such as standardization.	(0-100)	%

For the second topic, the performance of the projects, two constructs are used, overall project performance and operational project performance. In literature multiple measures for the performance of innovation projects are proposed but based on pragmatic grounds there is decided to include a measure for overall performance and for operational performance. The reason to include the operational performance construct can primarily be found in the wish to explain on which elements the project underperformed. These operational insights create a starting point to search for improvement in comparison with just a “weak overall performance”.

For the overall performance construct the article of Hoegl, Weinkauf and Gemuenden (2004) is used which resulted in the below mentioned elements:

Overall project performance

- Regarded as successful
- Project goals have been achieved
- Of high quality
- Project team satisfied with performance
- Top management satisfied with progress

For the operational project performance construct the article of Griffin and Page (1996) is used which resulted in the below mentioned elements:

Operational project performance

- On budget
- On schedule
- Meets quality specifications

The complete survey can be found in appendix 3.

4.3.2. Case studies

The data collection for the case studies is primarily done by interviews. For the interviews a limited number of employees, between two and four, involved in the selected projects will be asked to participate. The interviews will be semi-structured and are constructed around the five topics that are created in the theoretical framework. The list of questions can be found in appendix 1. All the interviews are, with permission of the interviewee, recorded.

Besides the interviews the project plan (if available), project diaries, presentation slides and some e-mail conversations are used. All this information is provided by the project leader at R&D or gained through the digital project administration of R&D.

4.4. Data analysis

The data analysis will consist of two parts. First the survey data will be statistically analysed using SPSS and Excel. The exact procedure for this part of the analysis will be explained in the first paragraph of the survey results chapter.

All the interviews, which are recorded, are completely transcribed as a literal text, no adjustments or corrections are made to the text. All the transcriptions are than coded. This procedure started with completely reading the transcript and dividing it in parts that seem to cover a single topic. After these relevant, single topic, parts are created every part is given a code. The code is word or short sentence describing the specific part. Finally all codes are assigned, if possible, to one of the five topics that are created in the theoretical framework.

To ensure that the experienced world view of the respondents is in line with the interpretation of this experience by the interviewer (Kvale, 1996) a communicative validation (IJzendoorn & Miedema, 1986) is used. All the transcripts are returned to the respondents and feedback is discussed in order to ensure that the opinion of the interviewee is correctly interpreted.

When all the interviews are kept, transcribed and analysed the results of the case study will be summarized for every case in the chapter case results.

5. Survey results

As there are currently no insights in how process innovations perform the first reason for performing this portfolio analysis can be found in the legitimization and boundary setting of this project. Before starting this study there already was the premonition of underperforming process innovation and unstable management but there was no evidence for these assumptions. The portfolio analysis can underpin these assumption and give direction for the search to points of improvement.

The survey data will be analysed in order to give answer to the five questions stated to achieve the target of this analyse that is mentioned above. The question's below do contribute to one of the general research question's in this thesis, which is "*What are the main problem area's in the current innovation process at Company ABC R&D?"*. Besides the goal of contributing to answering this research question this portfolio analysis will primarily contribute to the legitimization of the project and give direction for the search to points of improvement.

- *Is there a difference between the performance of product innovations and process innovations?*

This question is primarily stated for legitimization reasons. Answering this question should tell if the problem for R&D is not only the absence of a model for process innovation but also the underperformance of these projects.

- *Is there a difference between the performance of innovations in a more explorative setting and a more exploitative setting?*

This question is primarily stated to give insights in what the main problem areas are in the innovation projects of Company ABC R&D and should contribute to the recommendations on the topic of explorative vs. exploitative projects.

- *How is the innovation portfolio of Company ABC R&D composed over the last six years?*

This question does not directly contribute to answering the research question or to the legitimization of this research but it is supportive in getting a good overview of the projects at R&D and what part, explorative and exploitative, process innovations play in this portfolio.

5.1. The performance of product and process innovations

To determine the performance of different types of projects within Company ABC R&D and which type of performance (budget, quality specs, schedule, overall success) is falling behind in specific types of projects the first question is stated. This information can give direction for this research regarding the focus on types of projects and what the management problems are of the projects.

1. *Is there a difference between the performance of product innovations and process innovations?*

5.1.1. Descriptive statistics

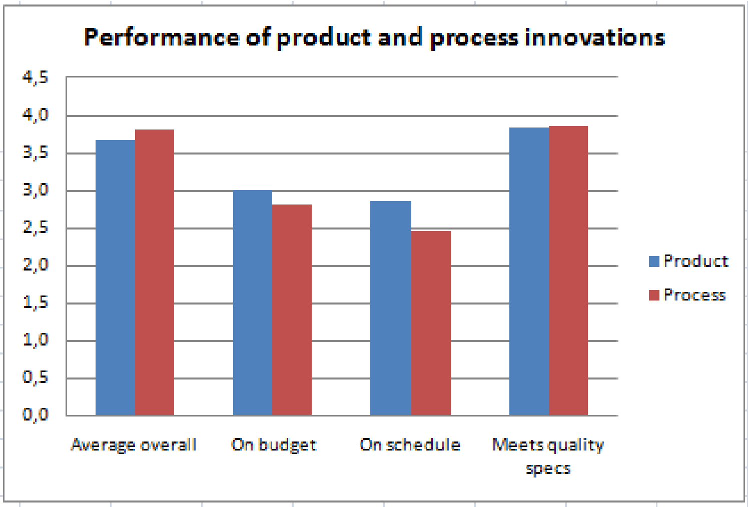


Figure 19: Performance of product and process innovations

Group Statistics

	Product or ...	N	Mean	Std. Deviation	Std. Error Mean
AV_OV	Product	21	3,66794	,378100	,082508
	Process	5	3,80667	,505607	,226115
OPER_1	Product	21	3,01159	,319961	,069821
	Process	5	2,81667	,170783	,076376
OPER_2	Product	21	2,86476	,606189	,132281
	Process	5	2,46667	,410792	,183712
OPER_3	Product	21	3,82921	,394858	,086165
	Process	5	3,86667	,315128	,140929

Table 4: Descriptive statistics question 1

5.1.2. Method of analysis

For the analysis of 5.1. and 5.2. the same method of analysis is used. For each of the constructs a t-test for two means with independent samples is generated in SPSS. For all tests the assumptions are checked. For a t-test for two means the assumptions are: the independent group assumption, independence assumption, normal population assumption and the equal variance assumption. As n general assumption the dependent variable, in this case different types of performance, needs to be at least of the interval measurement level. Strictly interpret a Likert-scale, as used to determine the performance constructs in this survey, is of the ordinal measurement level but in literature it is accepted to use a Likert-scale as an interval scale. This gives the possibility to calculate means, standard deviations and execute a t-test.

The independent group assumptions is accepted for all samples and therefore the t-test for independent samples is used. For all samples the independence assumption is accepted because of randomization and although more than 10% of the population is included in the sample the samples are assumed independent because just a very small number of projects are included in both samples. The normal population assumption is not accepted for all tests because of a too small sample. In the case of a too small sample size an alternative tests is used, the Rank Sum test Wilcoxon, using the formula $z=(W-\mu_w)/\sigma_w$. The equal variance assumption is tested by using the Levene's test. When accepting this assumption the pooled t-test is used, when unable to accept the assumption the "normal" t-test for two means is used.

Before executing the test a null and alternative hypothesis are formulated in which the null hypothesis predicts no differences between the two samples and the alternative hypothesis predicts a differences between the two samples without stating which, a two-sided t-test.

For rejecting or not rejecting the null hypothesis a confidence interval of 90% is chose which equals a "alpha" of 0,05.

5.1.3. Analysis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									90% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
AV_OV	Equal variances assumed	,191	,666	-,693	24	,495	-,138730	,200124	-,481119	,203659
	Equal variances not assumed			-,576	5,118	,589	-,138730	,240698	-,621289	,343829
OPER_1	Equal variances assumed	1,025	,321	1,304	24	,204	,194921	,149428	-,060733	,450574
	Equal variances not assumed			1,884	11,827	,084	,194921	,103481	,010263	,379578
OPER_2	Equal variances assumed	1,806	,192	1,384	24	,179	,398095	,287733	-,094182	,890373
	Equal variances not assumed			1,759	8,752	,113	,398095	,226381	-,018227	,814417
OPER_3	Equal variances assumed	,220	,643	-,197	24	,846	-,037460	,190449	-,363296	,288376
	Equal variances not assumed			-,227	7,344	,827	-,037460	,165183	-,348220	,273300

Table 5: Analysis stats 1 of question 1

Test Statistics[b]

	AV_OV	OPER_1	OPER_2	OPER_3
Mann-Whitney U	43,000	32,000	32,000	49,500
Wilcoxon W	274,000	47,000	47,000	64,500
Z	-,621	-1,367	-1,340	-,199
Asymp. Sig. (2-tailed)	,535	,172	,180	,842
Exact Sig. [2*(1-tailed Sig.)]	,569[a]	,200[a]	,200[a]	,850[a]

a. Not corrected for ties.

b. Grouping Variable: Product_or_Process

Table 6: Analysis stats 2 of question 1

Average overall performance

To determine the overall project performance, the five elements (regarded as successful, project goals achieved, of high quality, project team satisfied, top management satisfied) that build up this construct are averaged. Levene's test value: 0,666 which is not smaller than 0,05. H0 not rejected and equal variances are assumed. The minimal sample size required for this test is 20. With the smallest group being 5 projects the sample size is to small and the t-test cannot be used. The Rank sum test Wilcoxon is used.

H0: There is no difference between the average overall performance of product innovations and process innovations. Wilcoxon test value: 0,569 which is not smaller than 0,05. H0 cannot be rejected. There is no significant difference between the average overall performance of product innovations and process innovations.

Project on budget
Levene's test value: 0,321 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 2,07. With the smallest group containing 5 projects the sample size is sufficient to use the t-test for two independent samples.

H0: There is no difference between the "project on budget" performance of product innovations and process innovations. T-test value: 0,102 which is not smaller than 0,05. H0 cannot be rejected. There is a no significant difference between the "project on budget" performance between product and process innovations.

Project on schedule
Levene's test value: 0,192 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 2,88. With the smallest group containing 5 projects the sample size is sufficient to use the t-test for two independent samples.

H0: There is no difference between the "project on schedule" performance of product innovations and process innovations. T-test value: 0,089 which is not smaller than 0,05. H0 cannot be rejected. There is no significant, although close, difference between the "project on schedule" performance of product innovations and process innovations.

Project meets quality specifications
Levene's test value: 0,643 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 203. With the smallest group being 5 projects the sample size is too small and the t-test cannot be used. The Rank sum test Wilcoxon is used.

H0: There is no difference between the "project meets quality specs" performance of product innovations and process innovations. Wilcoxon test value: 0,850 which is not smaller than 0,05. H0 cannot be not rejected. There is no significant difference between the "project meets quality specs" performance of product innovations and process innovations.

5.1.4. Conclusion

When comparing the performance of product and process innovations projects within Company ABC R&D, in general can be stated that the overall project performance, is slightly lower for product innovations compared with process innovations. This difference is not statistically significant. When comparing the constructs of operational project performance a different picture emerges. On both "project on budget" and "project on schedule" process innovations underperform, resp. (on a 5 point scale) product:3,012, process: 2,817 and product:2,865, process: 2,467. Both differences are not significant. When comparing the scores on "project meets quality specifications" process and product innovation projects achieve a similar score.

When interpreting this analysis there can be concluded that process innovations are underperforming on the operational goals "on budget" and "on schedule" when compared with product innovations but that the overall value that employees give to process innovations projects is at the same high level as product innovations.

5.2.The performance of explorative and exploitative innovations

To determine if an more explorative or more exploitative setting has an impact on the performance of innovations within Company ABC R&D question two is stated. This analysis can help to get a better picture on the difference between explorative and exploitative innovations and potential areas that need problem solving.

