Designing R&D organisations in process industry
Essays on context, process, and structure

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2007:48 | ISSN: 1402-1544 | ISRN: LTU-DT--07/48--SE
Only two groups of people deny that organisation matter

- economists and everybody else...

James Q. Wilson (1989, p.23)
ACKNOWLEDGEMENTS

Four years of hard work – admittedly with plenty of good times thrown in - have come to an end. Acknowledgements are in order!

First of all I would like to thank Thomas Lager for starting it all. Although he was dead wrong about the date I would finish – some three weeks off from the date we initially set in that spring 2004 – I owe much of my success to his sharp insights. Secondly, I must give Andreas Larsson due credit for being the most successful research and travel companion. Of course, Jan Johansson deserves recognition for finishing the job, as does Alan Gilderson for making my ramblings at least somewhat comprehensible.

Though I would like to say that this thesis is the fruit of my great intellect alone – regrettably I cannot. Tough tutors, tough courses, and tough reviewers helped shape me into the thorough and analytical researcher that I am today. Naturally, for any shortcoming in this thesis though they must not be blamed. Furthermore, at the division of Industrial Organisation Torbjörn Nilsson made sure that we were fed and that we could pay our bills at the end of every month – no small task in these tough times for academia; Ossi Päsämaa introduced me to multivariate data analysis, structural equation modelling, and deep sea fishing during the illustrious visit to Bodø; Per-Erik Eriksson, Diana Chronéer and Anna-Karin Horney kept my dark side in check by always being excessively optimistic while Stefan Karlsson kept fuelling it by being the constant realist. In retrospect, two things never cease to amaze me – how is it that Karl Weick has something profound to say about everything in life, and how is it that Johan Frishammar always has the appropriate quote prepared?

For pouring money into such a venture as this I must thank Carl Kempe and the Kempe Foundation, the Jan Wallanders och Tom Hedelius Foundation, the Lars Hierta Memorial Foundation, the Research Centre for Technological Innovation at Tsinghua University in China, the Wallenberg foundations "Jubileumsfond", the Fondazione de Istituto per la Ricostruzione Industriale in Italy, Trelleborg AB’s Research and Educational Foundation, Fonden för främjande av ekonomisk utbildning vid Luleå tekniska universitet, the County Governor of Norbotten, Längmanska företagarfonden, Ångpanneföreningen's Foundation for Research and Development, and finally the Seth M Kempe Foundation. Much appreciated!

Friends and family are always acknowledged at the very last. That is a shame as it does not represent their importance in the schemes of things, so Terése – thanks for supporting my decision to do this! I also wonder, would there be a thesis without Sunday pizzas with Thomas, late-night salsa with Per-Erik, or road-trips into Finland with Lång-Per? I would have died of boredom. And finally - thank you Verena for talking to me in the elevator…

Yours sincerely,
Markus Bergfors
ABSTRACT

This doctoral thesis reports on a research project in R&D organisational design carried out at the Centre for Management of Innovation and Technology in Process Industry - Promote. The thesis itself consists of six appended papers and an extended summary covering the background of the project, the theoretical frameworks and methodologies used in studying R&D organisations in process industry, as well as a discussion of the research findings.

This project aims at furthering the understanding of how intrafirm industrial R&D is organised in process industry through studying the context of innovation process industry, the organisation of innovation strategy formulation processes, and intrafirm R&D organisational structures for product and process innovation. The research project employed several different methodological approaches – including case studies in Swedish process industry firms, an industry-wide survey, and a workshop survey consisting of a select group of R&D managers and industry experts.

In studying the issue of context, a ranking of critical management of technology issues was composed through a survey of industry experts. The ranking proposes that the top issue is involvement of manufacturing in new product development and issues concerning integration of manufacturing in product development. Discrepancies concerning critical issues in regard to other manufacturing industries are also noted.

In response to the issue of strategy formulation processes two opposing methodologies for innovation strategy formulation were studied. Findings from case studies suggest that the level of diversification, the characteristics of industry boundaries, customers, and competitors, and the role and organisation of R&D are key contingencies for choosing between innovation strategy processes either focusing on positions in the market or on internal resources.

In response to the issue of organising intrafirm R&D organisations two different studies were carried out. One case study focuses on the centralisation versus decentralisation of product and process innovation. It suggests that a distinction between product and process innovation should be made and that the organisation of these depend on how the firm views these activities. The second study, an industry survey, looks closer at the organisational affiliation of process innovation. It determines that the degree of newness is a key determinant and that radical innovation will be organised in R&D while incremental innovation will be organised in production. Pros and cons concerning organisational choices are also discussed in light of these findings.

Overall, the research project and the thesis stress the importance of context and how strategic choices should be reflected in the design of R&D organisations. Implications for management and academia are discussed and some avenues for further research are proposed.
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1. INTRODUCTION

While the management of innovation is becoming an increasingly popular research arena, limited attention has been given to innovation in one of our oldest industries, the process industry. This thesis, “Designing R&D organisations in process industry”, focuses on intrafirm research and development (R&D) organisations in process industry. It specifically considers the organisational context and structure of R&D units dealing with product and process innovation as well as organisational processes for technology strategy formulation. The research was carried out within the research platform of the Centre for Management of Innovation and Technology in Process Industry at Luleå University of Technology.

1.1. Innovation and the organisation of innovation

Innovation is the creation of the new, and as such it is the wellspring and driver of technical, social and economic progress. As innovation implies change, firms can benefit from this by taking advantage of new opportunities, or perish as they are replaced by those who do. Innovation can therefore be seen as either a Holy Grail – opening up new markets, attracting new customers, or improving performance - or a Pandora’s Box – unleashing a force of creative destruction on an unsuspecting industry. Consequently, effective innovation has not only become recognised as a primary contributor to competitive strength, but also as a central determinant of long-term survival amongst firms.

Naturally, given the competition-altering potential of innovation, firms want to find a way to harness its power within their organisations. Therefore, to bring about and control the process of innovation, firms will normally hire and organise individuals into specialised research and development (R&D) organisations in the hope that these will supply the firm with new products, processes, services or technologies. However, innovation is organisationally complex – it is hard to measure (see Adams et al., 2006), and R&D employees are difficult to manage (see Schneiderman, 1991; Sapienza, 1995). It is often a challenge for a firm to know whether they are successful in innovating and whether the organisation is up to the task or not. However, it is clear that the way R&D is organised has a substantial impact on its effectiveness and efficiency, and inappropriate organisational structure can hamper the deployment of R&D talent, increase the cost of output, and delay results. Managers in charge of managing the innovation process are thus put in a difficult position. In preparation for an unknown future they are expected to design organisations that are both creative and efficient, while neither conventional wisdom nor academia offers any clear guide to how this may be done. As a result, a number of different organisational structures have been employed in R&D over the years, “unfortunately with very little real basis for choosing among them” (Allen, 1984, p.218).

1The term “creative destruction” was coined by Joseph Schumpeter in 1942 and refers to the process of industrial development that destroys existing economic structures and replaces them with new economic structures (Schumpeter, 1975, pp. 82-85)
Effective management of innovation is as difficult as it is important. And while innovation is increasingly essential in the light of an increasingly competitive environment, it is also becoming increasingly difficult because of the changing nature of innovation itself. The uncertainty and accelerated rate of technological progress affects innovation strategies, whereas increasing complexity and the need for integration in development processes challenge existing organisational structures. In fact, while the business environment has changed significantly over the years, the innovation processes used by firms have changed very little (Tidd, 2001). The view held by Miller and Morris (1998), that it is not realistic to expect old organisational models to meet these new challenges and that we must look for new models to enable effective performance, is as true today as it was almost a decade ago.

1.2. Innovation in the process industry

The process industry includes, among others, of pulp and paper, mining and mineral, food and beverage, and chemical industry. Although these industry sectors are sometimes thought of as low-tech (hearing that they are “boring” is not uncommon), in fact they rely heavily on their R&D organisations to bring new products to market and improve manufacturing processes (Hirsch-Kreinsen, 2005). They are an important employer in most Western countries and drive economic development, not only through their own innovation activities, but also through innovation in the industries that serve them (Lazonick, 2002; Hirsch-Kreinsen et al., 2005).

Unfortunately, even though process industries are some of the oldest and most mature industries in business, to date not much research has focused on R&D in process industry. Ever since interest began taking off in innovation studies, research has predominantly focused on high-tech manufacturing industries. However, a number of studies have indicated that the process industry differs in many respects from other manufacturing industry in general and assembled high-tech products in particular (e.g. Utterback and Abernathy, 1975; Utterback, 1994; Barnett and Clark, 1996; Pisano, 1997; Traill and Grunert, 1997; Dennis and Meredith, 2000; Felcht, 2002; Moors and Vergragt, 2002; Walsh and Lodorfos, 2002; Lager, 2002a; IVA, 2006).

The type of previous research conducted in process industry has also been influenced by industry characteristics. For example, as process industries are often characterised by a high level of capital investment and long depreciation times, most innovations tend to be technologically incremental (Moors and Vergragt, 2002). Incremental improvements in cost are crucial for firms who strive to find ways of whittling down the cost of production, and for this reason, the literature on process industries has primarily focused on cost reductions and economies of scale (Barnett and Clark, 1996). However, innovation in process industry is much more than about this – especially as the business environment is changing.

It has long been reported that the business environment is shifting towards becoming increasingly competitive – or even hypercompetitive (e.g. D’Aveni, 1995). Recent studies by Chronéer (Chronéer, 2003; Chronéer and Laurell-Steinlund, 2006) confirm that the process industry is also very much part of this development, with an increase in mergers
and acquisitions, corporate restructuring, investments, and divestments as a result. The changing competitive structures within the industry, coupled with increasing customer focus and continual requirements for cost-cutting, suggest that process industry firms change their way of thinking about innovation – and in turn – their R&D organisations.

1.3. Research aim and purpose of thesis

Managers call for research that specifically targets their industry and the unique problems that they face. The need for research in the area of management of innovation and technology within the process industries prompted Luleå University of Technology to support the creation of a research centre with this very aim. The Centre for Management of Innovation and Technology in Process Industry (With the acronym “Promote”) was therefore established in 2004 under the direction of Professor Thomas Lager. For Sweden, process industry accounted for over 43% of total exports in 2006 (SCB, 2007) and in the region of Norrbotten, where the research centre is located, the process industry is particularly important with companies such as Billerud, Boliden, LKAB, Normnejerier, SCA, Smurfit Kappa Kraftliner, and SSAB as leading employers and income generators. The vision of Promote is to create a research-based platform of knowledge in the area of management that can serve as a foundation for the development of better models and working practices to be used to further improve industrial R&D in the process industries. It was within Promote and in this context that the research project was carried out.

While the question of what organisational structures and management processes facilitate or inhibit innovation has been asked before (see reviews and comments by Teece, 1996; Damanpour and Gopalakrishnan, 1998), historically very few organisational studies focus at the department level (Twomey et al., 1988), and only a small number have looked inside the R&D organisation itself (Cardinal, 2001; Argyres and Silverman, 2004). The research project “Designing R&D organisations in process industry” aims at furthering the understanding of how intrafirm industrial R&D is organised within process industry firms.

The central question in management research is why some firms perform better than others or, as stated from a manager’s perspective: “How can I make my company better and beat the competition?” Research in innovation and organisational design should take this into consideration, and scientists should ask not only how things are done, but also determine whether they are done well. The overarching purpose of this thesis is therefore:

- How can intrafirm R&D be effectively organised in process industry?

While this is a broad question that is impossible to answer in its entirety, be it in a doctoral thesis or anywhere else, it raises the following research issues:
- First of all, by including process industry specifically it is made clear that the industry context is to be seen as an important variable in the organising of intrafirm R&D.
- Secondly, the question implies that intrafirm R&D can be organised in different ways, resulting in varying degrees of effectiveness.

There are thus two thematic areas to this research; one having to do with the context of process industry, and the other with different aspects of organising R&D within this context.
THE CONTEXT OF PROCESS INDUSTRY
Concerning the issue of innovation, we need not only understand the process industry and the dynamics that affect R&D organisations today and in the future. To deal with organisational design issues we also need to understand what constitutes the main differences between managing and organising R&D in process industry as compared to other industries. The specific research question dealing with industry context is thus:

- What are the critical issues of organising intrafirm R&D in the process industry?

R&D ORGANISATIONAL DESIGN IN PROCESS INDUSTRY
In managing innovation in process industry, organisational structure and strategy are closely connected. An R&D organisation needs a strategic direction as much as the innovation strategy process needs to be properly organised. There are however many ways of designing organisational structures and strategy processes and in order to understand what variables to take into consideration we need to explore these choices more closely. The specific research questions dealing with R&D organisational design are thus:

- How can innovation strategy formulation processes be organised?
- How can intrafirm R&D organisational structures be organised?

Answering the research questions is done through appended research papers. Figure 1-1 on the opposite page summarises the aim, purpose, and specific questions of this research project in relation to the appended papers.
Purpose of thesis:
How can intrafirm R&D be effectively organised in process industry?

Context of process industry
What are the critical issues of organising R&D in process industry?

Organising R&D in process industry
How can innovation strategy formulation processes be organised?
How can intrafirm R&D organisational structures be organised?

Paper | Title
--- | ---
I | Corporate structure and R&D organisations
   Three retrospective case studies in the Nordic process industries
II | Focusing on heads or tails in innovation strategy formulation?
   A revisited methodology based on a resource-based view
III | A resource-based approach to the Booz Allen and Hamilton methodology
   Exploring new directions for practice
IV | Opening up intrafirm R&D
   Insights from the organisation of product and process innovation
V | Innovation of process technology
   Determinants for organisational design
VI | Critical management of technology issues in process industry

Figure 1-1: Aim of the research, purpose of thesis, and the research questions related to the appended papers.
1.4. Outline of thesis

This thesis consists of six papers and an extended summary of the papers and the project. The outline of this thesis is as follows.

1. INTRODUCTION
The chapter discusses the background of the research project and specifies the research agenda.

2. PROCESS INDUSTRY
The chapter defines process industry and explores the unique context of process industry as compared to other manufacturing industries.

3. THEORETICAL FRAMEWORK
Since the different parts of this study draw on different theoretical areas, the reader is advised to refer to the individual papers. This chapter describes the scientific bases that underpin the overarching research framework. This section also connects the papers to the research framework.

4. METHODOLOGY
Here, the methodological choices and views of the research project are discussed.

5. OVERVIEW OF APPENDED PAPERS
The chapter presents brief overviews of the selected papers one-by-one. This includes the background as to why they were written, problem statements, theory and method, and their contributions.

6. DISCUSSION
The research project and thesis are discussed in the light of the research aim, the research purpose, and the research questions. This chapter also includes some general reflections on the research project.

7. IMPLICATIONS
Implications of the research project are discussed in terms of practical applicability and relevance. Aspects of academic usefulness and further research ideas are also discussed.

APPENDIX I - APPENDIX VII
The appendices relate to method aspects – such as interview guides, survey questionnaires, case descriptions etc.