2. *Is there a difference between the performance of innovations in a more explorative setting and a more exploitative setting?*

5.2.1. Descriptive statistics

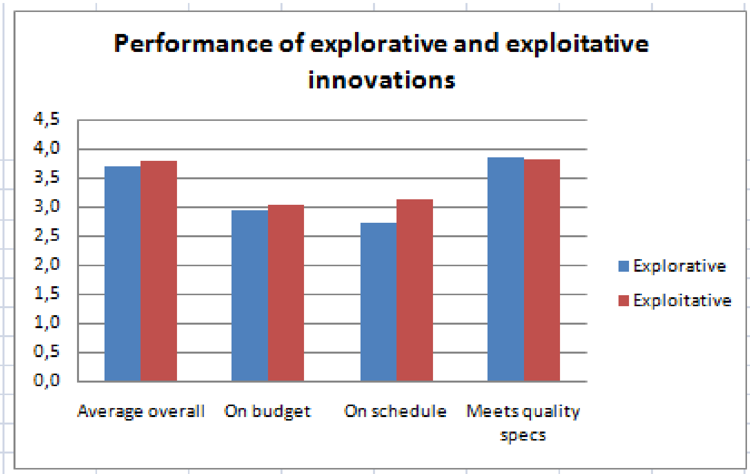


Figure 20: Performance of explorative and exploitative process innovations

Group Statistics

	Exploit or ...	N	Mean	Std. Deviation	Std. Error Mean
AV_OV	Explore	16	3,69375	,402529	,100632
	Exploit	7	3,78952	,477600	,180516
OPER_1	Explore	16	2,93708	,294334	,073583
	Exploit	7	3,05952	,295468	,111677
OPER_2	Explore	16	2,74438	,591629	,147907
	Exploit	7	3,13095	,466114	,176174
OPER_3	Explore	16	3,85083	,404955	,101239
	Exploit	7	3,84048	,439787	,166224

Table 7: Descriptive statistics question 2

5.2.2. Analysis

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									90% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
AV_OV	Equal variances assumed	,020	,888	-,497	21	,624	-,095774	,192745	-,427438	,235891
	Equal variances not assumed			-,463	9,925	,653	-,095774	,206671	-,470643	,279095
OPER_1	Equal variances assumed	,045	,834	-,917	21	,370	-,122440	,133528	-,352209	,107328
	Equal variances not assumed			-,916	11,475	,379	-,122440	,133739	-,361713	,116832
OPER_2	Equal variances assumed	,702	,411	-1,527	21	,142	-,386577	,253161	-,822202	,049047
	Equal variances not assumed			-1,681	14,548	,114	-,386577	,230030	-,790657	,017502
OPER_3	Equal variances assumed	,026	,875	,055	21	,957	,010357	,188156	-,313411	,334125
	Equal variances not assumed			,053	10,689	,959	,010357	,194627	-,340105	,360819

Table 8: Analysis stats 1 of question 2

Test Statistics[b]

	AV_OV	OPER_1	OPER_2	OPER_3
Mann-Whitney U	43,000	32,000	32,000	49,500
Wilcoxon W	274,000	47,000	47,000	64,500
Z	-,621	-1,367	-1,340	-,199
Asymp. Sig. (2-tailed)	,535	,172	,180	,842
Exact Sig. [2*(1-tailed Sig.)]	,569[a]	,200[a]	,200[a]	,850[a]

a. Not corrected for ties.

b. Grouping Variable: Product_or_Process

Table 9: Analysis stats 2 of question 2

Average overall performance

To determine the overall project performance the five elements that build up this construct are averaged. Levene's test value: 0,888 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 48. With the smallest group being 5 projects the sample size is too small and the t-test cannot be used. The Rank sum test Wilcoxon is used.

H0: There is no difference between the average overall performance of explorative innovations and exploitative innovations. Wilcoxon test value: 0,569 which is not smaller than 0,05. H0 cannot be rejected. There is no significant difference between the average overall performance of explorative innovations and exploitative innovations.

Project on budget

Levene's test value: 0,834 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 15. With the smallest group being 5 projects the sample size is too small and the t-test cannot be used. The Rank sum test Wilcoxon is used.

H0: There is no difference between the "project on budget" performance of explorative innovations and exploitative innovations. Wilcoxon test value: 0,200 which is not smaller than 0,05. H0 cannot be rejected. There is no significant difference between the “project on budget” performance of explorative innovations and exploitative innovations.

Project on schedule
Levene’s test value: 0,411 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 4. With the smallest group containing 5 projects the sample size is sufficient to use the t-test for two independent samples.

H0: There is no difference between the “project on schedule” performance of explorative innovations and exploitative innovations. T-test value: 0,071 which is not smaller than 0,05. H0 cannot be rejected. There is no significant difference, although close, between the “project on schedule” performance of explorative innovations and exploitative innovations.

Project meets quality specifications
Levene’s test value: 0,875 which is not smaller than 0,05. H0 not rejected and equal variances assumed. The minimal sample size required for this test is 4465. With the smallest group being 5 projects the sample size is too small and the t-test cannot be used. The Rank sum test Wilcoxon is used.

H0: There is no difference between the “project meets quality specs” performance of explorative process innovations and exploitative process innovations. Wilcoxon test value: 0,850 which is not smaller than 0,05. H0 cannot be not rejected. There is no significant difference between the “project meets quality specs” performance of explorative innovations and exploitative innovations.

5.2.3. Conclusion

When comparing explorative innovations with more exploitative innovations it becomes clear that innovations in a more explorative setting underperform on overall project performance compared to innovations in a more exploitative setting. The difference is not significant.

When comparing the operational project performance there are no major differences on the constructs “project being on budget” and “project meets quality specs” but on the construct “project being on schedule” explorative innovations score clearly lower (2,745) than exploitative innovations (3,131) but also this difference is not significant, although close.

Wrapping up the above stated analysis, the performance of explorative innovations stays behind with the performance of exploitative innovations. Assuming that explorative innovations have the same level of importance for Company ABC R&D this result can have influence for the recommendations of this research. Another conclusion that can be extracted out of the first two analyses is that process innovations have major problems performing on schedule, the only construct that scores below 2,5 points (product: 2,865, process: 2,467).

5.3. Composition of the portfolio

To determine what the amount of process innovations and the size of these projects has been over time question five is stated. This analysis is not intended to directly help solving the problem within Company ABC R&D but supports as an overview of the situation and to legitimate this study.

3. How is the innovation portfolio of Company ABC R&D composed over the last 6 years?

5.3.1. Descriptive statistics

Figure 21: Portfolio overview Company ABC R&D

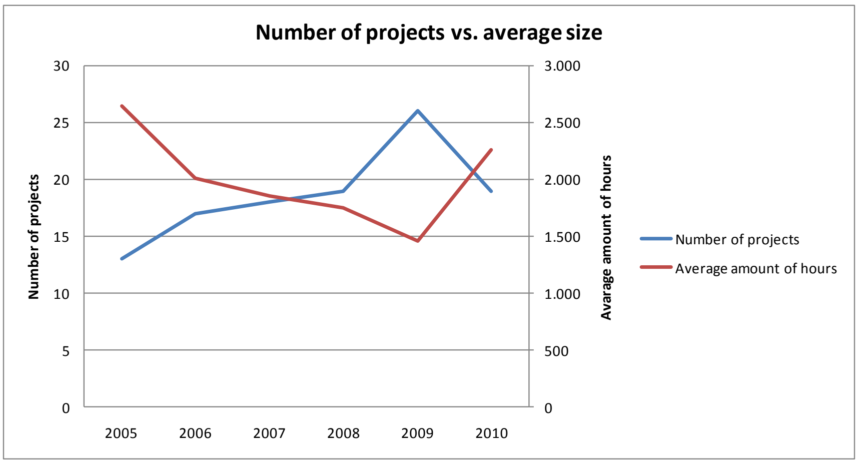


Figure 22: Number of projects vs. average size

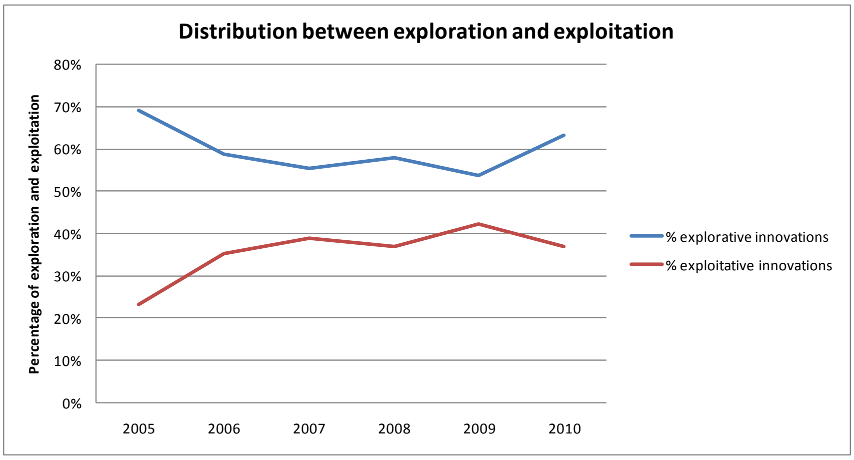


Figure 23: Distribution between exploration and exploitation

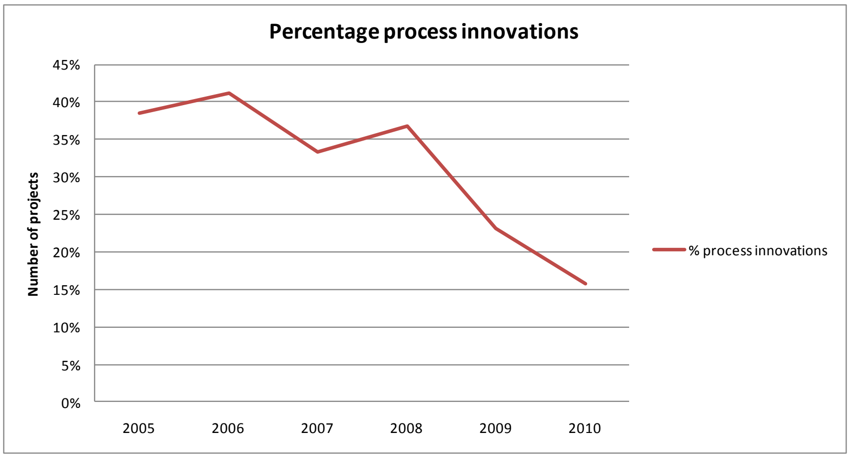


Figure 24: Percentage process innovations

5.3.2. Method of analysis

For composing the portfolio overview charts the classification as described in the research methodology chapter is used. Because a project can be both a product and a process innovation the both scores are subtracted to determine if a project is more product or more process innovation. Combining this with the already determined level of exploration vs. exploitation determines the location in the portfolio overview. The total number of hours invested determines the size of the circle.

5.3.3. Analysis

Based on the six years (2005-2010) for which portfolio overviews have been created a number of conclusion can be drawn. First of all the total number of projects active in a year have clearly increased over the years, peaking in 2009. In 2005 just 13 projects were active, in 2009 26 projects were active (2005:13, 2006:17, 2007:18, 2008:19, 2009:26, 2010:19). Although the number of projects raises through the last six years the number of hours invested does much less (2005:34317, 2006:34249, 2007:33333, 2008:33190, 2009:37826, 2010:42845). Where the number of projects increases from 2005 to 2009 with 100%, the number of hours invested raises with only 10,2%. This information would presume that the average size (in hours) is decreasing and this can supported by the data. The average amount of hours invested in the projects decreases (2005:2640, 2006:2015, 2007:1852, 2008:1747, 2009:1455, 2010:2255) with 2010 as an exception in the trend. Actually 2010 breaks with a trend from multiple perspectives. The number of projects decreases in comparison with 2009 and the amount of hours increases clearly after a period of stability for a number of years. The innovation portfolio of Company ABC R&D seems to changed direction in terms of composition starting in 2010. In this year the number of projects is smaller but the average size is increasing clearly.

When taking a closer look at the type of projects in the portfolio, especially the influence of process innovations, the following statements can be created. The number of process innovations is much lower than the amount of product innovations with between 16% and 41% of all innovation projects being considered a process innovation. The percentage of process innovations in the portfolio is decreasing in 2009 and 2010 (2005:38%, 2006:41%, 2007:33%, 2008:37%, 2009:23%, 2010:16%). There can be concluded that the amount of process innovations, both relative and absolute, in the portfolio is lower than that of product innovations and the number is decreasing even more. When examining the balance between explorative and exploitative innovations it becomes clear that explorative innovations are supernumerary but the differences get smaller through the years. It should be mentioned that in the majority of years the exploitative innovation projects have used more hours than the explorative innovation projects.

5.3.4. Conclusion

Based on the analysis of the composition of the innovation portfolio it can be concluded that the number of projects increases, the average size decreases, the number of process innovations obviously is lower than the number of product innovations and is decreasing further. More explorative than exploitative projects were active but exploitative projects use more hours than explorative ones.

6. Case results

As described in the methodology chapter three cases are studied in order to learn more about the practice at Company ABC when it concerns the structure of process innovations. The three projects are Project A (…), Project B (…) and Project C (…). The projects will first be introduced in general followed by an analysis of the theme's that are defined in theoretical framework.

6.1.Project A, …

This project started for R&D in 2009 and is still open in order to give support. The project used at its maximum 1227 hours (2010), about 3% of the total amount of hours spent that year. The project is classified as slightly more explorative than exploitative and primarily as product innovation. The project performed slightly above average on all points of measurement.

Table 10: Descriptive statistics …. … filled

6.1.1. Iterations

While studying the iterative characteristics of this project we focused on two types of iterations: the small iterations that can take place within the project and the larger type of iterations that Pisano (1997) are described as an approach that should ensure that knowledge generated in the "learning-by-doing phase" is brought back to R&D to ensure that R&D can initiate new process development projects with complete knowledge.

The first type, of small iterations, seem to be relevant for this project. In the development phase of the project (although no clear phases where defined), an number of iterations took place between R&D and the operating companies. This was described as "*R&D developed the sort of idea of the process and ask the OC's to try to manufacture it in a sort of operation environment. R&D came with ideas, R&D do trials and then the ideas where transferred to the OC and see if they can produce the product. It was a kind of iterative process where… just seeing which one worked best*"

The second type of iteration, the production environment as source of input for new innovation, can less clearly be distinguished in this project. Measuring and improving the production is a point of focus at the OC, *"at least we have our own approach with improvement team activities which are proposed on several parameters. So we can start a new product, we start with starting up the line and propose something on how we can improve the output of the line. Then we see how we can improve some parameters of the line, then we have another improvement action, which include how to improve these parameters and we get the benefits"*. But these figures and improvement actions do not seem to get back to R&D in order to get converted to new process innovation ideas. Small improvement after production started seem to be coordinated locally by both OC's: *"yes and I think that when you take a look at improvements in the product itself, those are more done at Department A, looking at how can we make improvements which make a better end product".*

6.1.2. Sources of process innovation

The first steps in the development of this project were already made before Department B entered the Company ABC group. *"actually, we have decided to invest on glass filled product well before Company ABC's acquisition of Department B. However, when acquisition interviews started, it was decided to cancel all investments. After acquisition completed, we started to work on this product again"*. The development process was primarily started because of market forces, competitors developed the product and the risk of losing market share was there.

This unexpected situation of a commercial, market driven force as the initiator of a process development is potentially due to the fact that this process innovation drives a clearly new product and not only an change in production or technology. The market driven initiation is described as *"what we saw in Country E in particularly, that other Country E manufactures, the competition and the largest manufacturer as well launched a glass filled product. And then immediately that became an issue to Department B. What we then saw at Department A was that their market, in Country C/ Country D, started to see glass filled on the market from Country E manufactures and then it also became a problem for Department A".*

6.1.3. Phases and structure

According to the project manager at R&D no formal structure was followed, including the stage-gate model: *"no, not used, from the beginning it was a project that was just a copy of a product that was already created by a competitor"* and also no formal gates or decision moments: *"actually it was already in advance known how the product should look like and that the development should continue. There is never a real decision moment taken".* The project followed a method used in more similar projects, smaller projects which are not initiated by the business unit. These projects do not follow the stage-gate structure and are managed without any formal model but in close cooperation between project manager and managing director.

Although no formal structure was used at least a development and an implementation phase can be recognized. Actually development took place after, or at least parallel, with the implementation of the process. Both Department B and Department A started the production of a copycat product as soon as possible and primarily Department A started developing alternatives later on. The technology was further developed at the production location while production was already started. This can be seen as an example of learning-by-doing.

A final point closely related to structure is central or decentralized coordination of process innovations projects. According to the project manager at R&D *"I think there is a big difference, when something is initiated by an operating company, than they would like to do the work related"* but he also states that *"with the current structure of business units this should not be possible anymore. It should be done much more central, which does not claims that R&D should do all the work, it can still be done at an operating company but it should be coordinated centralized".*

6.1.4. Measurements and targets

The general goal of this process innovation was quite clear from the beginning, it should deliver a product that can compete with other glass filled .... products on the market and it should be done in a very short period of time. Targets were set in the form of an list of requirements (LoR) with quite specific requirements for the final product. This LoR does also contain some “manufacturing requirements” but those are not or not fully filled in most of the cases.

The project manager of R&D states when asked about target setting for process innovations: *“i think that the development of a new process at itself brings more question marks in comparison with a new product. A new product can always be manufactured but a new process does not automatically says that it is technically feasible”.* Although he states that the development of a new process should always first be checked on feasibility before starting this does not become clear in this specific case. This can be due to the fact that the development in this project was not very extensive and the fact that the process innovation of the project was to a very high extend interwoven with the product development part.

6.1.5. The influence of exploration and exploitation

When discussing the level of exploration and exploitation with different stakeholders in this project different opinions become clear. From a very explorative vision: *“glass filled product for .... was new for both Department B and Department A and basalt filled product was novel for everybody. How much we previously knew about glass filling extruded products I am not sure, but a basalt filling in products was novel completely, as far as I am aware“.* While others defined it more exploitative *“the project was more exploitative than explorative. Since more or less the market size, customers etc. were known. Product was new for us but not for the market“* or even completely exploitative: “*yes that is completely on the exploitative side because it is an existing product*”. Overall can be stated that this technology of using .... is new to Company ABC but not to the market and the components of the technology (multi-layer product, using .... in a product) were not new to Company ABC. Overall it can be defined as a pretty exploitative project with limited real new technology or products.

When we focus on how the level of exploration/exploitation influenced the project management a number of statements can be made. The project manager at R&D states that although he thinks the project is completely exploitative that *“you have to do a part test work, development work for yourself, even if you are going to copy it”* and *“even this type of projects have a certain part uncertainty that cannot be estimated in advance”*. Although process development projects with a high exploitative character have a lower need for concept proof it still needs a preliminary phase in which the risks of the technology are defined before entering the more time driven product development phase. From the interview with operating company employee it can also be distillated that although the exploitative character of the innovation *“speeded up our execution for investment decisions, market launch, etc”*, developing a new process keeps having more than average risks, for example: *“we faced quality problem in the first productions. It made us lose time. This was the unexpected situation that we did not foreseen”.*

6.1.6. Conclusion

The project was aimed at developing a .... product for use in East European countries. The project was initiated and also for a substantial part developed at the operating companies Department B and

Department A. In the collaboration between R&D and the OC's very little of an iterative structure can be found. Although small feedback loops between R&D and the OC's existed a real feedback of production knowledge cannot be distinguished. The OC's do execute autonomous improvement projects but these are not linked to R&D or to other OC's.

The initiation of this project was primarily market-driven which is in line with the fact that this innovation project can partly be considered a product innovation. For the structure of this project no formal model was used but because of the NPD character target setting was done extensively and distinct.

The project scores above average on all constructs but achieving the lowest score on the "on budget" measurement. When connecting the characteristics of this project to performance the following can be stated. The project scored average to high on all constructs although it did not match with theory on some points. Potentially the intensive collaboration between the OC's and R&D combined with the exploitative nature of the project contributed to this "success". The measurements do not include the performance of the project after implementation but it can be assumed that this part of the innovation can be improved by a better feedback loop from production to R&D.

6.2.Project B, …

This project has used hours of R&D in a number of years with the highest amount in 2010. In this year 3976 hours are invested in this project. The project is scored average on both the level of product as process innovation and is considered more explorative then exploitative. The performance of the project is on average for both overall performance as “meeting quality specs” but clearly lower for “on budget” and “ on schedule” .

Table 11: Descriptive statistics Project B

6.2.1. Iterations

The Project B project is again, similar to the glass filled .... project, a combination of product and process development. The technology of producing a multi-layer product with recycled material is combined with the development of this product.

The larger sort of iterations in which production environment are tightly coupled to R&D environment in order to create input for new process innovations seems to be, in line with the … filled .... project, absent in this project. When asked, the project manager at R&D states that *“knowledge exchange within Company ABC is most of the times a bit hard. That is a pity. At one hand everyone wants to create everything by themselves all the time and on the other side companies are also not inclined to give without return. Actually there should be complete exchange of information and knowledge”*. This reduced will to share information contributes in this case to a situation in which: R&D is heavily involved in developing and implementing the new technology (actually in the lead) but this involvement stops after production starts. No clear and formal traces are found in how information of production returns to R&D.

When discussing this lack of iteration with an ABCD representative involved in the Project B project he mentions a structure that should potentially be an important source of feedback and knowledge sharing on the topic of process innovation/development. *“my role was to share knowledge and to do this I had workgroups with representatives of the region’s. I had a workgroup for TPM, a workgroup production method B and a workgroup production method C”* but later in the conversations, when discussing the current status of these workgroups the ABCD manager states that both the TPM and production method B workgroup are inactive and the production method C workgroup is active but on a low amount of meetings.

6.2.2. Sources of process innovation

The initiation of this project can be traced back to decisions at higher management. According to the ABCD involved employee *“Project B originates in Houdini which is a concept developed by a consultant of Bain. He developed two concepts which can save production costs which where: 1) a different* *approach to the production of sockets or 2) the use of more recycled material (Houdini)."* This top management decision, combined with the already existing interest of Company ABC UK to reduce the production costs of their ... products resulted in the start of the development of Project B. The source of initiation in this project was clearly internal and based on the current production figures.

The project manager at R&D, production method C expert and senior project leader, explains in the interview the types of initiation that are possible for process development projects in which his department is involved. *"the tasks of our group are the following: we are there for the optimization of processes, the development of new processes, the second part of our task is solving production problems wherever they emerge and the third part of the task is the management of knowledge and education of people, training etc. Most of the time a question of an operating company comes at our desk and rarely Zwolle gives a tasks such as in this case."* This description not only further clarifies the situation in this case it also makes clear that the process development part of R&D primarily works reactive and in a one-to-one contact with the operating company.

6.2.3. Phases and structure

When searching for a structure that is used in this project it becomes clear that again no formal structure or model is used. According to the project manager at R&D, the stage-gate model *"tells me nothing, so it is probably not used. No, we always have used the following approach: we get a task and we finish it. Our approach is: this piece of work needs to be done or this problem needs to be solved and I call all types of people together to brainstorm on the solution".*

When asked about where the initiative should be for developing (new) processes the project manager at R&D states that "*I prefer to walk into a problem, that gives the most cooperation at the operating company. If an operating company has a problem or a whish and they end up at R&D they are most willing the cooperate. If we say, we have developed this and this for you, this can be helpful, the operating company will say: well please proof it first".* This situation and work method does also contribute to a very reactive and problem solving approach to process development.

6.2.4. Measurements and targets

For this specific project targets were set quit clear on product level, it contains subjects such as the look, strength and filling of the multi-layer product. On the process development part no specific targets were set.

In a larger perspective measurements of the production process are a topic of interest at Company ABC. An involved ABCD manager mentions that because of TPM all factories measure, or in some cases measured in the past, multiple parameters of production efficiency which resulted in an OEE (overall equipment efficiency) and an OEU (overall equipment utilization). *"at every line, still when you enter a factory, you see at every line a OEE graph. That is still there, a combined number of the site ends at our department (ABCD)".* Although both ABCD employees mention the lack of focus and priority on this topic (TPM) the measurements are done and can provide a valuable source of information as input to process innovations.