PAPER I - PAPER VI
The appended papers are presented in full.
2. PROCESS INDUSTRY

The effects that the industry context has on an individual organisation are often difficult to assess (Rumelt, 1991; McGahan and Porter, 1997). However, industrial differences must be taken into account in applying research findings to real-world problems. While innovation is the key to building competitive advantages in all industries, the underlying cost and success drivers for innovation are different in different industrial contexts (Teece, 2000). For example, there are many accounts that tell of the distinctiveness in organising R&D in process industry as opposed to other manufacturing industries (e.g. Utterback and Abernathy, 1975; Utterback, 1994; Barnett and Clark, 1996; Pisano, 1997; Traill and Grunert, 1997; Dennis and Meredith, 2000; Felcht, 2002; Moors and Vergragt, 2002; Walsh and Lodorfos, 2002; Lager, 2002a; IVA, 2006), some of which will be discussed here.

2.1. Defining process industry

Several attempts have been made at defining process industry. Barnett and Clark for example see the process industries as “a unique set of industries built around the production processes that manipulate material properties to produce raw materials for use in a variety of applications” (Barnett and Clark, 1996). Dennis and Meredith focus solely on the material properties and propose that “all process industries share numerous characteristics resulting from the fact that they use nondiscrete materials” (Dennis and Meredith, 2000). Nondiscrete materials are “liquids, pulps, slurries, gases and powders that evaporate, expand, contract, settle out, absorb moisture, or dry out”. Because these materials change constantly, they cannot be held without containerisation. This is opposed to discrete materials that do not readily change and which maintain their shape and form without containerisation (Dennis and Meredith, 2000).

These definitions are still somewhat vague, even though the focus lies on the production processes and the materials used. Lager uses a combination process and materials when defining process industry as “process industry uses raw materials to manufacture non-assembled products in a production process where the raw materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow” (Lager, 2001).

Operationally, process industries can also be defined based on their industry classifications – such as the North American NAICS system (NAICS, 2007), the European NACE system (NACE, 1996) or the international ISIC system (ISIC, 2002). Using the NACE system, Lager (2002a) proposes that industries to be included in process industry can be clustered in six categories, as Mining & Mineral Industry, Food & Beverage Industry, Pulp & Paper Industry, Chemical Industry, Basic Metal Industry, and Other Process Industry [see Table 2-1]. Those groups of industries can be broken down in more detail into subgroups. Pulp & Paper Industry, for example, can be further divided into 14 different sub-
sectors (such as mechanical or semi-chemical pulp, paper and paperboard, kraft paper and paperboard, etc).

Table 2-1: Categories of process industry based on NACE classifications

<table>
<thead>
<tr>
<th>Categories</th>
<th>NACE Codes</th>
<th>NACE Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining &amp; Mineral Industry</td>
<td>CB 13</td>
<td>Mining of metal ores</td>
</tr>
<tr>
<td></td>
<td>CB 14</td>
<td>Other mining and quarrying</td>
</tr>
<tr>
<td></td>
<td>DI 26</td>
<td>Manufacture of other non-metallic mineral products</td>
</tr>
<tr>
<td>Food &amp; Beverage Industry</td>
<td>DA 15</td>
<td>Manufacture of food products and beverages</td>
</tr>
<tr>
<td>Pulp &amp; Paper Industry</td>
<td>DE 21</td>
<td>Manufacture of pulp, paper and paper products</td>
</tr>
<tr>
<td>Chemical Industry</td>
<td>DF 23</td>
<td>Manufacture of coke, refined petroleum products and nuclear fuel</td>
</tr>
<tr>
<td></td>
<td>DG 24</td>
<td>Manufacture of chemicals and chemical products</td>
</tr>
<tr>
<td></td>
<td>DH 25</td>
<td>Manufacture of rubber and plastic products</td>
</tr>
<tr>
<td>Basic Metals Industry</td>
<td>DJ 27</td>
<td>Manufacture of basic metals</td>
</tr>
<tr>
<td>Other Process Industry</td>
<td>DJ 28</td>
<td>Manufacture of fabricated metal products, except machinery and equipment</td>
</tr>
<tr>
<td></td>
<td>DJ 37</td>
<td>Recycling</td>
</tr>
<tr>
<td></td>
<td>E 40</td>
<td>Electricity, gas, steam and hot water supply</td>
</tr>
<tr>
<td></td>
<td>E 41</td>
<td>Collection, purification and distribution of water</td>
</tr>
</tbody>
</table>

2.2. Setting process industry apart from other manufacturing industry

While the process industry has characteristics that set it apart from other manufacturing industry, much of this seems to be missing in the innovation literature (Barnett and Clark, 1996). However, a large research project conducted by the Royal Swedish Academy of Engineering Sciences generated a list of key characteristics that distinguish process industry from other manufacturing industry (IVA, 2006). A summary, mainly based on the findings in the IVA study is shown in Table 2-2 [on the opposite page] and discussed subsequently. The factors listed and discussed here all affect intrafirm R&D activities in different ways. Some of the differences are discussed here while Paper VI: Critical management of technology issues in process industry discusses them specifically in relation to intrafirm R&D.

Input materials and typical position in the value chain

One of the key points is that process industry production is based on a diverging flow of materials and intermediate goods. This means that a few materials are used for a variety of products. Other manufacturing industry, on the other hand, is viewed as a converging flow, where different materials and intermediate goods are assembled into a few products (albeit with the option of many variations). Furthermore, process industry products are often homogeneous rather than heterogeneous as is the case for assembled products. Finally, the products are often based on raw materials and natural resources rather than intermediates. This implies that most process industry corporations are suppliers to producers of assembled goods and are therefore situated upward in the supply chain, several steps from the end consumer.
Table 2-2: Process industry versus other manufacturing industry

<table>
<thead>
<tr>
<th>Input materials and position in the value chain</th>
<th>Manufacturing Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diverging flow (raw materials and intermediate goods produce different types of products)</td>
<td>Converging flow (fewer products, but large variation possible)</td>
</tr>
<tr>
<td>Often homogeneous products</td>
<td>Heterogeneous products</td>
</tr>
<tr>
<td>Based on raw materials and natural resources</td>
<td>Based on intermediate goods (components and subsystems)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production process</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous production</td>
<td>Batch production</td>
</tr>
<tr>
<td>Highly automated</td>
<td>Varying degree of automation</td>
</tr>
<tr>
<td>High tech production</td>
<td>Varying degree of technology level in production</td>
</tr>
<tr>
<td>Less labour intensive – often capital intensive</td>
<td>Labour intensive – varying degree of capital investments</td>
</tr>
<tr>
<td>Generally very energy intensive</td>
<td>Comparatively low energy usage</td>
</tr>
<tr>
<td>Process control is necessitated by variable compositions of incoming raw materials</td>
<td>Even quality of intermediate goods (quality and measurements) require different type of process control</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R&amp;D - interplay between product and process innovation</th>
<th>Manufacturing Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product and process development difficult to separate</td>
<td>Product and process development possible to separate</td>
</tr>
<tr>
<td>Product variety achieved through small modifications of production process</td>
<td>Product variety achieved through altered or separate production processes</td>
</tr>
<tr>
<td>R&amp;D more focused on process innovation</td>
<td>R&amp;D more focused on product innovation</td>
</tr>
<tr>
<td>Develops few new products</td>
<td>More often develops new products</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Macro-level factors</th>
<th>Manufacturing Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroeconomic sensitivity (exchange rates, interest rates, etc.)</td>
<td>Varying degree of sensitivity to macroeconomic factors</td>
</tr>
<tr>
<td>Highly dependent on political decisions (energy, environment, etc.)</td>
<td>Lesser dependence on political decisions</td>
</tr>
<tr>
<td>High net export value</td>
<td>Lesser and varying degree of net export value</td>
</tr>
<tr>
<td>Environmental demands a driver for product and process development</td>
<td>Environmental demands are important but are not a driver for company development</td>
</tr>
</tbody>
</table>

Production process

A key characteristic of process industry production is that it is continuous rather than being based on batches as in the case of assembled products. The production process runs around the clock, and is often highly automated and technically sophisticated. Consequently, it is less labour-intensive and more capital-intensive (due to large investments in production technology) compared to less automated and less capital-intensive assembly-type manufacturing. And because production shut-downs and start-ups are extremely expensive and investments in existing production technology are large, process innovation activities have historically focused on evolutionary or incremental process improvements, while major breakthroughs have occurred in infrequent large steps (Utterback, 1994; McNulty, 1998). Also, the production process is generally very energy-intensive, as most sectors in the process industry (such as pulp and paper, mines and minerals) typically refine raw materials into semi-finished products. Another aspect of using raw materials as inputs is that strict process control is necessary because of the variable composition of the incoming materials. This is not the case in other manufacturing industry, where the quality of intermediate goods is uniform. As a result of this, changes in competitive positions in assembled-product markets occur with new generations of product technology, whereas the same phenomenon in non-assembled product lines appears to be linked not to product change but to major equipment innovations (Utterback, 1994).
R&D – the interplay between product and process development

A major feature of R&D in the process industry is the interplay between process development (driven by internal production objectives) and product development (driven by a desire to improve the properties and performance of finished products). On one hand, production ramp-up (the period between completion of development and full capacity utilisation) is complicated, as new products usually go direct from the R&D laboratory to full-scale production (Pisano, 1994). Hence, in process industry, it is not possible to gradually increase production volume from trial batches to full-scale production. That is, unlike the case with assembled products, it is difficult to separate product development from process development because the existing production system must be able to switch to a new product without causing major disruptions in the continuous production process. On the other hand, modifications to the production process (i.e. process development) frequently bring about unexpected changes in the characteristics of the end product (Pisano, 1994). Consequently, in process industry, product development activities and process development activities are intertwined (Lim et al., 2006), and extensive intrafirm collaboration between R&D and production is therefore needed. Another aspect of the intertwinement of process and product development is the connection between product modifications and the production process. In process industry, product variety is achieved through small modifications of the production process, while other manufacturing industry achieves product variety through altered or separate production processes. Moreover, process industry differs from manufacturing industry in general, and high-tech manufacturing in particular, with respect to what proportions of its innovation activities are classed as product or process development (Utterback, 1994; Lager, 2002a). High-tech firms focus more on product development, while process industry firms focus comparatively more on process development. As a result, process industry firms (with some exceptions) develop fewer new products than other manufacturing industry.

Macro-level factors

Process industry can also be distinguished from other manufacturing industries with regard to some key macro-level factors. As many Swedish process industry corporations produce commodity products, they are macroeconomically sensitive to exchange rates; they export semi-finished goods but do not import much in the way of raw materials, as they often are self-sufficient in that respect (iron ore, timber etc.)(IVA, 2006). They are also very sensitive to interest rates, as their production plants require large investments, while profitability in many sectors of the process industry is cyclic (e.g. pulp and paper, mines and minerals). Hence, sectors of the process industry (chemical, pulp and paper, mines and minerals) are highly dependent on political decisions related to the above-mentioned issues. Furthermore, process industries are also dependent on political decisions concerning energy and environmental issues. Consequently, environmental demands are often drivers for product and process development (Eltringham, 1998) – such as responding to new pollution legislation.
3. THEORETICAL FRAMEWORK

Innovation is believed to give companies a sustainable competitive advantage, and the fact that innovation activities are at the centre of firm development has been suggested by several researchers (e.g. Roussel et al., 1991; Utterback, 1994; e.g. Barnett and Clark, 1996; Teece, 1996; Brockhoff et al., 1997; Miller and Morris, 1998; Tidd, 2001; Galbraith, 2002; Stock et al., 2002). Evidence has also been found which demonstrates that activities that lead to firm-level innovations also have a significant aggregate effect on macroeconomic growth (Moran and Ghoshal, 1999), and it is therefore safe to say that innovation in organisations drives economic development as a whole. However, innovation does not occur by chance. Intrafirm R&D is performed by controlled processes, and to manage it effectively organisational structures and processes must be coupled with strategic consideration. Therefore, the research framework for this thesis requires a theoretical framework that spans innovation, organisational structure and design, and organisational strategy.

3.1. Innovation

Innovation is conceptualised as being context-dependent and influenced by environmental, organisational, and individual level antecedents. Studies of innovation have therefore focused on different levels of analysis. Much of the early literature focused on the adoption of new ideas and practices by autonomous individuals, whereas since the late 1950s there has been growing interest in innovation within and by organisations (Slappendel, 1996). This stream of research is often referred to as innovation management.

3.1.1. Defining innovation

General definitions of innovation are often broad, encompassing everything from internally generated or externally purchased new products, services, and production process technologies, new structures or administrative systems, to new plans or programs concerning organisational members. This breadth is exemplified by Rogers and Shoemaker, who argued that “any idea, practice, or material artefact can be an innovation” (Rogers and Shoemaker, 1971). However, the term innovation is also used for more than just the innovations themselves. Innovation is also seen as “a process where new ideas are conceived and brought into reality” (Robertson, 1967). The combination of these notions has lead to innovation management research becoming a discipline within management concerned with “all the activities involved in the process of idea generation, technology, development, manufacturing, and marketing of a new (or improved) product or manufacturing process or equipment” (Trott, 2002).

Current theories of innovation usually focus on inputs (variables predisposing organisations to innovate), on outputs (number and kind of innovations adopted), and on process (the sequence of events from input to output). However, other classification
schemes have been developed as well. For example, there is a distinction between *diffusion* (emphasising variables in the development and marketing of innovations that hasten their acceptance on the market) and *adoption* (focusing on the organisational characteristics that affect innovation adoption) (Sabet and Klingner, 1993). Innovation researchers can also discriminate between the sources of innovation, the three major ones being *imitative* (copying innovations introduced by other firms), *acquisitive* (acquiring innovations from other firms through purchase, licensing, or mergers), or *incubative* (developing innovations either internally through R&D or through joint ventures) (Burgelman and Sayles, 1986). The source of innovation that an organisation pursues is correlated to rates of diffusion, rates of adoption and organisational structure, and therefore the effectiveness of a certain source will be enhanced when combined with appropriate structural arrangements (e.g. Burgelman and Sayles, 1986; Hitt et al., 1991).

### 3.1.2. Perspectives of innovation in organisations

Because of the diversity inherent in innovations themselves, and the activities that bring them about, several different classification schemes have been developed based on type of innovation (technical versus administrative innovation, and product versus process innovation), degree of newness (radical versus incremental innovation), or stage of innovation (initiation versus implementation) (Damanpour and Gopalakrishnan, 1998). These are termed structural theories of innovation.

**Type of innovation**

*Technical versus administrative innovation.* Technical innovations are associated with products, services, and production processes (Knight, 1967). Administrative innovations are associated with the organisation's structure, such as work processes, authority relations, decision-making, communication, and reward systems (Knight, 1967; Daft, 1978). Through studying hospitals Kimberly and Evanisko found that different organisational variables predicted the adoption of technical as opposed to administrative innovation (Kimberly and Evanisko, 1981). For example, they found that specialisation, size, decentralisation, and functional differentiation correlate more positively with technological innovation than administrative innovation. They concluded that theory construction should focus on developing middle-range theories that can help explain a certain type of innovation. The “*dual core theory*” of organisations (Daft, 1978) states that organisations have a technical core and an administrative core, and innovation within each of these follows different processes. Organisations can be structured to encourage one type or the other, but not both. Depending on the type of innovation to be adopted, different organisational structures should be used (Daft, 1978). However, much research either fails to distinguish between technical and administrative innovation or considers only technical innovation (Sabet and Klingner, 1993).
Product versus process innovation. Technical innovation consists of both product and process innovation. Product innovations are designed to meet an organisation’s external needs, while the emphasis for process innovations is to incorporate new elements into the operations of an organisation (Knight, 1967; Utterback, 1974; Whipp and Clark, 1986).

- Product innovation is defined as development driven by a desire to improve the properties and performance of finished products. Objectives of product innovation may be to develop new products, improve product properties, improve product quality, etc. (Lager, 2002a).

- Process innovation is defined as development driven by internal production objectives. Such objectives may be reduction of production costs, higher production yields, improvement of production volumes, environment-friendly production, etc. (Lager, 2002a). As a note, managers and researchers have historically focused predominantly on product innovation and ignored process innovation (Pisano and Wheelwright, 1995). In fact, a recent review found that only about one percent of empirical studies in the field of innovation management studied process innovations (Becheikh et al., 2006).

Empirical research has suggested that product and process innovations are related to different organisational structures and processes (Utterback and Abernathy, 1975; Ettlie et al., 1984; Cohen and Klepper, 1996). For one, the adoption of product and process innovations requires different skills: product innovation require skills in assimilating customer needs and designing and manufacturing the product, whereas process innovation requires firms to apply technology to improve efficiency (Ettlie et al., 1984). Utterback and Abernathy (1975) showed that product and process innovation were emphasised at different stages of the product-process life cycle. From Cohen and Klepper’s (1996) studies comes the conclusion that firm size predicts whether a firm pursues product or process innovations, as firms with large outputs have more to gain by process innovations.

The different types of innovation and their internal relations are illustrated in Figure 3–1 below.

Figure 3–1: Types of innovation.
Degree of newness

Radical versus incremental innovation. Not all ideas, practices or objects are recognised as innovations. Instead, it is often stated that the perception of newness is a key feature for distinguishing innovations (Slappendel, 1996). There are however different views on what constitutes newness. One way of classifying the degree of newness is to vary innovations within a firm along a continuum from “incremental” to “radical” (Ettlie et al., 1984; Dewar and Dutton, 1986). Radical innovations are those that produce fundamental changes in the activities of the organisation and represent a large departure from existing practices (Hage, 1980) (i.e. major changes of technological directions with entirely new technologies, products, processes, or systems, and a high degree of new knowledge). Incremental innovations are those that result in a lesser degree of departure from existing practices (Hage, 1980) (i.e. technological innovation involving minor technological changes which control, adjust, renovate, modify or improve a current technology based on an existing principle). Knight (1967) put forward the idea that all innovations have a degree of performance radicalness and structural radicalness. Performance radicalness describes the amount of change in the performance of products, processes and services. A large change in output, positive or negative, that results from the introduction of a new idea is defined as an innovation high in performance radicalness. Structural radicalness describes how much structural arrangements (either physical – as in product or process design - or organisational) have differed. There are also other ways of classifying the concept of newness2. For example, the Oslo Manual takes a macro-perspective and classifies innovations as either “new to the firm”, “intermediary” (new to a particular market or region), or “new to the world” (OECD, 2005).

Empirical findings have found that different organisational characteristics can support or hamper either radical or incremental innovation. For example, organisational complexity promotes radical innovation while bureaucratic control predicts incremental innovation (Damanpour and Gopalakrishnan, 1998). Other findings suggest that radical innovations require technical knowledge and slack resources normally available to larger and more complex organisations (Damanpour, 1996). This is because organisations pursuing radical innovations need to be able to raise the human and technical resources necessary for radical innovations and absorb the higher costs of failure of such innovations. Studies of radical innovation have also found that this was more likely to emerge in centralised structures (Ettlie et al., 1984) and when separated from ongoing business activities (Rice et al., 1998).

Stage of innovation

Initiation versus implementation. An innovation process can be subdivided into a number of phases or stages. An early distinction between different stages of innovation was presented by Knight (1967) who concluded that available evidence showed that the innovators are not the creators and therefore separated the creation and development activities from introduction and adoption. Early innovation research following Schumpeter clearly differentiated between invention and innovation - which were viewed as two completely

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2 For a recent review on newness as referred to product innovations, see Danneels and Kleinschmidt (2001).
separate events: the inventor invented something and the innovator introduced it (Schumpeter, 1939; Solo, 1951). However, modern innovation scholars see invention and innovation as being generally intertwined through a continuous process. Zaltman et al. (1973) identified two stages in the innovation process, initiation and implementation, while Hage (1980) expanded the process to four stages, evaluation, initiation, implementation, and diffusion. Subsequent research in product development and the development of stage-gate models has sought to slice the innovation process into ever smaller stages (e.g. Cooper’s (1988) seven stages; idea-generation, preliminary assessment, concept evaluation, development, testing, trial, and market launch). Nevertheless, regardless of the number of stages, there is agreement that successful innovation requires different organisational arrangements for each stage. For example, low formalisation and centralisation are said to facilitate the initiation of innovation, while high formalisation and centralisation facilitate implementation (Zaltman et al., 1973; Duncan, 1976; Damanpour and Gopalakrishnan, 1998).

Much previous work on R&D organisation look at the R&D organisation as a single typology (see reviews by Cavone et al., 2000; Becheikh et al., 2006). However, published cases of reorganisation of R&D within firms suggest that different R&D activities require different organisations (e.g. Pisano, 1997; Damanpour and Gopalakrishnan, 1998; Cavone et al., 2000). Therefore, in order to understand innovation we must also understand the organisation where innovation occurs.

3.2. Organisational structure and design

The study of innovation and the study of organisation have always been closely coupled. Some of the early and most notable studies in organisation also commented on the link between organisation structure and innovation. Examples include Burns and Stalker (1961), who found that organic organisations are better suited for innovation while mechanistic organisations maximise efficiency; Lawrence and Lorsch (1967b), who concluded that integration between differentiated departments is generally required for successful innovation; and Woodward (1965), who noted that change in production technology affected the organisational structure of firms. In fact, many of the new organisational forms being used today were born out of the needs of innovation. The concept of interdisciplinary project teams traces its roots back to the problems faced in developing new products, where there was a need for a temporary well co-ordinated effort involving many different parts of the organisation (Allen, 2001). The complexity of product development activities, especially the need for technical specialists to communicate with their peers, was also what prompted the Boeing Company to come up with the matrix organisation in the 1960s (Allen et al., 2004). “Skunk works” (often used to describe an autonomous group within an organisation working on independent projects) is also a concept originating within an innovation context, more precisely the development organisation of Lockheed Burbank (Allen, 2001).
3.2.1. Defining organisational structure and design

Organisational structure

A basic definition of an organisation is a group of people who work together in a structured way and for a shared purpose (e.g. Etzioni, 1964; Arrow, 1974; Robbins, 1990; Daft, 2001; Burton and Obel, 2004). As such, an organisation is a complex entity, made up of many parts and layers. However, organisations consist not only of individuals, but also all the formal and informal social and physical relationships between these individuals, the knowledge and resources they employ, and the tasks which they must perform. The organisational structure of a firm is often seen as a formal system of tasks and reporting relationships that controls, co-ordinates and motivates these tasks.

Because of this complexity, organisational structure can be characterised in multiple ways. Table 3-1 exemplifies some different levels of organisational structure and their time-frames for organisational changes; the normative level (meaning the inherent long-term norms and culture of the organisation – also referred to as the ‘superstructure’ (Fombrun, 1986)), the strategic level (dealing basically with how different sub-units of the organisation are structured relative to one another – sometimes referred to as ‘sociostructure’), and the operational level (dealing with daily business operations such as tasks, routines and reporting relationships between groups and individuals – also referred to as ‘infrastructure’).

Table 3-1: Different levels of organisation structure.

<table>
<thead>
<tr>
<th>Level</th>
<th>Content</th>
<th>Time-frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normative</td>
<td>Norms, values, culture, creativity</td>
<td>Long-term</td>
</tr>
<tr>
<td>Strategic</td>
<td>Administrative structures, hierarchies, resources, knowledge</td>
<td>Middle-range</td>
</tr>
<tr>
<td>Operational</td>
<td>Tasks, routines, workload, reporting relationships</td>
<td>Short-term</td>
</tr>
</tbody>
</table>

Organisational design

Organisational structures are not static, but need to be continuously altered to ‘fit’ the environment and the strategy of the organisation. The properties of organisational structures have important consequences for the organisation’s effectiveness when it comes to control, adaptability, and member motivation (Ranson et al., 1980). Organisational design refers to both the management decisions and the set of structural elements used to create a best possible fit between specific tasks of the organisation and the context of the organisation (Mintzberg, 1999). As such, organisational design can be termed as being both process and content (Nadler and Tushman, 1997; Galbraith, 2002). Design process research is focused on the change processes taking the organisation from one form to another, while the design content research is focused on the structure of the organisation itself. Organisational design is a normative science with the goal of prescribing how an organisation should be structured in order to function effectively (realising its purposes and goals) and efficiently (utilising the least amount of resources necessary to create its products and services) (Burton and Obel, 2004).
3.2.2. Perspectives on organisational structure and design

The field of organisational theory has generated a variety of theories that try to understand, explain, and predict organisational performance. Closed rational and natural system models (e.g. scientific management, decision making, bureaucratic theory, and human relations – focusing solely on internal efficiency) were prevalent up to the 1960s when the open-system models emerged (e.g. bounded rationality, contingency theory, institutionalism, resource dependency, population-ecology, and transaction-costs theory – viewing organisations as a system of interdependent activities) (Scott, 1998). The open systems models stress not only the complexity and variability of the individual parts of an organisation, but also the importance of the environment. The emphasis is on the different aspects of a given organisation and how they are coupled together.

The classical theory of organisational design was marked by a preoccupation with universal forms and the idea of 'one best way to organise' and the work of Weber (1968) on the bureaucracy, and of Chandler (1962) on the multidivisional form, was very influential in this regard (Lam, 2005). However, the assumption of 'one best way' was, challenged by research carried out during the 1960s and 1970s, often drawing conclusions from large-scale empirical studies (e.g. Burns and Stalker, 1961; Woodward, 1965; Hage and Aiken, 1967; Lawrence and Lorsch, 1967b; Pugh et al., 1968; Blau, 1970), which tried to explain the diversity of organisational forms and their variations with reference to the demands of context. Much of this research would later fall under the label contingency theory research.

**Contingency theory**

Contingency theory is based on two conclusions: "There is no one best way to organise", and "Any way of organising is not equally effective" (Galbraith, 1973, p.2). The first statement implies that under different conditions, difference in structural arrangements will be observed, and the second statement tells us that some ways of organising are better than others.

There are several contextual determinants of structure that have been applied in the organisational theory literature, of which the most common have been size (e.g. Pugh et al., 1969; Ford and Slocum, 1977; Evangelista and Mastrostefano, 2006), technology (e.g. Woodward, 1965; Perrow, 1967; Thompson, 1967), strategy (e.g. Chandler, 1962; Miles and Snow, 1978; Covin et al., 1994; Kald et al., 2000), leadership and management style (e.g. Child, 1972; Miller et al., 1982; Lewin and Stephens, 1994) and environmental uncertainty (Burns and Stalker, 1961; Lawrence and Lorsch, 1967a; Duncan, 1979). As exemplified in Table 3-2 [on the next page] these factors determine organisational structure in different ways.

There have also been many attempts to link innovation propensity with different structural determinants (see meta-analysis by Damanpour, 1991), as well as with different organisational structures and processes (Teece, 1996; Damanpour and Gopalakrishnan, 1998).

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3 A note: Although labelled contingency theory, it is not a ‘theory’ in a strict sense, but rather a research paradigm sharing a set of premises (Donaldson, 1995).
Table 3-2: Examples of common organisational contingencies and their effects on chosen structural elements (adapted from Burton and Obel, 2004).

<table>
<thead>
<tr>
<th>Contingency</th>
<th>Effect on organisational structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>If the size of the organisation is large then formalisation should be high</td>
</tr>
<tr>
<td>Technology</td>
<td>If technology is routine then formalisation should be high</td>
</tr>
<tr>
<td>Strategy</td>
<td>If strategy is prospector then centralisation should be low</td>
</tr>
<tr>
<td>Leadership and management style</td>
<td>If the leadership style follows that of the manager then the centralisation should be high</td>
</tr>
<tr>
<td>Environmental uncertainty</td>
<td>If the environmental uncertainty is high then the centralisation should be high</td>
</tr>
</tbody>
</table>

There are several difficulties inherent in contingency theory research. Schoonhoven (1981) suggests that contingency theory often underrepresents the complexity of relations among contingencies and structural variables. Also, multiple conflicting contingencies are at work and design cannot be optimal with respect to every contingency simultaneously (Child, 1977). With regard to innovation, the propensity for an organisation to be innovative is different for differing innovations, organisational structures, and contexts. Burton and Obel illustrate the difficulties in designing organisations based on contingency variables by exemplification (Burton and Obel, 2004, p.xix): Assuming that an organisation can be defined as functional, divisional, or matrix, centralised or decentralised, specialised or not specialised, and formalised or not formalised, there are 24 possible designs from which to choose. Evaluating these for ten contingency dimensions with two values for each would mean evaluating 24 classes of structures under 1,024 different conditions. There are different solutions to this problem – either through operationalising theoretical propositions through computing power (as Burton and Obel themselves have done) or through the acknowledgment that it is more the overall configuration of a firm’s structure than any singular aspects of structure that affect performance (see Khandwalla, 1973; Child, 1977; Miller, 1981; Mintzberg, 1999). In the latter case, it is important to distinguish the organisational configurations or structural variables that are more important in any specific context.

4 Contingency theory proliferated in the mid-to-late 1960s and 1970s, and the organisation literature was filled with articles from a structural contingency perspective (see for example the reviews by Miner, 1984; Drazin and Van de Ven, 1985; Mowday, 1997; Pfeffer, 1997). Contingency theory laid the foundation to several complex propositions such as the McKinsey 7-S framework, Theory Z, and other characteristics of fit in excellent companies (Drazin and Van de Ven, 1985). In Miner’s (1984) presentation of his findings on the usefulness of 110 nominated organizational theories, contingency theory was most frequently mentioned as being important. However, while interest in the contingency theory research paradigm has since faded a follow-up study in 2003 still had contingency theory as listed “high” in “estimated usefulness of application” (Miner, 2003), and it still influences much work in organisational theory and design (Donaldson, 2001; Burton and Obel, 2004).
Innovation, organisation, and strategy are closely bound together. Past research has argued that organisational structure is the primary driver of innovation (for a review see Wolfe, 1994). Organisation structure provides the formal, internal context that is required in order for the process of innovation to occur (Roussel et al., 1991). In fact, the study by Kimberly and Evanisko (1981) claims that as much as 60 percent of the variation in the adoption of innovation in organisations is explained by organisational structure. Concerning the design of R&D organisations, Chiesa (2001) argues that design changes are linked with shifting views of strategy. It has also been noted that organisations in general evolve in a discontinuous manner, where long periods of stability are interrupted by brief periods of intensive change (Miller and Friesen, 1980).

3.3. Organisational strategy

Managing innovation in firms involves more than just creating a context where innovations can potentially develop. To make sure that the right decisions are being made and the right innovations are being pursued, an organisation must also have a sense of direction or purpose for its innovation activities. One of the enduring core assumptions in strategy literature is that the suitability of a firm’s strategy can be defined in terms of its fit, match, or congruence with the environmental or organisational contingencies facing the firm (see Chandler, 1962; Andrews, 1971; Hofer and Schendel, 1978; Miles and Snow, 1994). However, there are differing views on what strategy should be based on – such as either the firm’s position on a market or the resources that the firm commands. These opposing views are discussed in the following chapters.