6.2.5. The influence of exploration and exploitation

Although the projects asked for a relative large amount of R&D hours the project is not really explorative of nature. Using recycled material in ... products is a well-known technology for Company ABC as an organization. When the ABCD responsible employee was asked for his opinion on the level of exploration/exploitation: *"No, there was barely development necessary. Technical it was a case of buy that machine, that machine, that machine."*

For Company ABC UK it is a new process and the high quality level that was asked for by Company ABC UK is also new for the entire Company ABC organization. So even though it is not a very explorative projects for Company ABC in total, for this setting it was not that exploitative either. There is a remarkable fact in this situation, the technology is new for Company ABC UK but not for Company ABC as a group. The development of this technology should therefore be handled as an exploitative project but because knowledge transferring and sharing technology is low in these situations at Company ABC this project developed very explorative with investigating all aspects of the process as it is new to the company.

6.2.6. Conclusion

The Project B project can be summarized in a limited number of topics. When discussing the iterative character of the project it can be concluded that it is limited. There are no signals of R&D using measurements of the Project B production and the "knowledge workgroups" who should support such information sharing are not fully operational. The project is initiated by top management which used current production figures as their main source of input.

The project did not used a formal model but was managed as a close cooperation between the project leader at R&D and the MD of R&D. In this project also an expert of ABCD was involved. Target setting was done quite extensively but almost completely focused on the product part of the innovation project. No process targets were set although TPM structures do provide measurements of the current production processes.

The project is defined as being more explorative than exploitative mainly because of the research to the type of material needed for the production of this new product. According to the involved employees the project could have a much more exploitative character if all available knowledge within the Company ABC organizations was combined and used for this project.

The project scored high on achieving overall project goals and meeting the quality specs but scored relative low on performing on budget and on schedule. When trying to connect the performance of this project to specific characteristics the following can be concluded. To prevent crossing the budget and schedule thresholds improving the "gate-keeping" structures can be helpful. As currently no formal "gates" are used keeping a project on budget and on schedule can be more difficult because no provisional goals are set. Secondly an iterative structure seems to be helpful also in this situation. In this case gaining knowledge form other OC's in which similar production technologies and material are used can create an useful base of knowledge for new innovation projects in this field of expertise.

6.3. Project C, …

This project, the development of a new range of manholes, covers a period of multiple years and a high amount of working hours with a maximum of 6112 hours invested in 2008. The project is classified as being high product and medium process innovation which is in line with the fact that the project was mainly focused on developing this new product. The process development part of the project, using production method G, was not a planned part of the project but did influenced the course and end result quite heavily. The project was a small bit more exploitative then explorative of nature and performed lower than average on most of the criteria. The project performed well on “overall performance” and “meeting the quality specs” but performed clearly lower on “on schedule” and “on budget”.

Table 12: Descriptive statistics Project C

6.3.1. Iterations

This project is a good example of a project with a lot of iterations on multiple levels. This project was originally only concerned with the product development of the Product M. The decision to use production method G as the production method for low volumes models of the new product range was taken when the project already entered the development phase. Production method G was a really new production method for this type of products and according to an external consultant employed at R&D: *“in the feasibility phase of the project the potential risks where underestimated which led to major iterations in the implementation phase. The production method G technology was not familiar enough to the managers involved to proceed without an solid feasibility process”.*

Al parties involved see the issues with the risk assessment in this project and the fact that as a result this the development took much more time than estimated. The project manager at R&D states that: *“if we do risk management in the right way, if that was done, then production method G was not incorporated in this project. Then, during gate keeping, there should have been said more convincing: if we want to achieve the deadline we should use the handmade method that was proven in the concept method en not opportunistically go for production method G.”*

A feedback loop from production to R&D about how production performed and which problems emerged was at least partly present in this project. The project leader at R&D states that R&D is involved in a workgroup with the operating companies that use production method G to learn about production problems and solutions. In contradiction, according to the program manager of the project: *“ R&D is more or less finalizing the development, when drawings and design things are done. Than it is handed over to production , to the OC. And then R&D is out. Maybe you should really extend this period.*

Because it is quite normal that you have also after 1 or 2 years issues with the product due to production or behavior in practice".

6.3.2. Sources of process innovation

When focusing on the process innovation (production method G) part of this project there can be stated that the initiation is primarily done because of the NPD project.

The project manager at R&D states that in general initiation of process innovations come from: *"competences. We have conscious chosen to put production method G more on the map at R&D. We are looking for ways to get more knowledge inside this department. We visit seminars, follow education, etc. And then we start looking: can we do internal cooling, multi-layer, foaming, etc. With this process knowledge we can start developing new products".* Besides this R&D internal pool of process innovation ideas the project manager also mentions, when asked about external sources of process innovation, the collaboration with the operating companies as a pool of ideas: *"we have an internal workgroup production method G with Country H. There you have Country A, Country I and Country J and R&D is also associated. And there is also XYZ (Association of Production method G".* Later on there is also another topic discussed that can contribute to R&D becoming an innovator in production method G: *"you can do scale tests. To do so you need to have a production method G installation yourself, a small, scale model in the laboratory. This can help to do a lot of test"* and further in the conversation: *"then it is possible to take a look at the principles of cooling, multi-layer, etc. if you want to develop that. This type of development is very hard to do in a production environment. It takes too long and disrupts the entire production".*

The program manager mentions brainstorms and discussion in the project team as the source of innovation in this specific case. *"we had several brainstorm meetings and discussions how we can make a cheap base. So at the end it was clear that production method G was an option".*

6.3.3. Phases and structure

In contradiction with the two other cases this project did follow a clear structure. The stage-gate model at R&D, an adapted version of the original model of Cooper, is used for this project. This stage-gate model is designed to support the NPD projects of Company ABC R&D and is used for most NPD projects.

One of the remarks from the project manager at R&D deals with the problem of handling product and process innovations in one project: *"in general, do you think that the development of new processes should be part of a product development process or can it better be done separately? No, you should not do that within your NPD project. There is a high level of uncertainty, if you have a proven production method than it is possible to use it in NPD. If it is not proven for these tolerances or measurements you should first work on this prove".*

For this project all stages and gates of the stage-gate model are used but according to the project manager at R&D the stage-gate model was: *"not strong enough used, which is reflected in the number of phases the project is split up in. There are two parallel tracks chosen, we said: we chose for production method G but the fallback is an injection molded bottom plate, we continue anyway. There is no strong decision moment. When I look at gate keeping than I can state this is not sufficiently used".*

When discussing the suitability of the stage-gate model for process innovations both the project manager at R&D and the external consultant at R&D state that the stages of the current stage-gate model are probably also suitable for a process development. More urgent is the opinion of both that product and process innovations should ideally not be covered in one project and that the structure of the projects should be more adapted to the type of project, product/process, exploitation/exploration. The external consultant states that in this project: "t*he technology development process was so complex and unknown that it cannot be covered in the product innovation planning. One of the recommendations in this project stated that Company ABC should start road mapping his product and technological innovation programs."*

When examining the "phases and structure" in this project, discussing the current, formal, structures available at R&D is clearly of use. The stage-gate model is the only model in place for innovation projects at R&D but besides this model there are some additional project-management prescriptions for "technology" projects. First of all the current stage-gate model, as formally described in Procedure 08: "Group Product Innovation Program Management" will be discussed. As visible in Figure 26, the current stage-gate model consist out a front-end process, a feasibility stage, a development stage, a implementation stage and a follow up stage. The stage are separated by four gates with the Innovation Board as gatekeeper of the first two gates and the involved OC's as gatekeeper of the final two gates. The objectives of the stages are described as follows:

"The objective of the feasibility stage is to clarify the commercial benefit and the technical feasibility of the suggested New Product Development (NPD). At the end of this stage most relevant uncertainties should have been removed, by which it becomes possible to substantiate timing and costs for the subsequent realization stages (development and implementation) and thus make a realistic commitment for market introduction.

The objective of the development stage is to agree the final product design, proof the technology base and clarify the prime issues around manufacturing and sourcing. This will allow confirmation of the preliminary financial business case from the feasibility stage and issue an investment application on the back thereof.

The objective of the implementation stage is to implement the production and supply chain and prepare for and start sales in the countries that are actively participating in the NPP.

The objective of the follow-up stage is to secure a successful start of commercial product life by de-bottlenecking potential technical or commercial issues and potentially introduce the new product in more countries, which were not actively involved in earlier stages of the NPP."

There should be mentioned that currently the management of Company ABC R&D is collaborating with an external consultancy firm to create an improved version of this stage-gate model. Although this new version of the model is not yet implemented in the procedures in Figure 26 a visual version of the model can be shown in Figure 25.

Figure 25: Updated version of stage-gate model at Company ABC R&D

As mentioned previously there are some additional prescriptions made for “technology” projects. For these project the stage-gate structure is not used. In Procedure 20: “Projectbeheer + Uitvoering” there is stated that technology projects need a (short) project plan which consist of 1) project definition, 2) project set-up (phasing, planning and activities, project team) and 3) evaluation of potential risks. In this procedure there is not mentioned when a project is considered as a group innovation or a technology project. According to multiple interviewees in practice no specific approach is used at process innovation or technology projects.

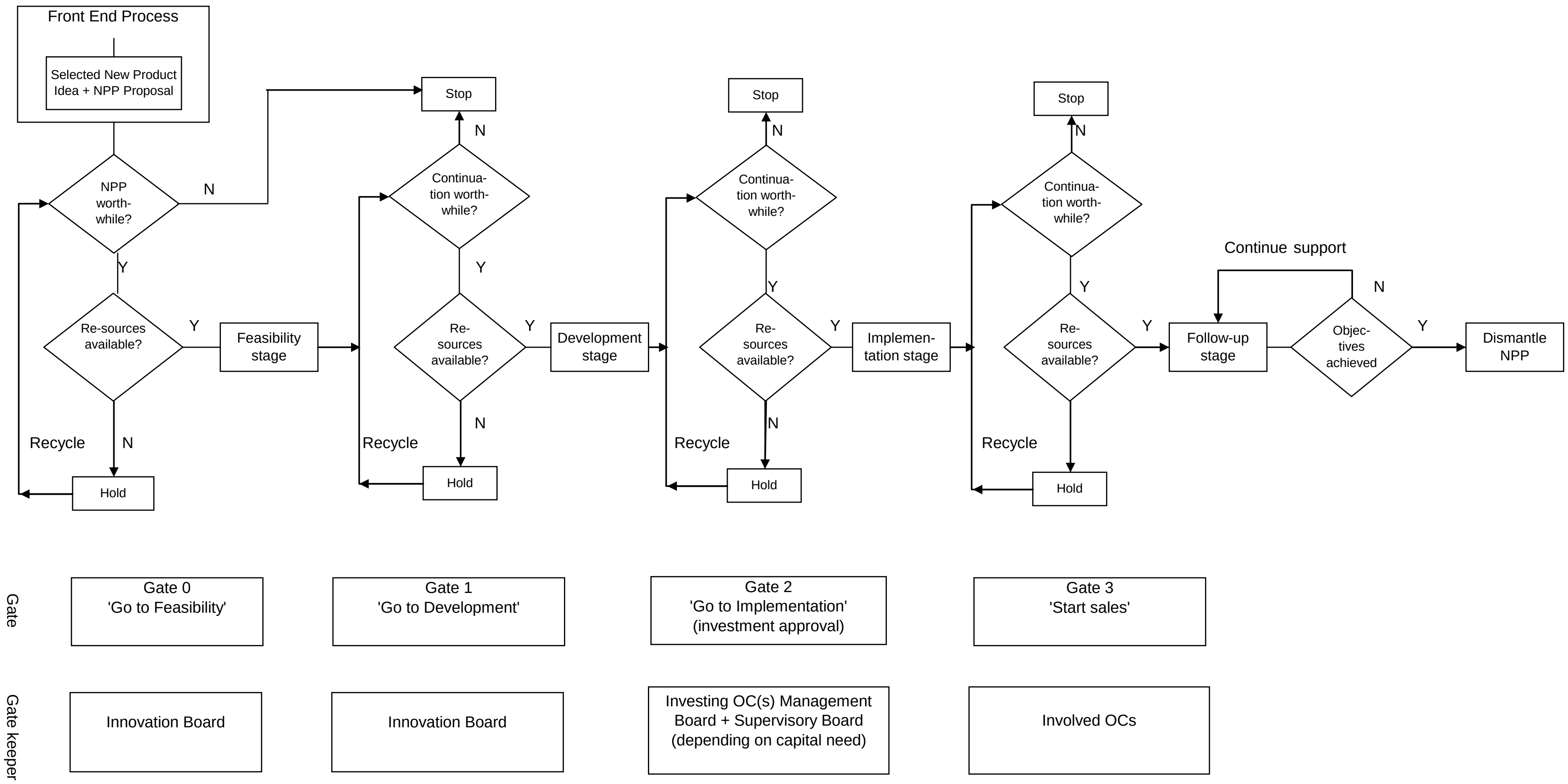


Figure 26: Current stage-gate model at Company ABC R&D

6.3.4. Measurements and targets

The target setting in this project was done in line with the structure that was used: a stage-gate NPD model. The targets where set very clear and also with a pre-determined time-horizon. The project used a complete LoR which should be fulfilled. According to the program manager it can be doubt if this is the most logical choice when you are developing a process that still has a lot of uncertainties. He states: "s*o the first thing we do is make an list of requirements. And this LoR, all requirements, all functions, all details are described in detail. Even the cost price is mentioned, the timing is already fixed, also the production method is fixed. So everything is ready and that is normally not development".*

A second part of "measurement and targets" is the measurement of the production process that is the subject of development in the project. Based on the interviews with both the operating company and R&D there are two main statements that can be made. First, measurement of the production process is a concept that is well implemented and does also result in improvement action at a local level. As the industrial engineer at the operating company states: *"we are more or less supervising the process all the time. We are trying to decrease cycle time and also if we see some failures we of course try to change it so we do not have so much scrap".* Secondly, there can be stated that although measurement and improving the production process is a point of interest at the operating companies there are no structures that create a feedback loop to R&D. There are no structural solutions to get production information back to R&D in order to involve process engineers in the further optimization of the process or to give input for new process innovations projects.