3.3.1. Defining organisational strategy

Explaining, and often predicting, organisational performance is a primary research objective in the field of strategic management (Hrebiniak et al., 1989; Meyer, 1991). Furthermore, organisational performance is dependent on the organisation or firm somehow achieving some sort of competitive advantage over the competition. The concept of strategy thus entered the management literature as a way of referring to what one did to counter a competitor’s actual or predicted moves (Steiner, 1979). Today, the concept has evolved – as a recent survey targeted at scholars within the field illustrates:

“The field of strategic management deals with… the major intended or emergent initiatives… taken by general managers on behalf of owners… involving utilisation of resources… to enhance the performance of firms… in their external environments” (Nag et al., 2007, p.943)

Considering the broad definition above, there are many views on what constitutes strategy. Mintzberg illustrates in his ‘Five Ps for strategy’ (1987) that the concept can be used in different ways:

- Strategy as a plan sees strategy as a means of getting from here to there.
- Strategy as a pattern sees strategy as a stream of consistent actions over time, intended or unintended.
- Strategy as a position sees strategy as locating an organisation in terms of contexts, such as products, markets, competitors etc.
- Strategy as perspective sees strategy as the way in which the organisation sees the world, in terms of its vision and direction.
- Additionally, strategy can also be seen as a ploy – a way to fool or discourage the competition through deception and trickery.

By these definitions strategy research can be divided into two fields – strategy process and strategy content.

**Strategy process**

Strategy process includes those activities involved with the choice of strategy. It can be seen as a sequence of behaviours where decision makers scan the environment to gather data on important events and trends, interpret this data, make decisions, and take actions that serve as the basis for performance (Ketchen et al., 1996). Managing this process is a vital management task because according to Hofer and Schendel, strategy is important so its formulation should not be “left to chance” (Hofer and Schendel, 1978, p.5).

Strategy processes are dependent on environmental and organisational contexts (Hutzschenreuter and Kleindienst, 2006). Environmental attributes such as uncertainty, complexity, and dynamism affect the strategic process as well as the strategic positions that the firm takes. The organisational context of strategy process includes attributes such as size, age, structure, technology and routines, as well as culture and values. The literature has focused on the individual level (e.g. Miller et al., 1982; Miller, 1993; Hiller and Hambrick, 2005), on the group level (e.g. Rindova, 1999; Golden and Zajac, 2001), and on the organisational level (e.g. Bower, 1970; Burgelman, 1983; Hall, 1984; Farjoun, 2002).

**Strategy content**

The expectation that the content of a firm’s strategy is a key determinant of its performance is a cornerstone of the strategic literature. Strategy content focuses on the strategic decisions themselves dealing with industry forces such as competition, buyer and supplier behaviour, substitutes, and market entry (examples taken from Porter, 1980). Porter’s (1980) view is that a firm must be better than the other firms in its industry at dealing with industry forces if it is to have a competitive advantage. Strategy content decisions can be taken in regards to diversification (Bettis, 1981), market share (Gale, 1972), market entry and defence (Zajac and Shortell, 1989), and vertical or horizontal integration (Porter, 1980; Garvey, 1995).

The generic strategies proposed by Porter (1980) of cost leadership (going for low price, high market share, economies of scale), differentiation (aiming at product uniqueness), and focus (focus on defined buyer group, product line, or geographical area) are firmly rooted in the strategy content field, as are the build (increase market share and capacity, growing industries), hold (keep market share by marketing and quality improvements, mature...
industries), and harvest (maximise short-term earnings, declining industries) strategies proposed by Gupta and Govindarajan (1984).

Naturally, strategy content and strategy process interact with each other (Huff and Reger, 1987; Miller, 1989; Ketchen et al., 1996; Ketchen et al., 2004). Also, organisational structures affect firm strategy through the strategy process and selected strategies. They presented four strategic types; the Defender (centralised, efficiency oriented, competing through low costs), Prospector (flexible structure, always seeking new product and market opportunities), Analysers (matrix structure, enters new markets carefully, core of established products), and Reactor (lacks coherent strategy and hosts inappropriate structure for purpose). Miles and Snow suggest that failure to maintain consistency between organisation, strategy and process will lead a firm to become a Reactor and suffer poor performance (Miles and Snow, 1978). Snow and Hrebiniak (1980) subsequently showed that the relative importance of strength in engineering, R&D, production varied between different strategic types.

In effect, in order to make good strategy decisions managers need to understand both the organisational (Burgelman and Sayles, 1986) and the competitive environment (Ketchen et al., 2004). However, managers should also realise that strategy is also dependent on the underlying perspectives of what constitutes competition and what it is that firms compete with. In strategic management – this is often viewed as the discussion of products versus resources.

3.3.2. Two perspectives on organisational strategy

The two dominant streams of strategy research from the 1980s and onwards have been the Porterian strategic positioning approach and the Penrosian resource-based view of strategy formulation (for a review, see Ramos-Rodriguez and Ruiz-Navarro, 2004). Both views address vital management issues – the Porterian view of strategy is primarily concerned with how the corporation competes with its products and services in the product/service market, while the Penrosian view of strategy is concerned with how the corporation secures the factors needed for establishing and sustaining competitive advantage.

Positioning approach

The principles of a positioning approach to strategy can be traced back to Mason (1939; 1949) and Bain (1956; 1968) and are set in the Harvard school of industrial organisation economics. The approach gained increased attention in the early 1980s, inspired by the seminal works ‘Competitive Strategy’ (Porter, 1980) and ‘Competitive Advantage’ (Porter, 1985) by Michael Porter. The positioning approach focuses on how corporations differ in product-market positions compared to their competitors. Thus, the critical task of strategy is determining which the most favourable product market is, and establishing the most favourable position in that particular product market.

The concepts of product markets and industry are central to the positioning approach to strategy. Sissors states that a product market is identified by a generic class of products,
and refers to “individuals who in the past have purchased a given class of products... [and] the assumption is usually made that those persons who will buy a product in the future will be very much like those who have purchased it in the past” (Sissors, 1966). Subsequently, an industry is identified as a bundle of similar product markets. The concept of product markets is founded on two fundamental assumptions: that each product market is distinct (there is clarity for customers and competitors), and that competition occurs at the level of product lines and/or businesses (Prahalad and Hamel, 1990; Prahalad, 1998). However, it is argued that as business boundaries are blurring and evolving and customers and competitors are increasingly unidentifiable, existing conceptions of product markets are not a good basis for understanding competitiveness (Prahalad and Hamel, 1990; D’Aveni, 1995; Prahalad, 1998; De Toni and Tonchia, 2002), thereby shaking the fundamental assumptions of the product markets. It has therefore been argued that in a dynamic environment where corporations search for continuity, this effort cannot be associated with positions in product markets but is more likely to be found in terms of the resources used for product application (Chiesa and Manzini, 1996). These insights have helped give increased attention to a stream of strategy research that views the creation of competitive advantage as an inside-out process, known as the resource-based view.

**Resource-based view**

The resource-based view assumes that corporations are heterogeneous because of the resources they own and control (Barney, 1991). Whereas the main objective of the positioning approach to strategy is to obtain and maintain favourable positions in product markets to earn revenues, the resource-based view sees strategy as both constrained by and dependent upon the corporation’s collection of resources (Penrose, 1959; Rumelt, 1984; Wernerfelt, 1984; Barney, 1986). The principles of a resource-based approach to strategy can be traced back to the work of Edith Penrose’s work ‘The Theory of the Growth of the Firm’ (1959). Penrose argues that:

- Corporations will grow in the direction of their slowly-changing resources.
- Resources in the short run are both a limit to and a catalyst for growth.

According to Grant (1991) the critical task in a Penrosian resource-based approach to strategy is to determine the most favourable composition of resources, in order to find the optimal configuration of product-market positions to maximise revenues over time. Resources are often classified into tangible (e.g. physical and financial resources) or intangible (e.g. competencies and relations) (Haanes and Löwendahl, 1997).

The resource based view can be seen as a common term for a broader wave of strategy literature that surfaced in the late 1980s and 1990s. The resource based view (e.g. Wernerfelt, 1984; Barney, 1991) can be set apart from the competence based view (e.g. Prahalad and Hamel, 1990; Sanchez and Heene, 1997) and the dynamic capabilities approach (e.g. Teece et al., 1997; Eisenhardt and Martin, 2000), as they vary in their conceptions of what constitutes firms and strategies, what the attributes of resources are, and how resources are developed. Other variations on the theme include strategic assets (Winter, 1987; Amit and Schoemaker, 1993) and distinctive competencies (Hitt and Ireland, 1985), core competencies (Leonard-Barton, 1992a), capabilities (Grant, 1991), and resource deployment (Selznick, 1957). For the purpose of this thesis, however, we need not concern ourselves
with the debate within these concepts, but simply focus on the basic premises of the resource-based approach.

There is evidently an interdependent and complementary relationship between positions and resources (see for example Mahoney and Pandian, 1992; Peteraf and Bergen, 2003). While the resource-based view is an inside-out process, the analysis of the environment is still critical since environment change “may change the significance of resources to the firm” (Penrose, 1959, p.79). In fact, Rumelt highlights the interaction between environments and resources when he suggests that strategy formulation concerns “the constant search for ways in which the firm’s unique resources can be redeployed in changing circumstances” (Rumelt, 1984, p.569). So, while the Porterian strategic positioning approach and the Penrosian resource-based view differ in their level of analysis and on the basis of how corporations achieve competitive advantage, current normative work in strategy should be oriented towards better integrating the product-market and resource-based approaches (Burgelman et al., 2004). Corporations can either specify activities in product markets and from these infer the minimum necessary resource commitments, or by specifying a resource profile for a corporation find the optimal product-market activities (Wernerfelt, 1984). From this logic Wernerfelt concludes that resources and products are two sides of the same coin, as the corporation could be seen as a portfolio of resources as well as a portfolio of products.

3.4. Perspectives of studying innovation in organisations

In the innovation, organisation, and strategy literature there are different models and perspectives on how to approach the domain. Slappendel (1996) presents three such perspectives: the individualist perspective, the structuralist perspective, and the interactive process perspective [See Table 3-3 on the next page for an overview]. These perspectives are in turn based on previous frameworks by Pierce and Delbecq (1977) in innovation, by Pfeffer (1982) in organisation theory, and by Chaffee (1985) in strategy.

Individualist perspective

The individualist perspective’s basic assumption is that individuals cause innovation. Innovative behaviour is explained by characteristics, actions, and cognitive capacity of organisational participants (Slappendel, 1996; Barker and Mueller, 2002). Studies often focus on the ‘traits’ of individuals and concepts such as age, education level, values, personality, goals, creativity, sex, and cognitive styles (for a review see Scott and Bruce, 1994). However, the individualist perspective does not necessarily focus on a single individual but can also focus on the characteristics of groups. Other central issues in the individualist perspective are the influence and role of leaders (e.g. Wilson, 1966; Hage and Dewar, 1974) and the concepts of champions and entrepreneurs (e.g. Chakrabarti, 1974; Howell and Higgins, 1990).
### Table 3-3: Main features of the three perspectives (from Slappendel 1996).

<table>
<thead>
<tr>
<th></th>
<th>Individualist</th>
<th>Structuralist</th>
<th>Interactive process</th>
</tr>
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<tbody>
<tr>
<td><strong>Basic assumptions</strong></td>
<td>Individuals cause innovation</td>
<td>Innovation determined by structural characteristics</td>
<td>Innovation produced by the interaction of structural influences and the actions of individuals</td>
</tr>
<tr>
<td><strong>Conceptualisation of an innovation</strong></td>
<td>Static and objectively defined objects or practices</td>
<td>Static and objectively defined objects or practices</td>
<td>Innovations are subject to reinvention and reconfiguration. Innovations are perceived</td>
</tr>
<tr>
<td><strong>Conceptualisation of the innovation process</strong></td>
<td>Simple linear, with focus on the adoption stage</td>
<td>Simple linear, with focus on the adoption stage</td>
<td>Complex process</td>
</tr>
<tr>
<td><strong>Core concepts</strong></td>
<td>Champion, Leaders, Entrepreneur</td>
<td>Environment, Size, Complexity, Differentiation, Formalisation, Centralisation, Strategic type</td>
<td>Shocks, Proliferation, Innovative capability, Context</td>
</tr>
</tbody>
</table>

#### Structuralist perspective

The structuralist perspective assumes that innovation is determined by organisational characteristics. The function of the organisation is to optimise performance and the task of managers is to manage the relations between an organisation and its changing environment (Slappendel, 1996). Studies often focus on relationships between innovation and a range of structural variables (such as size, centralisation, differentiation, and formalisation) (e.g. Damanpour, 1991). However, it has also been argued that organisations should be studied as configurations of structure rather than looking at individual determinants of structure (e.g. Khandwalla, 1973; Child, 1977; Miller, 1981; Mintzberg, 1999).

#### Interactive process perspective

The interactive process perspective states that innovation is produced as a result of both the actions of individuals and structural influences. Individual, organisational, and environmental conditions should all be taken into account when studying an organisation’s capability for innovation (Slappendel, 1996). Also there is a heavier focus on understanding the innovation development process, from initiation to implementation. There are two important theoretical aspects of the interactive process perspective; first, the non-rational aspects of decision-making and organisational behaviour are deemed more important (e.g. the political context of Child and Smith (1987)); second, emphasis is placed on understanding the dynamic nature of the innovation process (e.g. the two-way relation between the innovation output and the innovation process (described in Lim et al., 2006)).
The three perspectives are not necessarily mutually exclusive and often have blurred boundaries. However, the individualist and the structuralist perspectives tend to encourage research which for the most part focuses on the identification of key innovation determinants. This implies favouring the use of cross-sectional surveys. The integrative perspective focuses rather on exploring innovation and organisations using case study approaches.

3.5. The research framework

R&D managers who come to academia in search for advice on how to organise have a hard time finding relevant recommendations that fit their specific needs. This is a problem in the whole domain of organisational design according to Burton and Obel (2004, p.xviii):

“To date, there seem to have been only two ways of doing things in this field – either to be so general and so simple that the various interpretations do not yield practical design implications, or to be so detailed and specific that generalisation to other situations is almost impossible”

Thus, the challenge for a research framework is to balance the general and the detailed – being specific enough to make it applicable and being general enough to make the findings relevant to a wider audience. It is therefore necessary to move away from the traditional “what kind of organisation nurtures innovation?” way of formulating the research problem concerning the relationship between organisation design and innovation. Instead, by combining aspects of the different theoretical frameworks it is possible to put forward more useful models of designing R&D in process industry. This research project on furthering the understanding of organising intrafirm R&D organisations in process industry asks the following questions:

- What are the critical issues of organising R&D in process industries?
- How can innovation strategy formulation processes be organised?
- How can intrafirm R&D organisations be organised?

The research framework of this thesis is consequently based on the theoretical frameworks grounded in innovation, organisation, and strategy literature. Figure 3-2 on the next page illustrates the relations between the research framework and the theoretical framework.
From *innovation* theory springs the importance of distinguishing between product and process innovation. There are several reasons for choosing this particular classification as a starting point - First of all, innovation literature has focused predominantly on product innovation, or even equated the two. There is thus a gap in the innovation literature concerning the organisation of process innovation. Secondly, in process industry a substantial part of R&D is targeted towards process innovation, thereby making it an important area of study in this particular industry. Thirdly, process and product innovation in process industry is intertwined to a larger degree than in other manufacturing industries. Understanding the boundaries and the way they interface is critical for effective R&D management. Fourthly, on a methodological note, in order to promote consistency between studies, an attribute should the chosen that is capable of classifying the innovation without reference to the specific organisation under study (see Downs and Mohr, 1976 for a fuller discussion on this issue). Otherwise, innovations risk being classified differently in different organisations. An important limitation of this research framework is the general focus on internally generated innovations.

*Organisation structure and design* theory presents the idea that there are different ways of organising. Contingency theory suggests that for different contexts there are different organisational forms that may be more or less successful than others. Contingency theory also proposes that there are different contextual determinants which influence the organisation and that an organisation should strive to find a ‘fit’ with these determinants. Another valuable observation in organisational theory is that organisations prescribe different designs for different types of subunits (Drazin and Van de Ven, 1985). This suggests that different activities, even within an organisation, should be organised according to their specific environments. In terms of limitations the research frameworks mainly focuses on the strategic level of organisational structure. While important, norms and values are considered too complex, and the time horizon for such studies is considered too long for this particular project on R&D design in process industry. There is also reason to believe that it is especially on the strategic level and not in terms of either norms or
specific work tasks that the main uniqueness of innovation in process industry comes to light.

Organisation strategy theory proposes that organisations adjust to their environments through active decision-making and strategies (Child, 1972). This implies that firms have to make strategic decisions concerning which type of innovations they wish to pursue. The input from strategic management to the framework is the focus of innovation drivers, i.e. theoretical models that explain why firms pursue innovation. For example, a cost-focus strategy will lead a firm to pursue different innovation activities than would a strategy based on product differentiation. Furthermore, both the positioning approach and the resource-based approach assert the importance of innovation. The positioning approach regards innovation as critical for organisations to distance themselves from competitors by the development or adoption new products, processes, or procedures. The resource-based view, with its focus on intrafirm resources and knowledge also has a close bond with the concept of innovation; innovation is the creation of new resources and new knowledge.

There are different perspectives of studying innovation in organisations that this research framework builds on. The structuralist and interactive perspectives of studying innovation in organisation both focus on the organisational arrangements that promote innovation – in the structuralist view most often seen as uni-dimensional determinants and in the integrative view seen as parts of a larger context that also includes processes and actions. The research framework with its focus on the intrafirm organisational structure is to a large extent influenced by the structuralist perspective. However, the research project is also determined in exploring the wider contexts of organisational choices in designing R&D organisations. As such the research framework is geared towards understanding innovation and the design of R&D organisations as dependent on a wider array of internal and external variables and contexts.

The appended papers in this thesis accentuate different part of the theoretical frameworks. Table 3-4 is an attempt to summarise the key points in innovation, organisation, and strategy, and using the perspectives to illustrate how the theoretical and research framework relates to the individual papers of this thesis.
Table 3-4: Relating the theoretical framework to the individual papers.

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<tbody>
<tr>
<td>Stage of innovation</td>
<td>No distinction</td>
<td>No distinction</td>
<td>No distinction</td>
<td>No distinction</td>
<td>No distinction</td>
<td>No distinction</td>
</tr>
<tr>
<td>Degree of newness</td>
<td>No distinction</td>
<td>No distinction</td>
<td>No distinction</td>
<td>Radical versus incremental</td>
<td>Radical versus incremental</td>
<td>No distinction</td>
</tr>
<tr>
<td>Type of innovation</td>
<td>No distinction</td>
<td>Technical innovation</td>
<td>Technical innovation</td>
<td>Process versus product innovation</td>
<td>Process innovation</td>
<td>Technical innovation</td>
</tr>
</tbody>
</table>

| Organisation structure and design | | | | |
| Key variables | 4 organisational determinants and 11 structural variables | Two methodologies for strategy formulation | Two methodologies for strategy formulation | Centralisation versus decentralisation | Industry category, size, innovation intensity, newness |
| Structural level | Strategic level | Operational level | Operational level | Strategic level | Strategic level |
| Organisation strategy | Process versus content | Strategy process | Strategy process | Strategy content | Strategy content |
| Strategic perspective | No distinction | Resource versus positioning | Resource versus positioning | Resource based view | No distinction |

| Perspectives on studying innovation in organisations | | | | |
| Perspective | Integrative | Integrative | Integrative | Integrative | Structuralist | Integrative |
| Method | Case study | Theoretical | Case study | Case study | Industry survey | Workshop survey |

A final note on the positive underpinning of this research framework: The research project “Designing R&D organisations in process industry” is adamant on being able to provide valuable insights to R&D professionals. This view is evident in the choice of theoretical frameworks; innovation management as a field of research is very much oriented towards aiding practitioners in decision making, and much of the literature is focused on giving hands-on advice to practitioners. Contingency theory also offers a positive view of management, as it directly states that managers have the power to design organisations (Donaldson, 1995). Furthermore, as stated by Rumelt, Schendel, and Teece, “strategic management as a field of inquiry is firmly grounded in practice and exits because of the importance of its subject” (1994, p.9). While developing theory and conducting empirical studies based on the above described research framework may not provide the final answer concerning R&D organisational design, it will aid managers in understanding the important issues regarding organisational choices, and the wider context on which these decisions are based.
4. METHODOLOGY

Research basically concerns finding and solving a problem. This may sound simple enough – but it is not. A solid research methodology is needed to ensure that both the problems and the eventual findings are what they are claimed to be. This research methodology will be a product of the researchers’ approach to knowledge, the choice of research designs, and the ability to gather and interpret data. It is therefore important to describe these views and choices as clearly as possible so that others may judge the research.

4.1. Research approach

Simplifying somewhat, there are two different ends of a continuum when identifying research problems – either identify the problems in theory, or identify the problems in practice. The research project “Designing R&D organisations in process industry” and this thesis are based on a management-oriented view (see also the discussion in section 3.5 on the previous page). This implies that the research is aimed at managers and the real-world problems that managers face. After all, management science is an applied science in the sense that the end results of management research should not only further theoretical development, but be useful to managers. Also, as stressed by Burton and Obel, the domain of “organisational design is a normative science with the goal of prescribing how an organisation should be structured in order to function effectively and efficiently” (Burton and Obel, 2004, p.xviii). Theory development and empirical studies in this domain give us insight not only into how organisations operate, but how different designs have different effects on innovation.

This research project is phenomenological in that it focuses on exploring practical issues and is based firmly on the positive premise that organisations can be managed. Nevertheless, it is so without being overly normative. While managerial implications are discussed broadly, the research itself does not claim to provide the final answer to the question of how firms should design their R&D organisation. Rather, it seeks to provide insights regarding organisational choices and of important contexts and contingencies that determine them. Theoretically, it seeks to further the understanding of organising intrafirm industrial R&D in process industry – based on innovation, organisation, and strategy theory. The specific research questions are of a “what” and “how” character, highlighting the exploratory nature of this study.

4.2. Research strategy and process

There are several different research strategies, research designs, and research processes that can be pursued in management research. Historically, research in innovation has focused on product innovation in a manufacturing context relying predominantly on cross-

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1 Not to be confused with the term positivistic – used to label the assumption that all research should be derived from scientific experiments.
sectional survey data (see Brown and Eisenhardt, 1995), which points at possible gaps in both scope and methodology (Vincent et al., 2004). This research project seeks to broaden the scope by including process innovation and utilising a wider array of methodologies than cross-sectional surveys. The research questions in this particular research project are exploratory in nature. This implies that surveys and case studies, aimed at understanding complex contexts, are appropriate research strategies (Yin, 2003, p. 4). Also, the interactive process perspective of innovation research is more concerned with process than variance, which naturally leads to the use of case study methods (Slappendel, 1996).

This research project, also being a PhD thesis project, is described through a number of appended research papers. The planning of the project was based on this precondition. Commencing with a literature review, the plan was to follow up with case studies and from there form a theoretical framework. The framework would then be the foundation for a substantial industry survey, targeting all Nordic process industry firms. This planned research strategy with its planned papers is depicted in Figure 4-1.

As the project unfolded, the case studies that had originally been intended to be a limited part of the research project instead became the focal point. The case studies and literature review intertwined into an iterative process. The first case studies provided input for further development of the theoretical framework and subsequent reading. Two quantitative studies are part of the thesis; one workshop survey limited in scale and one statistical analysis of previous industrial survey data. The actual research process, with the papers appended to this thesis, is illustrated in Figure 4-2.
4.2.1. The literature review

The purpose of the literature review is to give an understanding of the main theories within the subject areas and how they have been applied and developed, as well as the main criticisms that have been made of work on the topic. The review forms the basis of the understanding of the topic and the frame of reference, but the emerging frame of reference also forms the basis of further reading (Hart, 1998). There are three important aspects of this literature review;

First of all, three major fields of research are drawn upon – innovation management, organisational theory, and strategic management – illustrated in Figure 4-3 and described in chapter 3, THEORETICAL FRAMEWORK. These are different areas with different research and theoretical paradigms, as well as employing different outlets in terms of journals and conferences. However, they often cross over into each other’s domains.

![Figure 4-3](image)

Secondly, the literature review was not carried out at one particular time during the writing of the thesis, but can best be described as taking place in waves. This has to do with the way that the thesis work is planned. Being a collection of research papers, each specific study and subsequent paper required additional readings and adjustments to the theoretical framework and the literature base.

Thirdly, the literature review was very much affected by external agents. Supervisors, reviewers and colleagues have given input on specific areas. PhD courses completed in parallel with the research project have to a large degree influenced the overarching theoretical framework. As such, it has become heavily predisposed towards what is termed as organisation theory and strategic management thinking – manifested in the references used. Nonetheless, innovation management has also influenced this thesis with its focus on applicability for practitioners.

The only paper which is purely theoretical is Paper II: Heads or tails in innovation strategy formulation?
4.2.2. Obtaining qualitative data - Case studies

Cases studies were used in Paper I: Corporate structure and R&D organisations, Paper III: A resource-based approach to the Booz Allen and Hamilton methodology, and Paper IV: Opening up intrafirm R&D.

According to Cassell and Symon comprehension of the detail of the processes and behaviour is paramount in studying organisational behaviour (Cassell and Symon, 2004). A case study is an in-depth examination of a single setting or event. It focuses on “understanding the dynamics present in a context” (Eisenhardt, 1989) when “the boundaries between the phenomenon and context are not clearly evident” (Yin, 2003).

To judge the appropriateness of the case based research strategy, Benbasat (1987) asks that we answer the following four questions:

1) Can the phenomenon of interest be studied outside its natural setting?
   No. Organisational R&D structures and innovation strategy processes are by definition confined to the studied organisation. Case studies in organisations allow for the studying of complex processes that could never be engineered in a laboratory or a controlled setting (Hayes, 2000).

2) Must the study focus on contemporary events?
   Yes. Even though a case study can be retrospective in nature, the studied phenomena are based on recent developments and the results should have present-day relevance (Yin, 2003). Pure archival studies can seldom yield the richness of data needed to understand organisational decision-making.

3) Is control or manipulation of subjects or events necessary?
   No control or manipulation is necessary. Studying R&D organisations based on the research framework of this project is strictly observational research. A more action-based approach, while theoretically possible, could not have been practically applied in these circumstances.

4) Does the phenomenon of interest enjoy an established theoretical base?
   Yes and No. Organisational theory has addressed the concept of structure on numerous occasions, although rarely at the functional level (Twomey et al., 1988) and not specifically at R&D organisational level (Cardinal, 2001; Argyres and Silverman, 2004). A case study highlights unique situations, processes and behaviour, and thus cases may give new insights into how established organisational variables interact. As existing theoretical models often cannot account for all questions raised by the case study, new research is stimulated. Therefore, one advantage of case studies lies in contradicting established theory. Case studies also sometimes challenge established assumptions, as these often come from generalised theories that do not explain a specific situation (Hayes, 2000). For example, while contingency theory, the differing strategic approaches, and many innovation-organisation links are well established theoretically, they also require a deep understanding of the phenomenological context to be practically useful and furthering theory development (see Donaldson, 2001 for a further discussion specifically on organisation theory).

After deciding on the appropriateness of case studies there are further issues to be addressed, such as sample size, case selection, data gathering method, and data analysis.
SAMPLE SIZE
A common view is that research results which are not based on large quantitative samples are insufficiently generalisable to be of academic or practical value. However, according to Alvesson and Deetz, the major theories that have shaped everyday thinking have had very little data but have instead offered compelling conceptions of core issues (Alvesson and Deetz, 2000). This opinion is also voiced by Westgren and Zering who argue that “many of the greatest contributions to economic theory are logical rather than empirical” (Westgren and Zering, 1998). Still, a key problem in management science is “how large must the sample be in order to be adequately representative?” According to Easterby-Smith (2002) it depends on the depth of the study, where more depth makes it difficult to gather large data samples. Cassell and Symon (2004) argue that smaller samples, tightly controlled for structural and other relevant dimensions, are likely to have a greater explanatory power than could be revealed by a large survey. Because of the “heterogeneity of populations of organisations and of their owner-managers” (Cassell and Symon, 2004, p.44) too general findings would be useful for no-one.

The fact mentioned above is an important aspect of management studies. As the organisational phenomenon to be studied may only concern very few companies; it more or less forces the researcher to draw on a small number of studies for data collection and theorising. For this study the selection of potential study targets is indeed somewhat limited as it requires large corporations that conduct R&D, preferably of international scope, active in the process industry. Considering that the total number of companies in the industry encompasses less than 100 companies of this calibre, conducting a quantitative study would border on being a total census (see Lager, 2001 for a fuller discussion of the Swedish sample).

While single-case studies can give useful insights (see Yin, 2003, p.39–46) the papers in this thesis draw on a multiple-case design. That means that for every case study – several actual cases were drawn upon. Descriptive generalisations based on a single case should be treated with caution (Hutzschenreuter and Kleindienst, 2006). Another logic behind multiple cases in this thesis is that there can be theoretical replication – i.e. contrasting results from different cases can be predicted by theory (Yin, 2003, p.47).

CASE SELECTION
The problem of sampling is based on the fact that only a subset of the total set of units will be studied, which gives rise to the dilemma of selection (Galtung, 1969). In qualitative research there are no statistical guidelines to follow and therefore, in a multiple-case study design, the means of case selection must be transparent in order to avoid tarnishing the results.

According to McKeown (1999), case studies are often undertaken because the researcher expects that the clarification of causal mechanisms in one case will have implications for understanding causal mechanisms in other cases. Following this reasoning, the chosen case or cases should be typical for the greater context of the study – in this instance: R&D organisations in the process industry.

In this study case selection has been made on the basis of industry sector. By looking at different sectors the study will have a wider relevance for the process industry as a whole.
Also, some other aspects were taken into account, such as size and degree internationalisation, in order to have similar companies in more respects than just industry sector. By basing the selection on these criteria it was assumed that it would be easier to conduct relevant cross-case analyses. Because this study looks at intrafirm R&D organisational structures in process industries, fairly large and internationally active companies were favoured for the case study. To meet these requirements, Arla Foods in the food and beverages sector, Billerud in the pulp and paper industry, and New Boliden [in-text referred to as Boliden] in the mining and mineral sector were selected to form the basis of this study [see Appendix I - Case company descriptions for a fuller description of the individual cases].