6.3.5. The influence of exploration and exploitation

According to the classification based on the questionnaires at R&D the project is not highly explorative or exploitative but is slightly more exploitative in nature. But when the involved employees are asked to the nature of this project the involved employee form the operating company states that: *"it was really a development project. Because we were testing something that has never been done before. I have never seen it at our competitors or other places. It was really new not only for Company ABC but also for the market".* The project manager has an opinion in the same direction and states that: *"the product itself is not new, this housing was already used for …. But there is one difference: you are going to use the production method B tolerances for a Production method G product".* This statement clarifies another main issue in the estimation of the level of exploration/exploitation in this project: the product development part was to a large extent exploitative of nature, a similar product was already developed but the process development part was mainly explorative of nature, production method G was not used for this type of product ever before, internal or external of Company ABC.

When discussing a possible separation of real developing technology and the better plannable project work the program manger states: *"we are currently starting mostly development projects when we know already, or think we already know, the end result at the beginning. If you are really starting development when you don't know what at the end the result would be than it gets a bit critical. And our organization is not really doing this, we are not really doing research and development, we are running projects. You must have a kind of platform where we are allowed to make an research development in terms of process, in terms of product where at the end we have an outcome which is maybe positive but may also negative."*

6.3.6. Conclusion

When summarizing the five topics discussed in this case study on the Project C project a number of statements can be made. The project can be characterized by a lot of iteration, the new production technology required a lot of feedback loops between production and design. Also after the implementation in the production environment R&D and the OC connected heavily to exchange knowledge, problems and solutions regarding the production method G production. This exchange of knowledge is / can be used at R&D to inventory and start new innovation projects in this field of production.

The initiator of process innovation part of this project was clearly the NPD project. In more general this case contributes to the idea that the initiation of a process innovation can only be done at of competences on this specific topic. The involved employees emphasize that for the topic of this project, production method G, it became clear that the level of knowledge on this technical subject determines the potential change of contributing to innovations in this field.

In this project the stage-gate model of Company ABC R&D is used. Although the model is quite well described in the procedures at R&D the involved employees are not fully satisfied with the way the “rules” of the model are followed. Potentially the fact that a (partly) process innovation is managed in a model that is primarily developed for product innovations contributes to this unsatisfied use. In line with the use of this stage-gate model the target setting was focused on the NPD part of the project. All aspects were determined at the start of the project including time-span, production method and technical specifications.

The product innovation part of the project can be described as more exploitative as it is a new generation of an existing product. In contradiction the process innovation part of the project was more explorative as producing such a type of product with production method G was not known to Company ABC and probably not to the entire market.

The performance of this project is average on “overall performance” and “meeting the quality specs” but is clearly lower on performing “on budget” and “on schedule”. According to a different research at R&D the total project took 5,3 years were 2,8 years were estimated. In this study the unplanned use of production method G highly contributed to this delay. Based on the research in this thesis combing both product and process innovation in one project was not suitable for this situation. The process innovation had a much more explorative character which did not match with the highly exploitative target setting. A second contributor to the delays and exceeded budgets is the fact that the competences on production method G were not yet established at R&D at the start of the project. Although these competences were available in the Company ABC organization (Company ABC Country A, Country I and Country J) the department responsible for developing the product and matching process, R&D, was not on the same level. Developing a product on a production process that is not well known creates potentially underestimating of risks and high amounts of iterations because the design restrictions should be discovered.

7. Cross – case analysis

In this part of the thesis the results of the case studies will be combined and analyzed. On every, of the five, topics there will be one or multiple point(s) discussed that are distillated from the cases.

7.1. Iterations

According to the theoretical framework in this thesis two types of iterations are of importance when discussing a model or structure for process innovations. About both types of iterations there is discussion in theory about how this should be designed. First there is a discussion to what extend a process innovation model should be iterative in general, which can be explained as, to what extend the model should use "learning-by-doing", production knowledge, as input to new process innovations or developments. The second discussion argues whether or not some of the phases in a process innovation model should be iterative before it can progress to a next step.

In all three the projects one or more of the involved employees mention that there are currently no structures to get current production information and knowledge back to R&D as a source of new process developments. This absence of production feedback suggests a very reactive approach to process innovations which is confirmed by a process engineer of R&D who states that process development projects are most of time initiated by a question of an operating company or a request of the headquarter. In both the .... … filled as the Project C it is confirmed that continuous improvement is a main point of focus at the operating companies, locally, but no trace can be found of structures that support a feedback loop to R&D.

In the Project B project an involved ABCD manager mentioned the use of "knowledge workgroups" for the sharing of knowledge about production process and developments on these processes. These workgroup are most inactive with exception of the production method C workgroup but in the Project C there is mentioned that these workgroups can be a useful source of information about the production problems and solutions. In the Project C there is mentioned that a relative large amount of problems arise a couple of years after the market introduction of a product or process and the fact that R&D is then completely out of the project is not in line with this fact.

When focusing on the small iterations that potentially take within the phases of an process innovation model there is a lot less information that can be extracted from the cases. In the Project C there were a lot of iterations because of the use of an immature technology for the product development. Just as in the .... … filled project this was an interaction between R&D and the operating company. Especially in the Project C this extensive use of production equipment resulted in multiple problems. It decreased the efficiency of the operating company and it created delays in the development process because R&D need to wait for the operating company to create space for the tests. This potential problem, a decreased efficiency, occurs in both product and process developments but the delays are assumed to appear specific in process innovation because a lot of these innovations are small changes to machines or material that only can be tested representative enough in a production environment.

7.2. Sources of process innovation

When discussing the sources of process innovation both the potential sources as how these sources can be used are of importance. In the theoretical framework there is a distinction created between internal and external sources created, just as distinction between sources that are suitable for more exploitative and more explorative innovations.

A number of sources of innovation are mentioned in the cases. According to a process engineer at R&D the most process development projects start with a question of an operation company and he also mentions that almost no process innovation projects are started as an initiative of R&D. In the .... … filled and Project C also market forces such as customers and competitors and, a NPD project are mentioned as potential sources of initiation. In both theory as in the cases NPD are a important initiator for process innovations.

An important finding on topic of sources of initiation is the fact that only competences on a specific field of knowledge can create input for new process innovation or development projects. In the NG Manhole project, the project leader at R&D states that creating competences in a field of knowledge can happen by knowledge transfer within the Company ABC group and gaining knowledge externally by seminars, workshops, etc. By having this competences, in this case about production method G, new ideas can be generated on how the production process can be improved.

7.3. Phases and structure

In the theoretical framework this part was mainly concerned with the discussion on which phases should be part of a process innovation model and how they should be arranged. During the case studies it became clear that two out of three cases did not follow a clear, formal structure. The third case was managed by the stage-gate model that is developed for the NPD projects at Company ABC R&D.

In both the .... … filled and the Project B the topic of central coordination emerged. Based on these cases the image emerges about a very decentralized coordination of process innovations in which R&D only is supportive and both ABCD and R&D are not in the lead. The project manager at R&D for the .... … filled project does mention that for product innovations a more central coordination is already implemented since the new business unit structure is available. It can be questioned if the business unit is the most logical choice to be also responsible for the central coordination of process innovations. The departments with the most technical knowledge about the production process are most the most logical candidates for starting and coordinating these process development projects. R&D and the operating companies are most likely to be these departments.

In the NG Manhole project two topics became clear. First multiple employees involved state that the stage-gate model that is used for this project is quite appropriate for this type of development and no clear recommendations are made. Secondly they state that this project is good example of a NPD, time-driven, project used an immature, not proven technology. This technology should first have been further developed for this type of products in a process development project and both state that this probably should be done separately from a NPD project.

7.4. Measurements and targets

The topic of "measurements and targets" is discussed in the theoretical framework of this thesis with two main points of result. Firstly a number of scholars mention measurements of current production process as an important source of input for new process developments. Secondly measuring production process is defined as an important point in defining the targets for a process development project.

The first conclusion that can be extracted from the cases is the fact that for process innovation projects a lot more effort is needed in the feasibility phase because the idea of a new process does not automatically says that it is technically feasible. There is stated that target setting in a process innovation project can only be done effectively after the feasibility phase because of this uncertainty. In the NG Manhole project there is mentioned that establishing a LoR, the targets for a project, does already include a time-limit which is doubted to be most logical, especially in a high explorative project.

A second topic that is extracted from the cases is the measurement of current processes. According to employees in multiple departments and places in the corporate hierarchy a number of process KPI's are currently measured in at least the majority of operating companies. These measurements result in overall KPI's such as an OEE per factory that is shared with ABCD. At the same time there is concluded that there are no structural solutions to get these production measurement at R&D. Although these structures cannot be found there is already awareness at the management of R&D that analyzing production data can create useful insights for process innovations. To improve the data analyzing competences at R&D some R&D employees have started a "Six Sigma Green Belt" training.

7.5. The influence of exploration and exploitation

Based on the theory about this point, relevant for process innovations, two topics emerge. First scholars suggest that the idea generation can be shaped different based on the level of exploration, from more focus on (market-) assessment and (financial-) analysis in exploitative settings to a broader search perspective with a focus on emerging technologies for more explorative settings. Secondly there is suggested that the model that suits a more explorative situation should potentially be less sequential, more iterative and have more overlap especially in later phases.

Based on the case studies a number of topics can be defined. In the .... … filled project it became clear that even when a project is largely exploitative in nature a solid assessment of risks (FMEA) is necessary before a technology / process development can enter a time-driven NPD project.

In the Project B project it is notable that a technology that is quite exploitative in nature, when all knowledge at Company ABC is taken into consideration, is developed as quit explorative project. This is according to the involved employees at least partially due to a very low amount of knowledge and information sharing between the different operating companies and other departments.

In the NG Manhole project the program manager mentions the absence of room for real explorative R&D projects. He states that R&D is currently most of the time running projects and does not perform real R&D development. He suggests a platform that can solely focus on real explorative projects. He states that this count for both product and process innovations.

7.6. Conclusion

In this cross-case analysis for every topic the main results of the case study are presented. In this final paragraph the most important conclusions are summarized to create clear input to the final parts of this thesis.

One of the most clear conclusions is that there are currently no structures to get current production information and knowledge back to R&D as a source of new process developments. This absence of production feedback suggests a very reactive approach to process innovations. In both the .... glass filled as the Project C it is confirmed that continuous improvement is a main point of focus at the operating companies, locally, but no trace can be found of structures that support a feedback loop to R&D.