Specifically, the firms in this research project’s case studies are appealing on three bases: Firstly, though the process industry as a whole may be defined as low-tech, firms rely heavily on their R&D organisation to bring new products to market and improve manufacturing processes (see Hirsch-Kreinsen et al., 2005). The selected firms are no exceptions in this regard, as R&D proficiency is seen as critical for achieving competitive advantage. Secondly, the selected firms can be viewed as being typical in their respective industry sectors (see Eltringham, (1998), Phillips (2000), and Traill and Grunert (1997) for accounts of R&D conduct in the respective industries) and the R&D intensity of the selected firms is also equivalent to the respective industry averages (see Lager, 2002a). In addition, the firms were interesting from an organisational change perspective, as they had all been involved in corporate restructurings and mergers in recent times.

A further aspect of the sampling problem and case selection is the difficulty of attaining access to organisations and their managers. The firms in this research project were accessible only through the personal standing and connections pertaining to the director for Promote.

DATA GATHERING METHOD
The choice of case studies does by itself not determine what the methods of data collection should be. The type of data to be collected is based on the dimensions of the units of analysis. Multiple methods of data collecting are available, and many entities exist from where to collect the data on organisational phenomena (people, groups, or organisations) (Benbasat et al., 1987). Collecting the data in an organisational setting can be achieved either through interviews with key personnel or through documentation and archival records (Yin, 2003). Several categories of data were utilised for the case studies in this thesis – mainly interviews, public records, and company records.

The case study interviews were conducted with informants in top management positions in Swedish process industry firms between 2004 and 2006. The interviews were a mix of semi-structured formal interviews and open-ended discussions, conducted by a pair of researchers who kept separate case protocols [See Appendix II - Case interview compilation for the complete listing of interview format, occasions and informant information].

Used extensively in the case studies as an effective way of utilising both interviews and documents simultaneously is the Critical Incident Technique (CIT). CIT was originally an observational tool in occupational setting focused on individuals, but has evolved in such a
way that is also used in organisational analysis (Chell, 2004). It focuses on significant occurrences (events, incidents, processes, or issues) identified by the respondent or the interviewer. The objective is to gain a wider understanding of the incident and its context, and unlike an unstructured interview there is more focus and more probing. However, as CIT is developed from the respondent’s perspective, there is a need for fact-checking and triangulation (Chell, 2004). For this reason documents play a vital role in CIT. The data from the interviews have been integrated and triangulated with further case data collected via articles in printed press, annual reports, internal reports and internal strategy documents. [A list of example reference data is available in Appendix III - Partial list of non-referenced case study sources]. The critical incidents in the case studies were often changes in the R&D organisational structure, so in this particular project archival records give vital input as to what the critical incidents are; corporate mergers and dynamic market changes are often described in detail in annual reports and suchlike. The semi-structured interview guides themselves can be found in Appendix IV - Semi-structured interview guide and Appendix V- Centralisation interview guide.

ANALYSIS
The data from the case studies were collected and analysed by two researchers in tandem. Usually, one research issue would take up one corresponding interview session with the informant. Notes from the interviews were compared to ascertain whether there had been any misunderstandings or differences in interpretations. On such occasions follow-up questioning was conducted by phone or e-mail. The data were then analysed by contrasting cases against each other and through comparisons with the theoretical frameworks and research purposes for the specific papers. Additional data, such as company reports etc., were gathered before and after interview sessions – to help build questions and to fact-check. By iterating between theory and data, i.e. returning to the cases to find more information on specific issues and contingencies as done in the studies in this research project, the theoretical saturation advocated by Eisenhardt (1989) was sought. Finally, as suggested by Yin (2003), individual case reports were prepared and sent to the informant for validation to support the reliability of the case findings.

METHODOLOGICAL REFLECTION ON CASE STUDIES
Arguably, much of the reservation against case studies stems from the argument that case studies do not allow generalisations to be made. This is true concerning statistical inference, but case studies permit generalisation of a theoretical nature — generalising from data to theory (Yin, 2003, p.21). Also an analysis of multiple cases enables the researcher to relate context with outcomes, and to “look for repetition of patterns” in the data (Chell, 2004), which would label it a cross-case analysis. These patterns may form a basis of case-based theory derived from the study, as well as increasing generalisability (Miles and Huberman, 1994). Moreover, there are some further disadvantages of case study research method that must be noted. The most apparent problems are that the uniqueness of a case study may limit replicability and that it is difficult to generalise from the results of case studies as the phenomenon studied may be very “atypical” (Hayes, 2000). The issue of replicability, validity, and reliability are especially problematic in case studies as they concentrate on a
Subjectivity is also a problem as the complex data gathering and summation may enhance the tendency to bias on the part of both respondent and researcher. Also, but often forgotten, subjectivity is an important issue concerning archival records; Rowlinson (2004) states that “validity and reliability of company documentation must be questioned more than other sources, since it has been collected and processed for the purpose of legitimating a company”. It is important to remember that the archival data have not been collected for the benefit of the researcher.

Judging the credibility of case studies and surveys is no easy thing. Glaser and Strauss (1967, pp.228-233) discuss how one may best overcome this problem in three steps - First of all, the reader must understand the theoretical framework. Secondly, the reader must understand the data. Finally, the reader must understand how the results were obtained from the data. This is especially difficult concerning qualitative data where the analysis is often based on the understanding and knowledge of the researcher, with little or no aid from formal tools. A researcher makes a lot of decisions; what problems to study, what questions to ask, what to write down, what to interpret, and what to present to the reader. These decisions are difficult to convey to the reader. This research did not employ the aid of tools, such as computerised data-based text analysis, partly because interviews, unlike questionnaires, are difficult to codify. However, using semi-structured interviews centred on specific theoretical topics has made it somewhat easier. Also, four methods were utilised to circumvent these questions of reliability and increase the credibility of the case studies. Firstly, triangulation of sources between interviewees and written documents allow crosschecking of information. Secondly, the longitudinal aspect of the studies made persistent observations possible, increasing depth of studies and allowing repetitive questioning. Thirdly, the case studies in this thesis were undertaken by a team of two researchers working together. This meant that there is already an aspect of control in questioning and gathering, as well as in analysing the data. Finally, allowing the interviewees to read and comment on the case reports and final articles lessens the likelihood of inaccuracies.

Naturally, humility is in order when discussing research conduct and methods. Had the research project started now, more consideration would be given to the handling of the data. The choice not to use recording instruments, although it in the authors opinion did not affect the quality of the analysis, did make it more difficult to go back to previous interviews to search for answers when new topics came up. Better records should be kept of interviews, company reports, and other sources (such as newsprints) that were not quoted directly, but used to build an understanding of the selected cases and the process industry as a whole.

4.2.3. Obtaining quantitative data – Surveys

Surveys are typically used to collect standardised data from a large number of people. Two different surveys are present in this thesis. One was conducted as part of this research project – the “workshop survey” - and one was conducted as part of a previous research projects – the “industry survey” (the research project is described in full by Lager (2001)).
I: THE ‘WORKSHOP SURVEY’
In studying R&D in process industry it is important to understand the differences between this industry and other manufacturing industries. To meet this necessity, a survey was conducted among managers and experts on innovation in process industry. The survey consisted of two parts; one concerned with the critical management of technology issues in process industries [Based on a previous study and depicted in Paper VI: Critical management of technology issues in process industry], and one concerned with ways of measuring R&D performance in process industries [Resulting paper not appended to this thesis – Bergfors and Larsson (200Xb)].

Selection of respondents
The survey was carried out as an integrated part of a workshop for R&D managers from various sectors of Swedish process industry and academics specialising in innovation in process industry firms. The topic of the workshop was “Management of Innovation and Technology in Process Industry”, and it was held in Luleå, Sweden, on 16th May 2006. The workshop is an annual executive forum, by invitation only, for discussions on management of innovation and technology in process industry. The industry participants of the survey are a homogeneous group, as their firms and industry sectors are considered as part of process industry. In addition, the participants’ firms have annual turnovers ranging from approx. EUR 700 million and upwards, and have production plants and R&D units in more than one geographical location.

Data gathering and analysis
The questionnaires were handed out and completed in a secluded lecture hall where the respondents had access to two academic researchers who could assist when needed. The questionnaire is found in Appendix VI - Workshop Survey, and the raw data concerning the paper on critical management of technology issues are exhibited in Appendix VII - Data from workshop survey. Analysis in the case of management of technology issues consisted of ranking the responses and comparing these rankings with the original study on which the workshop survey was based.

Methodological reflections on the workshop survey
The central issue of any survey is the question of sample and sample size. An objection to this study could be that the sample is neither large nor wide enough to represent the process industry as a whole. However, the sample does cover a homogeneous group of process industries. The sample is therefore considered representative of larger firms within the Swedish process industry as a whole. Furthermore, the fact that the participants in the workshop are considered experts – i.e. with a solid understanding of the issues concerning innovation in the process industry – in part makes up for the small sample size in terms of quality of the answers. As the object was not to make a census of what managers in process industries think, but rather to enquire into what the critical issues may be, a small and well-informed group of respondents is preferable to a larger group that may not be as well informed. Also, the fact that the respondents had access to researchers for questions during
the survey added to the quality of the answers, as any ambiguities or misunderstandings in the questionnaire could be avoided.

As one of the objects of the survey was to map future research areas in innovation management on behalf of the research centre in which most firms at the workshop have a stake, it must be assumed that all respondents answered the questionnaire truthfully on the basis of their actual needs. Moreover, there is no part of the workshop survey that specifically deal with sensitive information issues or the performance of the R&D managers themselves. In summary, there are two main reasons why these results are considered reliable, given the low number of respondents - One, they are industry experts on R&D; Two, there is little reason to be untruthful.

Concerning the concerns of basing and comparing the survey of management of technology issues on a previous survey in high-tech manufacturing - these are further discussed in Paper VI: Critical management of technology issues in process industry.

II: THE ‘INDUSTRY SURVEY’

The industry survey is part of a previous research project within Promote focused on the development of process technology in process industry. In that previous project a survey was conducted among R&D managers in European Process Industry during 1999. It included a lengthy (8-page) questionnaire concerning various aspects of process development. At the time of that project the organisational design of innovation was not an issue. However, one question in the survey did touch on the subject of organisation:

- Will process development work in the company belong in the future to the organisation for R&D, or to Production?

The question of organisational affiliation was only a small part of the survey. Nevertheless, the specific research question about organisational affiliation could be studied in relation to many other variables in the survey.

Selection of respondents

The total questionnaire was pilot tested on three R&D managers before being distributed to 327 R&D managers in European process industry with a focus on Swedish process industries. Since the Swedish sample included nearly all process industries (can be regarded as a census), the discussions of statistical significance in that case is a non-issue.

Data gathering and analysis

The questionnaire was sent out to R&D managers in the companies concerned. All questionnaires were sent to a specific person who had been identified as the respondent. The Swedish part of the survey was carried out as follows: telephone contact for checking data and confirming participation; mailing questionnaire; fax reminders; telephone reminders; final fax reminder. The Nordic and European survey was carried out as follows: mailing the questionnaire; new mailing after new information (e.g. new contact person or new address); fax reminder; final fax reminder. The response rates are given in Table 4-1. Statistical independence was tested using a Pearson chi-squared test.
**Table 4-1: Response rates for industry survey.**

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Other Nordic countries</th>
<th>Other European countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number contacted beforehand</td>
<td>109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of mailings</td>
<td>99</td>
<td>80</td>
<td>148</td>
</tr>
<tr>
<td>Number of responses</td>
<td>79</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Response rate (%)</td>
<td>72</td>
<td>23</td>
<td>11</td>
</tr>
</tbody>
</table>

**Methodological reflections on the industry survey**

Relying on a single respondent to address an organisation-level question is always problematic. Researchers should seek the views of multiple organisation members to reduce the potential for common method variance. The other main critique of this survey is that the data is aging, having been carried out in 1999. However, the theoretical underpinnings and variables are not restricted by temporal issues. Therefore, it is likely that the results would have been the same had the survey been made more recently.

Concerning response rates – the main issue in ensuring that the results are valid is that the data must be representative of the entire population that is being assessed. The lack of guidelines in this area leads to a practice in most articles of justifying response rates with references to obscure articles or other articles in the same area with lower response rates. However, in this case it can be determined that they are high in the case of Sweden and low in the case of other Nordic and other European countries see (see Roth and Be Vier, 1998 for a discussion on response rates). Higher response rates are needed when the assessment's purpose is to measure effects or make generalizations to a larger population. However, high response rates are less important when the purpose is to gain insight. As this study attempts to statistically ascertain whether a select number of determinants affect organisational affiliation a higher response rate for the European sample would have been preferred. While fortunately, there seem to be no bias in the Swedish sample compared to the European sample (see Lager, 2001) a lesson can still be learnt from this: Advanced notification has been shown to significantly improve response rates. This is evident in this survey, and also pointed out in the meta-analysis by Roth and Be Vier (1998).

4.3. Methodological discussion

Being management-oriented in the way described in this thesis places certain limits on the category of questions being pursued and the way in which they are pursued. The focus will be on identifying problems in practice, and that practical usability of the results should be an important factor when the research is assessed. However, this means that the research is governed by specific interests (Alvesson and Deetz, 2000), which may limit the researcher as to critical reflection on other research goals and considerations, and potentially also limiting the research to a specific group. There are many ways of *slicing and dicing* the cake that is organisation studies and many interesting perspectives may be lost because of the management focus of this project. However, as the goal of the research
centre Promote is to further the development of industrial R&D in the process industry the practical focus is more or less mandated.

Research on organisational structure has historically focused heavily on cross-sectional studies to identify key determinants; both in the innovation field (Brown and Eisenhardt, 1995; Slappendel, 1996) and in the organisation theory field (Donaldson, 2001). Cross-sectional studies have many merits and give much insight into our understanding of organisations. On the other hand, there are also several not-so-grand reasons for this focus – ranging from ways of delimiting research scope (Slappendel, 1996) to career planning (Van de Ven, 2004). Qualitative studies entail significant investments in time and defer publication of study findings (Van de Ven, 2004). Of course, there are also some unflattering reasons for researchers to adhere to a qualitative approach – such as the complexity of the phenomena, difficulty in finding a relevant sample, having a too large sample, or difficulty in understanding and interpreting the results (usually an unfamiliarity with statistical methods) (Benbasat et al., 1987). For this research project, both a quantitative and a qualitative approach were chosen. It was planned as such on the onset for one major reason – so that the doctoral candidate would get acquainted with a diverse set of methodological tools.

As in most management research, the limits to data collection are set not by the researcher but by the realities of the organisational environment (Easterby-Smith et al., 2002) (Remenyi et al., 1998; Alvesson and Deetz, 2000). This reality is that few managers or organisations have the time or resources available to allow extensive research in their midst. This was a fact that became apparent in this research project. Finding firms that were willing to participate and grant access to the researchers proved more difficult than expected. Furthermore, finding time for long interviews was also difficult. While it can be argued that more interviewees could have been questioned in the case studies, the questions themselves were deemed to be of a kind that are not sensitive and open to personal interpretation.