When discussing the sourcing of process innovations an important finding is the fact that only competences on a specific field of knowledge can create input for new process innovation or development projects. With this “competence” precondition in mind it is remarkable to conclude that very little process innovation projects are started at R&D. Currently NPD projects are one of the major initiators of process development projects.

When discussing the structuring of process innovations and in specific hybrid projects, multiple employees state that separating process and product development should be the best solution particularly because of the uncertainty included in a large share of process innovations. Another important part of structure is central coordination. Currently most of the process innovations are initiated and coordinated by an OC but multiple respondents state that a central point of coordination would probably stimulate sharing of knowledge and best-practices.

Target-setting in the projects that are investigated happened very little or in the same structure as the NPD project. Multiple employees argue that targets setting at the start of a process innovations cannot be aimed at quantitative KPI’s and time limits. First feasibility should be examined and room should be created to investigate multiple options in a project. A second conclusions on the topic of “measurements and targets” can be made on bringing production measurements, that are already in place because of the TPM concept, into R&D as a foundation for target setting.

On the final topic, explorative vs. exploitative process innovations, two main conclusions can be made. First multiple interviewee’s state that currently very little room is available to perform really explorative projects. This observation is probably closely related to the target setting, which is currently always quantitative and time driven from the start of project. Secondly it can be concluded that Company ABC as an organization has a lot of knowledge on multiple production process but this knowledge is often scattered through the organization. This situation contributes to the fact the projects that should be highly exploitative to Company ABC as a complete organization is highly explorative to the departments or employees involved because not all knowledge in the organization is combined.

8. Modeling the innovation process

In this chapter a number of general recommendations to Company ABC R&D are stated which should contribute to "*structure their explorative and exploitative process innovation projects effectively*". Based on these recommendations and all other knowledge gained during this research a proposal for modeling this innovation process for process innovations will be given.

8.1. Recommendations for Company ABC R&D

Recommendation 1:
Ensure that knowledge gained during production returns to R&D to potentially initiate new process developments and to share innovations and best-practices to other operating companies.

After a process innovation or development is implemented and in use at an operating company there is an new process started, the operating company will in most cases keep on learning and developing to further improve the process. This "learning-by-doing" knowledge, that is generated at an operating company, is currently not structurally returned to R&D. Using this production knowledge at R&D can give input to new process innovations projects and contribute to a better sharing of knowledge on process developments.

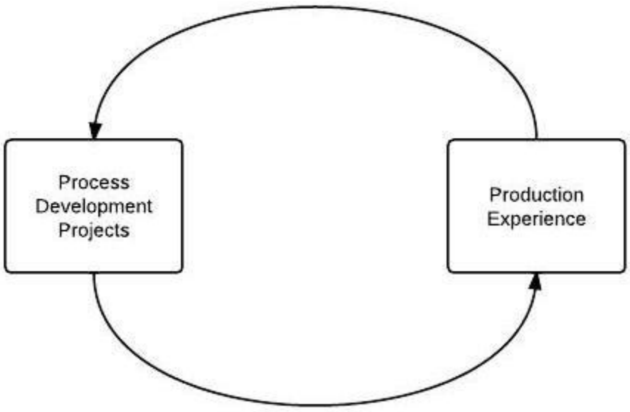


Figure 27: Iterative cycle, adapted from Pisano (1997)

Establishing this feedback loop from operating companies to R&D can be done in multiple ways but a limited number of options look feasible for the situation at Company ABC. A first good option is revamping the concept of "knowledge workgroups" which have been used at Company ABC previously. Sharing the outcomes of new implemented process developments can happen in dedicated workgroups. Potentially these workgroups should build more "light-weight" including only the production managers of the operating companies that are involved in a specific topic such as "using unfoamed recycled material in a multi-layer product".

A second feasible option to get more information about the production environment is by mean of measurements. Currently most plants and production lines have clear measurements in place which can be used by R&D to monitor the performance. This information can be used to create new innovation ideas.

Another option to create more feedback can be found in the continuous improvement programs that are executed at the operating companies. Currently these programs are executed in isolation at the operating companies. Actively involving R&D in these programs can not only provide potential better improvement actions but at the same time gets R&D more connected to the production knowledge.

When observing these type of processes at R&D it becomes clear that already some first steps are set to create a better collaboration between the production environment and R&D. Currently some brainstorms are planned in which employees of multiple operating companies, R&D, ABCD and external consultancy firms discuss production problems and solution in a specific production process. This type of brainstorms can contribute to a better feedback loop of production knowledge to R&D.

Recommendation 2:
Idea generation should be more structured and be based on different sources when compared to product innovation. Measurements of the current processes and, knowledge and competences are important sources. R&D can have a more proactive role in this phase.

The first phase of the process innovation model, an ideation phase, should be focused on explicitly different sources compared to the product innovation ideation pool. In the current situation, primarily focused on product innovation, the main contributors are the business units and incidentally an operating unit. Sources for process innovation should be searched for more internally and in specific R&D and the operating units should be the main contributors those this pool of idea's. Contributing to this phase can only happen out of competences. Especially R&D should be aware of these competences and reserve efforts to create this competences where necessary. Getting and maintaining these competences can be done by activating both internal as external sources.

Internally there are a number of sources that should be considered when working on idea generation for process innovations. First of all the already mentioned people and departments can be a main contributor, specifically R&D staff, production staff, technical people and when applicable scientist. Based on the portfolio analysis that is conducted there can be recommended that in specific the departments "materials" and "laboratory" can contribute more to the generation and selection of ideas for process innovations. Besides personnel also measurements of the current production processes can be a main contributor. The measurements, that are part of the TPM concept, are probably not only a direct sources of ideas but can also create focus on which process should deserver more than average attention. Finally NPD projects or ideas create input for process innovation projects.

Secondly external sources can be used. Collaboration with suppliers, non-academic partners and other external parties can create useful threads to new process innovations. How these types of open innovations should be managed is not in the scope of this thesis but there can stated that external sources can be used for two purposes. First external sources can contribute to the previously mentioned competence building and secondly an external collaboration can create direct ideas or input for process innovations.

Recommendation 3:
Target setting is best be done in two steps. First for boundary setting reasons to enable the feasibility check. Secondly, after feasibility and risk are mapped, targets covering KPI improvement or product requirements can be set.

Based on the lessons learned during the case studies it should be useful to shape the target setting of process innovations differently from the NPD process. Where in the NPD process the complete end-product including a time horizon and cost price is defined upfront in a list of requirements the target setting of a process innovation contains more uncertainties.

At the start of the process, targets can be defined but envisioning the end result including time-horizon and cost price will be difficult, particularly in more explorative projects. A solutions better fitting to process development project can consists out of two steps. At the start of the project targets will be set to set the boundaries of the investigation and give direction to the technology screening phase.

After the feasibility is established and the potential risk are mapped a new set of targets can be defined. These targets can have a more similar concept as the targets used at NPD projects. At this point the goals of the project can be quantified and be related to the current production process KPI's.

To further clarify this recommendation an example will be used. After a brainstorm about improvement ideas to reduce scrap in the production of a specific product range three (process innovation) options are listed. At this point for every idea goals should be set. These goals should be aimed at proving the feasibility to use this technique to reduce scrap for this product range. The targets should be clear about the boundaries of the project and a limited amount of time should be spend on defining the feasibility. After the technology screening phase is finished one, two or even all three of the ideas are selected to be developed. For the selected ideas new targets are set which should quantify the improvements on the KPI and should define a time-horizon for the complete project.

Example of a target in the first target setting step:

- Define in a six month period the feasibility and potential of *technology A* for reducing scrap in producing *product range X.*

Example of an target in the second target setting step:

- Develop and implement *technology A* in a two year a period to reduce the scrap for the *product range X* with 7% without influencing the quality of the product or the speed of production.

Recommendation 4:
Central coordination of process innovations. To ensure the spread of best practices and to prevent that an existing process in one operating company is going to be developed / improved again in another operating company. R&D should be in the lead because of the available knowledge and competences, potentially supported by ABCD.

Currently the project responsibilities of projects with a large share of process innovation is scattered. When the process innovation is included in a NPD project the involved business unit is leading, when a process development is initiated by an operating company this OC in the lead and finally ABCD or R&D can be in the lead for specific projects.

To ensure that all knowledge that is gained during process development project can be used again for similar projects in other parts of the Company ABC organization a central point of coordination for this type of project can be useful. Irrespective to the initiator of the innovation a central point of coordination can prevent “re-inventing the wheel”. R&D seems the most logical department to be responsible for this coordination because of the available knowledge and competences. Obviously these competences should be present in order to positively fulfill this central, coordinating function. If a process innovation is initiated by an NPD project, coordination should be transferred from the project leader at the NPD project to R&D. The projects should be separated in order to give the process innovation the possibility to follow the new model for process innovations.

When R&D becomes the central point of coordination for process innovations one remark should be made. The employees at R&D that are involved in process innovations mostly have a very technical background and potentially less well developed (project-) management skills. To prevent problems in this area two solutions can be used. First of all the skills can be created at R&D by hiring project leader(s) specifically for process innovations or by training the current technical experts in project management. A second option is the separation of management and execution of these types of projects. Execution can continue to be done at R&D but management should in this case be transferred to a more skilled department within Company ABC such as ABCD.

Recommendation 5:
The setting of the innovation, being more exploitative or explorative in nature, should be assessed upfront. The setting of a process innovations should give reason for some adjustments the model concerning phasing, sourcing and target setting.

Based on both literature as the case-studies there can be stated that ideally a number of topics should be adapted based on the setting of the innovation. To adapt on the type of innovation the level of exploration or exploitation should be determined on forehand. When a new process innovation or development is considered highly explorative in nature more freedom and room for real research is necessary to prevent potentially high profit innovations that need a long development time to be killed in a early stage.

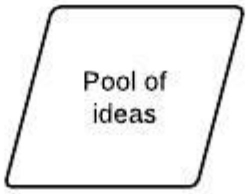
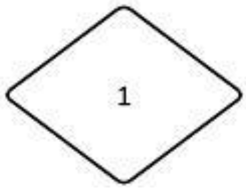
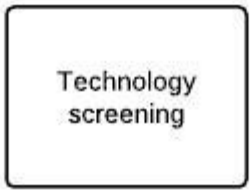
For more explorative settings a different set of sources apply. Having a high share of firm sales from new products, a cost-focus strategy and collaboration contributes to being a radical process innovator.

8.2. Modeling process innovations

In this part of the thesis the visualization of the process innovation model for Company ABC R&D is proposed. The proposed model is composed to serve in specific “technological process innovations in the manufacturing process”. The process innovations that the model is aimed for are “new elements introduced into an organization’s production operations - input materials, task specifications, work and information flow mechanisms and equipment used to produce a product or render a service – with the aim of achieving lower costs and/or higher product quality”.

Based on the industry Company ABC is in, one with both a medium to low rate of product and process innovations, Pisano (1997) states that the innovative situation can be described as “mature”. In this situation process development is primarily focused on cost reduction. Although “mature” is quadrant that suites the context of Company ABC best this study supports the statement that Company ABC needs elements that are active in the “process enabling” quadrant. In this quadrant process innovations are highly related to product innovations and are aimed at solving complex technical problems, rapid time to market and fast ramp up. As Pisano (1997) states “it is in this quadrant that the capability for fast, efficient, and high-quality process development has a direct impact on the commercial success of product introductions”. So besides the general goal of cost reduction and quality improvement, process innovations in the industry of Company ABC are ideally also aimed at contributing to the success of NPD projects.

This model is created to exist next to the current stage-gate model for product innovations. Although in the theoretical framework also an hybrid model is proposed this is not used as an recommendation to Company ABC because the case studies make clear that separating product innovation from process development has advantages such as: potential better target setting, clearer risk profiles and more options to adapt the structure to the type of project. Based on all the insights generated during this study the model as presented in Figure 29 is created. The different steps will now be explained briefly in Figure 28.

		
Not a phase but a precondition to provide input to the pool of ideas. This competence can be created by both internal and external sources.	A formal database of ideas that, after selection, creates input to the model. The “pool” can be filled by measurements of current production processes, production knowledge at the OC’s or by competences at R&D.	At this gate the setting of the innovation, explorative or exploitative, is determined. Simultaneously the boundaries for the technology screening or research phase are set.
		
This phase is only applicable for explorative projects and gives room for more explorative research without having strict goals on which KPI’s should be improved. Before entering this phase boundary setting and setting a time horizon are of importance. The goal of this phase should to research whether or	This gate serves as the entry to the “technology screening” phase. At this point the technology should be considered feasible for Company ABC. At this gate the production process or NPD project for which it can contribute should be selected.	In this phase all projects analyze the current performance of the process and check on the feasibility and potential risks of the innovation at hand. It is at this phase that measurements of the current process and production knowledge should be incorporated.

not a technology can be suitable for Company ABC.		
2	Concept development	3
At this gate for the second time targets are set for the project. Based on the "technology screening" targets for improving production KPI's or supporting a NPD can be set. No projects should pass this phase until the project team has ensured itself from the fact that all knowledge in the Company ABC organization is used before the concept development starts.	In this phase one or more concepts of the innovation should be developed. End result of this phase should be a agreed on concept on how to improve the selected process or NPD project.	Most important gate. Start of the time driven part of the project. Risk, feasibility and technical concept should be clear, just as the "need" for this technology/development. All involved parties should agree on the solution chosen. The targets set at gate one should now be complemented with a fixed time horizon.
Development	4	Prototyping
In this phase the actual reengineering of the process takes place. The technology is developed, laboratory and production test are done.	At this gate there should be agreed on that the project is ready to a) be installed in a production environment or b) be produced as an prototype as proof for an NPD project.	In this phase a prototype of the process is created which should be used as "concept proof" at the start of a NPD project. A NPD project that needs a process innovation cannot proceed to the time-driven part of the NPD process without this "prototyping" to be completed.
5	Implementation	5
The final gate before the process development can enter the NPD process. At this point the time-driven part of a NPD process can be started.	In this phase the process innovation is actually implemented in a running production environment. If applicable the implementation takes place in multiple OC's.	This is the final gate. As this point the project is closed at R&D. The innovation is now implemented in a OC. Important here is to ensure the required feedback from the production environment to R&D.

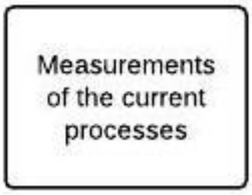
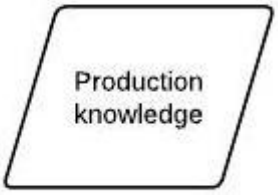
		
The current production process already are measured for i.e. TPM purposes. This data should be monitored by R&D to a) check if recent innovations perform well but also how b) all other production process perform in order to find points of improvement or well performing places to learn from.	The knowledge that is generated in a "learning-by-doing" setting should create input to the idea pool, both directly as via measurements of the new improved process. This knowledge should be transferred to the competence center R&D. R&D should then be responsible for using this knowledge to start new innovation and transfer the knowledge to other OC's that could possibly benefit.	

Figure 28: Explanation of phases and gates

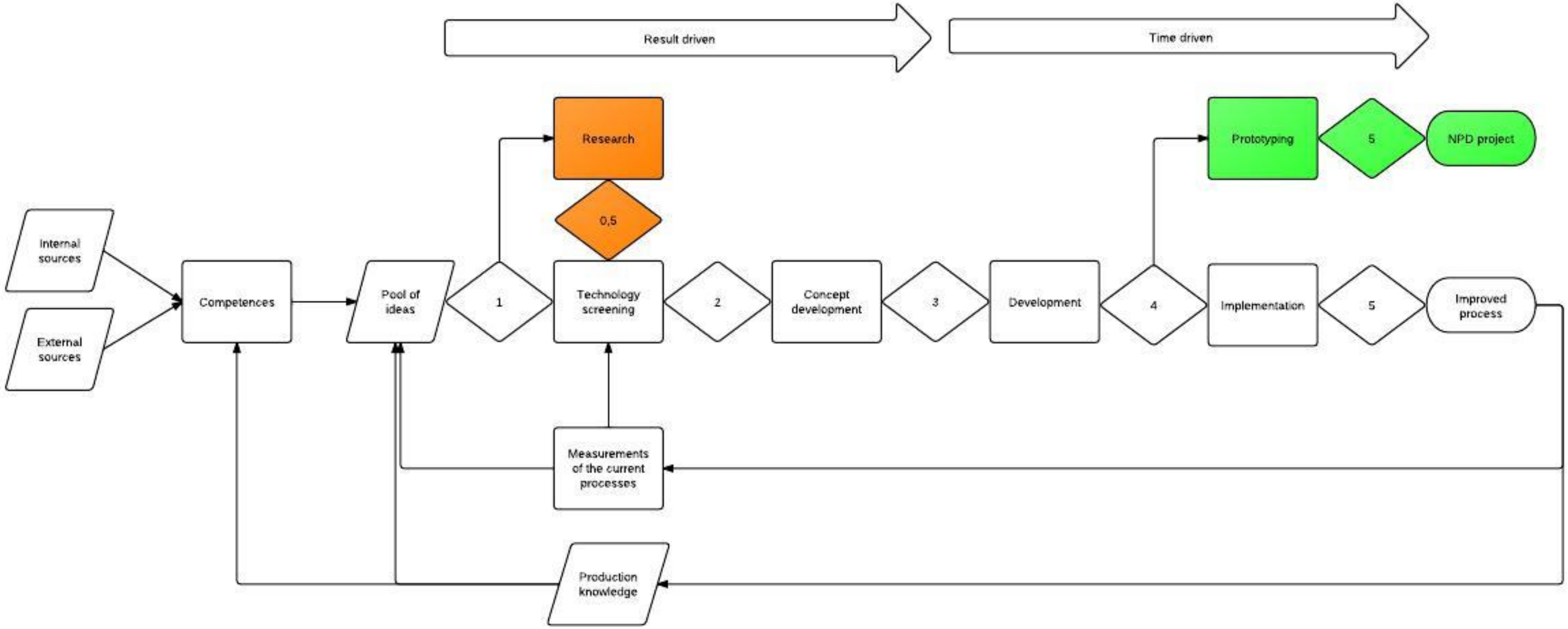


Figure 29: Process Innovation Model for Company ABC R&D

As all the major steps are explained in Figure 28 just two remarks are left. When at gate 0 the project is defined as explorative the **orange** step, the research phase, should be followed which ends via gate 0.5 again in the technology screening phase. When the project should contribute to a NPD project at stage 3 there should be chosen for the **green** phase, prototyping, which results via gate 4 as input to an NPD project.

9. Conclusions, limitations and further research

This final chapter will be constructed as follows, first a lead will be given in answering the main research question and secondly the implications for theory, limitations of the study and suggestions for further research will be given.

9.1. Answering the research question

Based on both the current situation at Company ABC R&D and the insights theory gives on this topic this thesis tries to give recommendations on how to effectively structure the exploitative and explorative process innovations at Company ABC R&D. This goal resulted in the following main research question: *"How can Company ABC Research and Development structure his explorative and exploitative process innovation projects effectively?"* In this paragraph an answer to this research question will be formulated.

In the first part of this study, a literature study, a number of models and articles concerning process innovations are studied. Divided in five topic, points of interest are generated based on these scholars, being: iterations, sources of process innovations, phases and structure, measurements and targets and, the influence of exploration and exploitation.

In the second part of the research, the portfolio analysis it became clear that process innovations are performing lower on operational goals but not on overall performance. Other important conclusions are: process innovations were clearly outnumbered by more product innovations, explorative process innovation perform less then more exploitative projects and, explorative process innovation perform in specific low on the parameter "on schedule".

Finally a case study is executed which resulted in a number of practical insights in the five topics that were already defined in the theoretical framework. It can be concluded that process innovations are currently executed without formal structure or as part of NPD project and the main areas of improvement seem to be: an iterative structure in which production knowledge gained during "learning-by-doing" is returned to R&D, different types of sources with competences and measurements of current process as central concepts, more central coordination and a two-staged type of target setting.

When zooming in on the differences between more exploitative and explorative process innovations small differences in performance are visible but according to the case studies and the theory on this topic the project management of these types of projects should not necessary contain huge differences. A similar model can suit both types of projects but one distinction should be made, for more explorative settings a "research" phase in which room is given to explore the potential of a technology without having targets on improving KPI's can be helpful. Although not being focused on directly contributing to a KPI the time-horizon and boundaries of the phase should be clearly determined.

As an overall conclusion there can be stated that Company ABC R&D can structure their process innovations more effectively by implementing a well structured model that suits both explorative and exploitative projects, ensures central coordination and a feedback loop from a production environment to R&D and uses competences as the main driver for initiation. Implementing such as structure can be justified not only by the underperformance of process innovation on operational goals but primarily on the fact that the case study revealed an great potential for improvements in process innovation management.

9.2. Implementing the process innovation model

Implementation is a key part of the development of a new innovation model. To understand how the implementation of this process innovation model can best be executed it is of importance to give insight in the exact differences between the current stage-gate model for product innovations and this new model for process innovations.

Starting with the similarities. Both models have four major phases with four gates, both models contain a "concept development", "development" and "implementation" phase. The first phase which is "data collection" in the current stage-gate model is renamed to "technology screening". Although the phases contain some different content the basis of both model is similar: a four phases, four gates, stage-gate like model. Besides this similar base the process innovation model has some different features designed to serve the specific situation of process innovation. These differences are summarized below to give input to a effective implementation that can focus on "using a similar innovation model for process innovations but with some clear differences compared to the current stage-gate model for product innovations".

Difference 1: Two exit-options

One of the main differences is the fact that a process innovation can be used to improve a production process or it can serve as input to a NPD project. When serving as input to an NPD a phase of prototyping should be included to prepare the proof of concept to start with the NPD project. If the innovation is aimed at directly improving a production process a phase of implementation should be included.

Difference 2: A research phase

When a project is considered explorative it should be given a phase of "research" in which the concept can be explored without quantitative goals. This phase should be aimed at an technological exploration in which a direct contribution to a production process should not per se be clear yet.

Difference 3: stage-gate vs. iterative process

Where the current stage-gate model has a clear start and end of the project the proposed model for process innovations relies for a large part on its iterative character. In practice this should result in production knowledge and production measurements that return to R&D as input to new innovations.

Difference 4: Ideation at R&D

Where currently the business unit is to most important ideation source in product innovation the ideation in process development is differently sourced. Production measurements, production knowledge and competences at R&D should contribute to a ideation pool from which can be selected. The vision out of this thesis focus on technical competent people creating idea's in contradiction to the NPD process in which departments close to the market, such as the business units, are the most logical source of ideation.

A final point of relevance for implementation is embedding the structure into the organization. In order to create a successful structure for process innovations the model should not only formally be included into procedures. Relevant, key-employees at R&D, ABCD and the OC's should be informed and enthused about this iterative process of innovation, production knowledge and innovation again. They should be able to characterize a project on type (product or process) and setting (explorative or exploitative) and adapt the structure to it. Particularly important during the implementation of this model is the determination of the "central point of coordination". As proposed R&D should fulfill this role possibly supported by ABCD. All OC's should be aware of this central position of R&D and cooperate to a better sharing of production and (manufacturing) process knowledge. R&D should act more proactively on initiating process innovation and sharing this knowledge through the Company ABC organization.

9.3. Implications for theory

The theoretical framework in this research summarized multiple models on process innovations and compared them not only with each other but also with the stage-gate model of Cooper (1990). Because the models differ quit much, five topic are constructed to create a "most used approach" on each of these topics. Most of the models discussed in the theoretical framework are build up in a complete different way than the traditional stage-gate model for product innovations. The model that is created in this thesis aims at combining the project management strengths of the stage-gate structure with the specific elements that are different for process innovations. By combining elements of the models from Papinniemi (1999), Jensen and Westcott (1992) and Pisano (1997) with the core structure of Cooper (1990) model is created than enables process innovation to perform according to target and makes implementation in a company more easily.

The current models on process innovations distinguish on types such as manufacturing vs. organizational process innovation none of the scholars focuses on the differences between more exploitative and more explorative projects. In the product innovation literature the difference between exploitative and explorative projects is well established in articles such as Veryzer (1998) but in process innovation literature this topic is barely explored. In this thesis the setting of the project (explorative vs. exploitative) is determined for every project and the effects of the setting on the project management are discussed. The main conclusion of this part of the thesis can be summarized as; for both exploitative and explorative process innovations the same core model seems suitable but for more explorative setting a "research phase" in which more freedom is given to explore a certain technology can be helpful.