This thesis presents three case studies, two surveys based on different samples, and one theoretical paper. A relevant question concerns how the results from these different studies can be generalised. There are however different aspects of generalising. One way is to consider the sample cases as representatives of a population. By that logic, firms in process industry that share the external characteristics of the studied organisations will readily generalise to the industry as a whole. However, while this type of statistical generalisation works for surveys, it is not the best way to deal with case-based studies (Yin, 2003, p.37). Case studies rely more on analytical generalisation, which argues that findings can be applied theoretically to organisations in similar contexts. The challenge is to find these contexts, or contingencies, within the cases.

On a final note on research methodology, extensive site visits and in-depth discussions with R&D managers and R&D employees were conducted with firms that are not listed as being part of the case studies, but which have also contributed to the understanding of industrial R&D in process industry firms. This deserves a mention as these meetings, may also have influenced the studies and the choice of research questions.
5. OVERVIEW OF APPENDED PAPERS

The papers in this thesis are presented in the order that they were written and chosen to represent the progress of the research project. The chapter aims at covering the background and rationale of the individual paper, including notes on practical and theoretical problems that the paper wishes to address. Methods, theories, and major contributions of the papers are also briefly commented on.

5.1. Paper I: Corporate structure and R&D organisations


Summary and background
The paper provides a good introduction and background to R&D organisational design, as it relates to the developments and dynamics of the process industry. The study sets out to explore organisational change that has taken place within three process industry firms in three different industrial sectors. The aim was to get a grasp of the major organisational issues facing modern process industry firms and a better understanding of how, why and when these firms change their R&D organisational structure. This was done by examining the major changes in the R&D organisation over a period of 10-20 years. The study laid the foundation for further research into the R&D context and the R&D organisational design in process industry undertaken in this research project. Furthermore, the initial case studies were meant as a precursor to the planned quantitative study and can therefore also be read with that condition in mind.

Practical problem
The process industry is becoming more dynamic as a result of greater customer focus, technological developments, increased cost competition, etc. The design of R&D organisations should reflect this change and strive to keep up with the new competitive environment. An important aspect of the paper was to explore the R&D organisation in order to find critical areas for industry-relevant future research activities within the research project.

Theoretical problem
The relation between corporate structure and R&D organisational structure is not well developed in theory. Contingency theory hypothesises that organisations change to achieve better ‘fit’ with their environment. The environment of the R&D organisation is the corporate structure. It is therefore interesting to study how R&D organisations react to changing corporate structures in an increasingly dynamic industry.
Theoretical framework
The paper is based on contingency theory, the premise being that contextual determinants affect structural variables which in turn affect performance. There is a long history within the field of organisation theory of studying structural variables for innovation – this paper draws mainly from the meta-analysis by Damanpour (1991).

Method
The paper is based on three case studies of Swedish-based process industry multinationals. Four organisational determinants and eleven structural variables were related to firm performance and critical changes in R&D organisational structure. These were explored in semi-structured interviews [see Appendix IV - Semi-structured interview guide].

Contribution
The paper illustrates how the three selected firms have changed the structure of their R&D organisation during the past few decades. The findings illustrate that while the industry is becoming more turbulent than ever, R&D organisations themselves have been fairly stable. Corporate mergers and restructuring have not affected the R&D organisations of these firms to any high degree and it was also found that major changes in the R&D organisation had not been brought about by the necessities of the R&D organisation itself, i.e. improving performance through better ‘fit’. Instead, the major changes were often the result of restructuring at the corporate level or changing conditions in the external environment. The study noted that as the logic for innovation differed between firms, so seemed the organisation structure, an idea that subsequently formed the foundation for further studies in organising intrafirm R&D organisations.

5.2. Paper II: Heads or tails in innovation strategy formulation?

A previous version was presented by the author of this thesis at The First International Conference/Workshop on Business, Technology and Competitive Intelligence in Tokyo, Japan, 25-26 October 2005.

Summary and background
The Porterian positioning approach and the Penrosian resource-based approach have differing views as to what firms should base competitive advantage on. While these views are often seen as opposing each other, they are in fact two sides of the same coin. In this paper a popular strategy formulations process based on the positioning approach, the Booz Allen and Hamilton methodology, presented in the 1980’s is analysed using both the resource based view and positioning approach. Two distinct strategy formulation methods emerge which are theorised to suit different organisational and environmental contexts. The paper contributed to the theoretical framework that influences much of the
subsequent studies in this thesis. Many of the ideas concerning the resource-based view and innovation sprang from the work on this paper.

**Practical problem**
The positioning approach to strategy has presented many working models over the years, while the resource-based approach has not. However, as increasing market complexity may make old models obsolete executives are often frustrated by the lack of prescriptive guidelines emerging from the resource-based view (Bowman and Collier, 2006). New and better models are needed; models that also incorporate the resource-based approach. Furthermore, practitioners need guidance as to which models they should adhere to under differing conditions.

**Theoretical problem**
Whether positions or resources best explain firm performance has been an ongoing debate within the domain of strategic management. The question is often put in a way as to ascertain which approach offers the best explanation to firm performance.

**Theoretical framework**
The Porterian approach to strategy states that firms compete on product markets where they must position themselves favourably against competitors. The Penrosian approach to strategy states that firms compete on the basis of the resources they control. However, there are suggestions that the two approaches complement each other. This paper focuses on exploring this complementary relationship.

**Method**
This is a purely theoretical paper. By revisiting the Booz Allen and Hamilton methodology for innovation strategy formulation in a step-by-step manner using resource-based logic, seven theoretical propositions are developed that differentiate the original methodology from the revisited methodology.

**Contribution**
The seven propositions developed in this paper in response to the resource-based approach point to there being two distinct models of strategy formulation processes. Four main contingencies that affect the choice of methodology are also suggested from positioning and resource-based theory: the “nature of the competitive environment”, the “impact of technological discontinuities”, the “characteristics or resources used”, and the “number of product markets served”. Depending on these contingencies it will make sense to organise the innovation strategy formulation process on the basis of either the original or the revisited methodology. In short, an organisation’s internal and external context determines which model should be used.
5.3. Paper III: A resource-based approach to the Booz Allen and Hamilton methodology


A previous version was presented by the author of this thesis at the Copenhagen Conference on Strategic Management in Copenhagen, Denmark, 15 December 2005.

Summary and background
This paper is a continuation of Paper II - Heads or tails in innovation strategy formulation? which also incorporates empirical case-study data. The two methodologies, the original Booz Allen Hamilton positioning-based and the revisited resource-based, are scrutinised in light of actual innovation strategy formulation activities in two different organisations. Findings suggest that the original methodology and the revisited methodology fit different industry contexts. Studying strategy formulation is interesting from an organisational design standpoint because it is an ongoing organisational process.

Practical problem
The formulation process forms the basis for decision-making concerning innovation options, and it is therefore critical that it is both effective and efficient. For this firms use tools or methods. Not much research is focused on the tools that are actually used by firms on a day-to-day basis. However, practitioners are as much in need of useful tools as ever.

Theoretical problem
Whether positions or resources best explain firm performance has been an ongoing debate within the domain of strategic management - Which approach offers the best explanation to firm performance? Under what conditions is the one better than the other?

Theoretical framework
The Porterian approach to strategy states that firms compete on product markets where they must position themselves against competitors. The Penrosian approach to strategy states that firms compete on the basis of the resources they control. However, there are suggestions that the two approaches complement each other. Eight propositions are presented that differentiate the resource-based approach from the positioning approach.

Method
Case study incorporating two Swedish-based multinationals in the process industry. Eight theoretical propositions, and two differing methodologies, were analysed against the case firms in a step-by-step manner. The two cases were selected on the basis that they are very different in the number of products they produce and the dynamics of the markets on which they compete.
Contribution
Through empirical investigation the four contingencies of the conceptual Paper II were condensed to three; the “level of diversification”, the “characteristics of industry boundaries, customers, and competitors”, and the “role and organisation of R&D”. Depending on these contingencies, firms can choose to adhere to either the positioning-based model or the resource-based model. Managers can use this as a checklist to see what they could do differently based on their specific context. From the perspective of the strategic management field this paper develops a tool based on the resource-based approach. This paper also implies that it is time to bury the hatchet and end the debate between positions and resources – at least concerning the notion that one is automatically better than the other. Or, as the paper suggests – it depends!

5.4. Paper IV: Opening up intrafirm R&D

Presented at the International Association of Management of Technology (IAMOT) Conference in Beijing, P. R. China, 22-26 May 2006.

Summary and background
The paper takes departure in the fact that much research that focus on innovation in general overlooks some of the nuances that exist between different types of innovations. In this study product and process innovation are thus seen as separate activities. By studying product and process innovation separately and in relation to their degree of centralisation it is shown that there are several possible organisational designs that a firm can adopt. The paper is based on the resource-based approach and in that aspect builds on the previous studies on innovation strategy formulation and organisational structures in process industry. The paper was grounded on the fact that centralisation and decentralisation issues are still a current topic amongst R&D managers.

Practical problem
R&D managers are still struggling with the question of centralisation versus decentralisation of innovation activities. Previous research and findings are at odds with each other while managers need sound advice on what factors should come into play in making the decision to centralise or decentralise.

Theoretical problem
The link between centralisation, decentralisation and innovation is disputed. One of the reasons for this is that previous research has failed to characterise innovation in an effective way. Usually, the definitions have been too broad. Particularly, the significance of the type of innovation, especially the distinction between product and process innovation, has largely been overlooked.
Theoretical framework
Innovation activities can be either centralised or decentralised. Resource-based logic is used in this study to model the choices between centralised R&D and decentralised R&D. The choices are contingent on three factors: strategic importance, width of applicability, and potential disruptiveness. Simplified; if innovation activities are strategically important, their output is widely applicable within the organisation, and the potential disruptiveness is high – then the innovation processes should be centralised.

Method
Three case studies of Swedish-based multinationals in the process industry. The model was compared against previous and current organisational designs at the individual firms, focusing especially on the rationale for the designs used.

Contribution
The findings of this paper demonstrate the importance of discriminating between product and process innovation when designing R&D organisations. To illustrate, a matrix - depicting nine possible organisational forms based on the relation between product and process innovation on one axis and the degree of centralisation on the other axis - is presented. The paper also provides three contingencies based on the resource-based view for making these choices. The matrix can be useful for managers and researchers, as it suggests which organisational form is more suitable for differing contexts. The paper also stresses the importance of organisations making active strategic choices concerning aspects of innovation as part of their organising activities.

5.5. Paper V: Innovation of process technology

Summary and background
Process innovation is important in process industry, and process industry firms spend a relatively larger amount of their R&D budgets on process innovation than firms in other manufacturing industries. Effectively organising process innovation activities is therefore a critical task for R&D managers in process industry. Unfortunately, academic research has focused predominantly on the organisation of product innovation. This paper centres on the organisation of process innovation activities within firms and relates the organisational affiliation of these activities, either in the R&D department or in the production department, with several organisational variables. The variables are “industry category”, “size of R&D organisation”, “process innovation intensity”, and “degree of newness of process innovations”. The paper is based on data from a previous industry survey that was revisited and mined for new contribution in organisational design.
Practical problem
R&D managers need sound advice on how to organise innovation activities. The choice of organising process innovation in the R&D department or within the production unit has both benefits and drawbacks. Managers therefore need advice on what organisational determinants should be factored into design decisions.

Theoretical problem
General determining factors of organisational design have been debated and tested, verified and disqualified. However, no studies exist which test these factors in relation to departmentalisation and process innovation.

Theoretical framework
Organisation design is often a question of departmentalisation. However, few studies have dealt with this issue, especially in R&D. This study draws on structural theories of organisation and innovation and relates those to innovation and the question of organisational affiliation. In this study industry category, size, R&D intensity, and degree of newness are all proposed to determine the choice of organisational affiliation.

Method
Based on an extensive survey conducted in 1999 for the research project “Success factors and new conceptual models for the development of process technology in process industry” (presented in full in Lager, 2001) [see also Chapter 4.2.3 - Obtaining quantitative data – Surveys]. Statistical analyses were made relating to four organisational variables (industry category, size of R&D, process innovation intensity, and newness of process innovation) to the question of organisational affiliation (R&D department versus production organisation). Independence was tested using a Pearson chi-squared test.

Contribution
The findings suggest that in organising process innovation, the newness of the process innovation is the deciding factor. The paper also raises some issues of pros and cons of organising process innovation in either production or R&D units. As such it is valuable for R&D managers who may wish to improve process innovation effectiveness or efficiency by organisational measures. The study also furthers theory on radical innovations by lending empirical support to previous theories that also propose that some organisational structures are more suitable than others for generating radical innovations.
5.6. Paper VI: Critical management of technology issues in process industry


Paper accepted at the First International conference of Industries and Mines R&D Centers in Teheran, Iran, 25-26 June 2007.

Summary and background
R&D in process industry is different from other manufacturing industries. R&D managers in process industry have differing priorities than R&D managers in other industries. This paper reports on a survey carried out with the aim to find out what the top-rated management issues for managing industrial R&D in process industry are. The survey and questionnaire itself is based on a previous study in high-tech manufacturing industry. The original survey was conducted by Scott (2000) and is further discussed in the paper. The differing results from the two surveys are discussed in the light of industry discrepancy.

Practical problem
R&D managers in process industry who wish to follow scientific advice on organising and managing innovation have to rely on findings based on other industries than their own. However, managers should not manage or organise their R&D organisations on the basis of advice meant for other industries and contexts. Different contexts encounter different problems and therefore also demand different solutions.

Theoretical problem
The context of process industry is under-researched, and previous findings that exist suggest that the process industry is in need of different research than other manufacturing industry, as theories concerning organisation and management of innovation do not necessarily transfer from one industry to the next.

Theoretical framework - Industrial context
Process industries were found to differ from other manufacturing industry on four sets of variables; Input materials and position in the value chain (e.g. raw materials versus intermediate goods), production process (e.g. continuous versus batch production), R&D interplay between product and process innovation (e.g. focus on process versus product development), and macro-level factors (e.g. level of dependence on political decisions).

Method
A survey conducted at the Promote annual workshop in 2006 [see Chapter 4.2.3 - Obtaining quantitative data – Surveys]. The questionnaire is based on previous studies on critical management issues in high-tech industry where critical issues were ranked according their importance [see Appendix VI - Workshop Survey].
Contribution
This paper contributes to the field of innovation management by presenting several areas and directions for future research concerning innovation in process industry. These areas are those that were deemed most important by a group of R&D experts representing process industry. The findings of the survey are also discussed in the light of the distinctive characteristics of process industry and other manufacturing industry. The paper is valuable as it discusses the effects of industry discrepancies in detail.
6. DISCUSSION

“Only two groups of people deny that organisation matter - economists and everybody else…” James Q. Wilson (1989, p.23)

It is not uncommon to hear people question the role that organisational structures play in a firm’s performance – often arguing that it is strategy that provides direction or that individuals do the actual work. This is a matter of perspective as all three parts must come together for a firm to function properly. Appreciating this, the findings of the research project “Designing R&D organisations in process industry” lend further support to the notion that organisation matter. More than anything, this thesis accentuates the importance of organisational context. It illustrates how external context in terms of industry specifics and internal context in terms of strategic choices can clarify some of the issues facing R&D managers in process industry.

The overall aim of this research project was to further the understanding of how intra-firm industrial R&D is organised in process industry. The thesis seeks to answer the question more pointedly – “How can intra-firm R&D be effectively organised in process industry?” Before we can arrive at that point however, we need to answer to research questions.