9.4. Limitations and future research

This thesis has aimed at covering as much of "structuring process innovation for Company ABC R&D" topic but of course the research has some limitations or parts that deserve further research.

One of the main limitations is nested in the three case study design of the thesis. As the field of (manufacturing) process innovations is broad just as the current structures to manage these projects the three cases that are used in this study cannot cover all aspects and variations in process innovation projects. As a result of this limitation the recommendations of this study do cover the most types of process innovations but potentially some variants or problems are not included in these solutions.

The proposed model in this thesis is based on theory but also for a large part on the case studies. As these case studies gave very specific problems for the Company ABC organization the recommendations and proposed model is not by definition also suitable for other organizations. In order to develop a model that can be suitable for a large number of organizations a study with a case study of cases in multiple types of organizations should be useful.

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11. Appendices

11.1. Appendix 1: Interview questions

Depending on the case and the type of position the interviewed employee is in, a selection of the questions below are used.

Front-end phase / Ideation phase / Sources of process innovation / Initiation

- How can the exact cause of initiation at this project best be described? Think of both why and who. (measurements, management decision, new product development, etc)
- Which sources of information are used in the idea generation phase of this project? Think of both internal and external sources.
- Can you describe the involvement of external organizations in the ideation process? Think of suppliers, clients, competitors, consultants, related firms, universities, etc.
- What are in your opinion, in general, potential ways to stimulate process innovation idea generation?
- Is there a manufacturing policy/strategy? (general question for management)
- How are potential process innovation candidates identified and selected? (general question for management)

Development / Reengineering

- Can you describe the division of tasks between R&D and the OC when focusing on the development and implementation part?
- Is there a difference between the scientific research (material, etc.) and the development and testing of the product? Should there be a distinction (in phases/time) in your eyes? And why?
- Can you explain to what extend their was a “design” phase and a “executing” phase or where these to handled parallel.

Implementation

- How can the learning during this project best be described, as learning before doing or learning by doing? Can you give examples of this?
- What can you tell about the test methods of this new production process? (CAE, laboratory, pilot plant, full scale production)
- What is your opinion about the transfer of the innovation from R&D to production?

Follow-up

- How, if, is the performance after intervention measured?
- To which extend is, in your view, production knowledge stored and used for new process improvement projects? This question can be answered both for this project in specific and for production knowledge in general.
- When the project was finished, to what extend was there still focus on improving the process?
- If a focus on further improving the process after closing the project is important in your eyes, how should this be organized, and where should the responsibility be?

Measurement / Targets

- Goal setting for process innovation projects, how is this done in this project? Where there specific goals/targets for the process part of the project? And based on what where these set?
- How, if, is the current performance of the process measured and used in this project? And is this performance also measured after the innovation?

Structure

- Which department / person was overall responsible for this project? Is this in your opinion the most logical choice when you look beyond the rules and hierarchy in the Company ABC organization?
- What do you think about the evaluation moments / decision moments in this project? At which moment where these the most clear and what do they cover?
- Was there a list of requirements, project plan, schedule, budget defined? How useful is this in your eyes? (for project leader only)
- Can you describe to what extend the stage-gate model of Company ABC R&D is used in this project? (for project leader only)
- Process innovation targets internally at R&D / process innovation targets in Company ABC as complete organization? (general question for management)
- What is your opinion about the incentives for process development at R&D and for Company ABC at large? (general question for management)

Exploration / Exploitation

- How is/should the responsibility for continuous improvement vs. process innovation be organized? (general question for management)
- How can this project be considered (exploit / explore) now and how was this project judged on forehand?
- Can you give your opinion about how this categorization (exploit/explore) influenced the project management of this project? Are their suggestions for improvement?
- *How are process innovations related to the product innovation process?*
- *How are process innovation related to the current production process?*
- Is exploitative process innovations the same as continuous improvement? And are there strategies/procedures for continuous improvement? (general question for management)

Project A

- Is there time / efforts / knowledge lost because of two department separately working on the same technology?
- How is the collaboration with the University of Prague established and what where their contributions?

Production method G

- How is knowledge about production method G shared between different departments of Company ABC?
- On which reasons is the change of process initiated?
- Reason for starting up production method G in Germany?

11.2. Appendix 2: Summaries of introduction interviews

Appendix 3: Survey questions

COGNITIVE STYLE INDEX

NAME **RESPNAME**...................................(XXXXXXX)............ AGE **AGE**.....(####).........
JOB TITLE **OCCUPATION**.......................(XXXXXXX)............ SEX **SEX**.......(m/f)...........
FIRST YEAR OF EMPLOYMENT **1YEAREMPL** …………(####)…………………………….
DEPARTMENT DEPART………………..(XXXXXXX)………………………………………….
EDUCATION EDUCAT…………………(XXXXXXX)………………………………………….

People differ in the way they think about problems. Below are 38 statements designed to identify your own approach. If you believe that a statement is *true* about you, answer **T**. If you believe that it is *false* about you, answer **F**. If you are *uncertain* whether it is true or false, answer **?**. This is not a test of your ability, and there are no right or wrong answers. Simply choose the one response which comes closest to your own opinion. Work quickly, giving your first reaction in each case, and make sure that you respond to every statement. Indicate your answer by completely filling in the a....opriate oval opposite the statement:

T True	**?** Uncertain	**F** False

		T (2)	? (1)	F (0)
CSI1	In my experience, rational thought is the only realistic basis for making decisions.	0	0	0
CSI2	To solve a problem, I have to study each part of it in detail.	0	0	0
CSI3	I am most effective when my work involves a clear sequence of tasks to be performed.	0	0	0
CSI4	I have difficulty working with people who ‘dive in at the deep end’ without considering the finer aspects of the problem.	0	0	0
CSI5	I am careful to follow rules and regulations at work.	0	0	0
CSI6	I avoid taking a course of action if the odds are against its success.	0	0	0
CSI7	I am inclined to scan through reports rather than read them in detail.	0	0	0
CSI8	My understanding of a problem tends to come more from thorough analysis than flashes of insight.	0	0	0
CSI9	I try to keep to a regular routine in my work.	0	0	0
CSI10	The kind of work I like best is that which requires a logical, step-by-step approach.	0	0	0
CSI11	I rarely make ‘off the top of the head’ decisions.	0	0	0
CSI12	I prefer chaotic action to orderly inaction.	0	0	0
CSI13	Given enough time, I would consider every situation from all angles.	0	0	0
CSI14	To be successful in my work, I find that it is important to avoid hurting other people’s feelings.	0	0	0
		T	**?**	**F**

		(2)	(1)	(0)
CSI15	The best way for me to understand a problem is to break it down into its constituent parts.	0	0	0
CSI16	I find that to adopt a careful, analytical approach to making decisions takes too long.	0	0	0
CSI17	I make most progress when I take calculated risks.	0	0	0
CSI18	I find that it is possible to be too organised when performing certain kinds of task.	0	0	0
CSI19	I always pay attention to detail before I reach a conclusion.	0	0	0
CSI20	I make many of my decisions on the basis of intuition.	0	0	0
CSI21	My philosophy is that it is better to be safe than risk being sorry.	0	0	0
CSI22	When making a decision, I take my time and thoroughly consider all relevant factors.	0	0	0
CSI23	I get on best with quiet, thoughtful people.	0	0	0
CSI24	I would rather that my life was unpredictable than that it followed a regular pattern.	0	0	0
CSI25	Most people regard me as a logical thinker.	0	0	0
CSI26	To fully understand the facts I need a good theory.	0	0	0
CSI27	I work best with people who are spontaneous.	0	0	0
CSI28	I find detailed, methodical work satisfying.	0	0	0
CSI29	My approach to solving a problem is to focus on one part at a time.	0	0	0
CSI30	I am constantly on the lookout for new experiences.	0	0	0
CSI31	In meetings, I have more to say than most.	0	0	0
CSI32	My ‘gut feeling’ is just as good a basis for decision making as careful analysis.	0	0	0
CSI33	I am the kind of person who casts caution to the wind.	0	0	0
CSI34	I make decisions and get on with things rather than analyse every last detail.	0	0	0
CSI35	I am always prepared to take a gamble.	0	0	0
CSI36	Formal plans are more of a hindrance than a help in my work.	0	0	0
CSI37	I am more at home with ideas rather than facts and figures.	0	0	0
CSI38	I find that ‘too much analysis results in paralysis’.	0	0	0

PNUMBER Project number (#####) / **PNAME** Project name (XXXXX) / **PDATE** Project start date (00-00-00)

Project activities

How was the total amount of project time allocated over the next two types of activities?

Share

EXPLOR 1) Explorative activities such as fundamental research, …
(0-100) %

EXPLOIT 2) Exploitative activities such as standardization, …
(0-100) %

100%

Cooperation

CO1 Did collaboration take place with other XXX's departments within the framework of this this project? Yes (1) ☐ no (0) ☐

CO2 If yes, how intense was this collaboration? very intensive (1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ not intensive

CO3 Did collaboration take place with other companies /organizations within the framework project? Yes (1) ☐ no (0) ☐

CO4 If yes, how intensive was this collaboration? very intensive (1) ☐ (2) ☐ (3) ☐ (4) ☐ (5) ☐ not intensive

Overall project performance (Hoegl et al. 2004)

OV1 Going by the status of the project, (1) (2) (3) (4) (5)
it can be regarded as successful — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OV2 Going by the status of the project, (1) (2) (3) (4) (5)
all project goals have been achieved — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OV3 Going by the status of the project, (1) (2) (3) (4) (5)
the output of the project is of high quality — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OV4 Going by the status of the project, the team, which is (1) (2) (3) (4) (5)
responsible for this project, is satisfied with its performance — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OV5 Going by the status of the project, our top management (1) (2) (3) (4) (5)
can be fully satisfied with the progress of this project — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

Operational project performance (Griffin & Page, 1996)

OPER1 Going by the status of the project, (1) (2) (3) (4) (5)
the project expenditures are on budget — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OPER2 Going by the status of the project, (1) (2) (3) (4) (5)
the project duration is on schedule — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

OPER3 Going by the status of the project, (1) (2) (3) (4) (5)
the project meets quality specifications — strongly disagree ☐ ☐ ☐ ☐ ☐ strongly agree

Project phase PROPHASE

What is the current project phase of this project?

1 Ideation	☐	(1)
2 Investigation	☐	(2)
3 Development	☐	(3)
4 Testing and validation	☐	(4)
5 Production and market launch	☐	(5)

Individual project time (Cooper & Kleinschmidt, 1997)

How was your individual project time allocated to the following project phases in this project?

PHASETIM1	1 Ideation	……	%	(0-100)
PHASETIM2	2 Investigation	……	%	(0-100)
PHASETIM3	3 Development	……	%	(0-100)
PHASETIM4	4 Testing and validation	……	%	(0-100)
PHASETIM5	5 Production and market launch	……	%	(0-100)
		100	**%**	

Project typification (Roussel)

PTYPE Please put a mark in the table on the right;
Where would you position this particular project in the matrix?

Core target Market of the project

	known to XXX	new to XXX	new to the world
known to XXX	(1)	(2)	(3)
new to XXX	(4)	(5)	(6)
new to the world	(7)	(8)	(9)

Core Technology of the project

11.3. Appendix 4: Personal Learning Objectives

In order to measure personal development during the period of the master research there are three personal learning objectives defined. The objectives are based on personal considerations about the strong and weak points in the researchers professional character, uncompleted objectives in earlier internships and the, informal, input of both the external as internal supervisors.

1. Expanding personal knowledge about innovation management and new product development in general and the technical steps that are required in such a process in specific.
2. Further improving professional communication skills by means of different meetings, presentations and interviews that are going to take place.
3. Improve the knowledge about academic research and academic writing. This because of the fact that in my previous study this was not a high priority topic but it can be very relevant in the work field.

11.4. Appendix 5: List of projects that are used for the portfolio overview

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11.5. Appendix 6: Recommendations applied on the Project D project