6.1. Answering the research questions

This research project attempts to answer three broad research questions; “What are the critical issues of organising R&D in the process industry? - How can innovation strategy formulation processes be organised? - How can intrafirm R&D organisational structures be organised? These questions are categorised under two headlines – Context of process industry, and Organising R&D in process industry. See Figure 6-1 on the following page.

6.1.1. Context of process industry

That process industries are different from other industries is acknowledged by R&D managers in the field. There is however some frustration at times with academia, policymakers, and even shareholders, who do not always seem to understand this distinctiveness. As one industry manager commented with dry humour on a discussion on outsourcing of production capabilities: “But you cannot relocate a mine”.

6 However, as illustrated by the shipping of the 275,000 ton ThyssenKrupp Dortmund steel mill to China (depicted by Kynge, 2006), the notion of process industry production plants as permanent fixtures may come to change.
- What are the critical issues of organising R&D in the process industry?

The significance of industry context, that R&D is somehow managed and organised differently in process industry than other manufacturing industry, is discussed in all articles of this thesis. It is one of the reasons why the Centre for Management in Innovation and Technology in Process industry was founded and in a way it forms a foundation for the entire research project.

As seen in Figure 6-1 two of the appended papers have dealt with the factor of industry context more directly: **Paper I: Corporate structure and R&D organisations** and **Paper VI: Critical management of technology issues in process industry**. While Paper I in more general terms tell the story of three evolving R&D organisations in process industry over recent decades, Paper VI specifically aims at setting R&D in process industry apart from R&D in other manufacturing industry.

Part of the research question above has already been answered in this thesis – a key contribution from Paper VI is the distinction between process industry and manufacturing industry presented in chapter 2, **PROCESS INDUSTRY**. As a background for the subsequent workshop survey several characteristic of process industry uniqueness are
presented. These characteristic are deal with Input materials and typical position in the value chain, Production process, R&D – the interplay between product and process development, and Macro-level factors. The second part of the answer comes through the rankings in the workshop survey and through comparing and discussing the discrepancies with these rankings and the rankings of the Scott Delphi study on which it the workshop survey was based. The findings of the workshop survey of industry experts, mainly R&D managers that are active in process industry, are displayed in Table 6-1.

Table 6-1: Comparing rankings of management of technology issues.

<table>
<thead>
<tr>
<th>Management of technology and innovation issue</th>
<th>Ranking in process industry</th>
<th>Ranking by Scott</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involvement of Manufacturing in New Product Development.</td>
<td>1</td>
<td>17</td>
<td>+16</td>
</tr>
<tr>
<td>Technology Core Competence.</td>
<td>2</td>
<td>4</td>
<td>+2</td>
</tr>
<tr>
<td>Soft Skills for Technical Personnel.</td>
<td>3</td>
<td>12</td>
<td>+9</td>
</tr>
<tr>
<td>Creating a Conducive Culture.</td>
<td>4</td>
<td>6</td>
<td>+2</td>
</tr>
<tr>
<td>Involvement of Marketing Groups.</td>
<td>5</td>
<td>9</td>
<td>+4</td>
</tr>
<tr>
<td>New Product Project Selection.</td>
<td>6</td>
<td>2</td>
<td>-4</td>
</tr>
<tr>
<td>Senior Managers’ Involvement in Technology.</td>
<td>6</td>
<td>11</td>
<td>+5</td>
</tr>
<tr>
<td>Customer/Supplier involvement.</td>
<td>8</td>
<td>10</td>
<td>-2</td>
</tr>
<tr>
<td>Coordination and Management of New Product Development Teams.</td>
<td>8</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>Productivity of Product Development Activities.</td>
<td>10</td>
<td>21</td>
<td>+11</td>
</tr>
<tr>
<td>Within-Company Technology Diffusion and Transfer.</td>
<td>11</td>
<td>15</td>
<td>+4</td>
</tr>
<tr>
<td>Organization Structure for R&amp;D.</td>
<td>12</td>
<td>13</td>
<td>+1</td>
</tr>
<tr>
<td>Strategic Planning for Technology Products.</td>
<td>12</td>
<td>1</td>
<td>-11</td>
</tr>
<tr>
<td>Project Continuance/Discontinuance.</td>
<td>14</td>
<td>23</td>
<td>+9</td>
</tr>
<tr>
<td>Establishing a “Technology Vision”.</td>
<td>15</td>
<td>20</td>
<td>+5</td>
</tr>
<tr>
<td>Organizational Learning About Technology.</td>
<td>16</td>
<td>3</td>
<td>-13</td>
</tr>
<tr>
<td>Rewarding and Educating Technical Personnel.</td>
<td>17</td>
<td>22</td>
<td>+5</td>
</tr>
<tr>
<td>Alliances/Partnerships Between Technology Companies.</td>
<td>18</td>
<td>14</td>
<td>-4</td>
</tr>
<tr>
<td>Cycle Time Reduction.</td>
<td>19</td>
<td>5</td>
<td>-14</td>
</tr>
<tr>
<td>Resource Allocations to High-Tech Activities.</td>
<td>20</td>
<td>19</td>
<td>-1</td>
</tr>
<tr>
<td>Oversight of High-Tech Activities.</td>
<td>20</td>
<td>24</td>
<td>+4</td>
</tr>
<tr>
<td>Using High-Tech for Competitive Advantage.</td>
<td>22</td>
<td>16</td>
<td>-6</td>
</tr>
<tr>
<td>Technology Trends and Paradigm Shifts.</td>
<td>23</td>
<td>8</td>
<td>-15</td>
</tr>
<tr>
<td>Globalization of Product Development Processes.</td>
<td>24</td>
<td>18</td>
<td>-6</td>
</tr>
</tbody>
</table>

The top-ranked issues in management of technology in process industry are briefly outlined below (See Paper VI for more detailed description of the issues):

1. **Involvement of manufacturing in new product development.** Issues concerning integration of manufacturing in product development.

2. **Technology core competence.** Issues involving identification and development of technology core competencies.

3. **Soft skills for technical personnel.** Improved “soft skills” among project leaders, technical managers and other technically trained new product development personnel, including such soft skills as negotiating, listening, communicating, coaching, and understanding people’s motivations for work and creativity. Issues having to do with creating a corporate culture.

4. **Creating a conducive culture.** Issues having to do with creating a corporate culture that promotes innovation.

5. **Involvement of marketing groups.** Issues related to the involvement of marketing, market research and customer service personnel in product development.
Because of the focus on differences between process and other manufacturing industry, the discussion in the paper pays special attention to those issues that have either risen or dropped in the ranking. The six issues that have changed most, by 10 or more positions, are marked in bold in Table 6-1. These are: Involvement of manufacturing in new product development, Productivity of product development activities, Strategic planning for technology products, Organisational learning about technology, Cycle time reduction, and Technology trends and paradigm shifts. These issues, and the possible reasons as to why there are discrepancies, are further discussed in Paper VI.

For an overview of the context of process industry and understanding of why there are differences in the way that R&D is managed and organised see Paper VI. However, one issue will be discussed here: Of the 24 critical issues surveyed in the study “Involvement of manufacturing in new product development” not only topped the ranking, but also exhibited the biggest shift – leaping up 16 positions. It serves as a good example of the importance that industry context plays in managing innovation and R&D organisations.

It is suggested that involvement of manufacturing in new product development is more important in process industry partly because product innovation, process innovation, and manufacturing are closely linked. In high-tech manufacturing, separating product development from these activities is less problematic. However, in process industry the integration between process and product development is necessary, as process technologies directly influence a product’s characteristics, and changing the product inevitably leads to changes in the production process. At the completion of development work, both products and processes may look completely different from what the firm had conceived from the outset (exemplified by Lim et al., 2006 in the biopharmaceutical sector). Another reason for involving manufacturing in new product development is because of the heavy capital investments that are required for process industry production. Together with a high degree of automation and high-tech production, it is difficult to make any major changes once the production process has been started. For these reasons, introducing new products or making ramp-ups in a continuous production process is difficult, so it is important to get everything right at production start-up. A further reason for involving manufacturing early on is far-reaching environmental legislation that stipulates how raw materials and residual products are to be handled. Hence, it has to be ensured that the new product is possible to produce without violating environmental laws and legislation.

In short, the answer to the research question concerning the context of process industry is: The critical issues of organising R&D in process industry, as judged by a select group of industry experts, are ranked and presented in Table 6-1. The top issues and the issues that have changed position the most between the two studies can be further discussed in light of several industry-context-dependent characteristics that affect how innovation is managed and organised in process industry. These concern input materials and the position in the value chain, production processes, the interplay between product and process innovation, and macro-level factors.
6.1.2. Organising R&D in process industry

It is frequently noted that R&D organisations are under increasing pressure to deliver results, often in face of an increasingly tighter cost focus. This has also become evident when talking to people involved in innovation within process industry. For example, one manager interviewed in preparation for the research project voiced his concern for the future as “we are constantly battling [with top management] to keep our R&D” while another simply stated that because of top-down mandated downsizing “our R&D organisation is anorectic”. In light of this reality for many R&D organisations, the issue of effectively organising innovation is more important than ever before.

- How can innovation strategy formulation processes be organised?

In designing innovation strategy formulation processes there are several aspects that must be taken into consideration. Evidence shows that there is a clear need for adopting an approach consistent with the corporate internal context and competitive environment. However, more than simply stating that ‘it all depends’, several aspects of the design choice are presented in Paper II: Heads or tails in innovation strategy formulation? and Paper III: A resource-based approach to the Booz Allen and Hamilton methodology.

The Booz Allen and Hamilton methodology, developed by Pappas (1984) and based on a positioning approach to strategy, is used as a starting point for studying the strategy formulation process. Analysing the methodology through the positioning and resource-based perspectives respectively offer two very different points of view. In short, the Porterian, or positioning-based, perspective on innovation strategy formulation focuses on factors external to the firm while the Penrosian, or resource-based, perspective focuses more on internal factors.

The conceptual paper, Paper II, illustrates in detail how the resource-based approach to strategy can transform the original Booz Allen and Hamilton methodology into a new process for innovation strategy formulation. The seven propositions that are developed in a step-by-step fashion result in a new rationale for actions in every step of the methodology. See Figure 6-2 and Figure 6-3 on the next page to compare the two models.
The conceptual Paper II also identifies from theory a number of contextual factors that would prompt a firm to choose either the original methodology or the revisited methodology. These are:

- **The nature of the competitive environment.** The original methodology is better suited in a stable competitive environment while the revisited methodology is more suitable in a turbulent and dynamic environment. This is because turbulent environments make it more difficult to monitor and scan the markets and the competitors. Resources are more stable.

- **The impact of technological discontinuities.** The original methodology, with its focus on the products and markets themselves, is better suited when there is a low risk of technological discontinuities. The revisited methodology, with its emphasis on technology and resources, is preferably used when firms wish to guard against new technologies from competitors.

- **The characteristics of resources used.** When there are fewer synergies in employing resources across markets, a firm may use the original methodology. On the other hand, a firm with internal resources useful in a wide variety of different product markets will be better equipped for handling this using the revisited methodology. This allows the firm to focus
on the core resources, and then apply them in different markets or in a variety of products.

- The number of product markets served. A firm present in just a few product markets can utilise the original methodology. However, firms who are present in many markets with a variety of products will have a harder time managing the portfolio. Instead, they can fare better with the revisited methodology. The theoretical arguments for adopting either the original or the revisited methodology suggest not that one methodology is better than the other, but that different internal and external contexts require different innovation strategy processes. Paper III describes how these conceptual ideas were applied in an industrial R&D organisational setting. Given the findings in the two case studies, however, the context model was somewhat altered; the four contextual factors were reduced to three. The contextual factors include:

- The level of diversification. A high level of diversification makes it difficult to support the original methodology. With a smaller number of products and customers it is manageable to focus on all of them during the innovation strategy formulation process.

- The characteristics of industry boundaries, customers, and competitors. Blurring industry boundaries, where customers turn into competitors and vice versa, makes it difficult to analyse the product markets. Here the revisited methodology can be more readily used. In stable environments, where boundaries, customers, competitors are easily identifiable the original methodology is better suited.

- The role and organisation of R&D. Where technology changes much more slowly than markets and product-lines emerge and disappear, the R&D organisation can be used as a wellspring of knowledge and resources. Having the necessary skills and resources when opportunities arise necessitates interaction between business and technology strategies. Here the revisited methodology is better suited. If product markets are slow to change, positioning of products is relatively more important and innovation strategy is aligned to business strategy as in the original methodology.

In conclusion, the two papers show that innovation strategy formulation processes can be organised according to two different methodologies, based on two theoretical approaches. Theory and empirical data suggest that for different contexts the one may be better suited than the other.

In short, the answer to the research question concerning the organisation of innovation strategy formulation is:

It has been shown that innovation strategy formulation can be organised according to either a positioning-based methodology or a resource-based methodology. One is not necessarily better than the other, but the choice between the two is dependent on both internal and external contexts such as the level of diversification, the characteristics of industry boundaries, customers and competitors, and the role and organisation of R&D.
- How can intrafirm R&D organisational structures be organised?

Three papers deal with the question of organisational structures; Paper I: Corporate structure and R&D organisations, Paper IV: Opening up intrafirm R&D, and Paper V: Innovation of process technology. Paper I explores the concept of contingency theory that states that organisations should change when there is a misfit between the organisation and the contingency factors. A retrospective case study covering three selected process industry firms describes earlier organisational changes in R&D. This gives insight to how both the process industry and the R&D organisations of process industry firms have changed. The study shows that large-scale organisational changes in R&D were fairly uncommon in the case firms, even in the light of several mergers and acquisitions by each of their respective corporate organisations. This observation is in line with the arguments made by Miller and Friesen (1980) that organisations evolve in a discontinuous manner, where long periods of stability are interrupted by brief periods of intense change. Furthermore, the study suggests that differing views on what the R&D organisation should do affected the way in which it is organised. These ideas were subsequently explored in subsequent studies.

First, Paper IV reports on a study product and process innovation through the looking-glass of centralisation. Then, Paper V goes on to focus on the organisational affiliation of process innovation.

Centralisation

Paper IV: Opening up intrafirm R&D deals with centralisation and decentralisation of product and process innovation. Unlike most previous studies of innovation this study examines the organisation of product and process innovation separately. Foremost, the cases studied show that firms may organise product and process innovation differently in terms of centralisation and decentralisation. In that sense the conventional notion of R&D organisational design, equating innovation and R&D more or less with product innovation, does not present a complete picture. This illustrates that innovation can function under dual structures, which is not apparent when R&D is considered more or less synonymous with product innovation. Figure 6-4 illustrates nine possible organisational forms that can be chosen for R&D in terms of centralised and decentralised product and process innovation.

Apart from just confirming that innovation can be organised in different ways the study also accentuates the importance of a firm’s demands on innovation. It does so by showing how these demands can be linked with the structure of the organisation. The resource-based view proposes that managers need to ask what kind of innovations the organisation is looking for in terms of product innovation and process innovation. Depending on the degree of strategic importance, width of applicability, and potential disruptiveness of R&D activities, managers can make different choices concerning the centralisation or decentralisation of product and process innovation – illustrated in Figure 6-5.
Factors influencing centralisation or decentralisation of R&D
- Strategic importance
- Width of applicability
- Potential disruptiveness

Centralised R&D
- R&D activities that are more important for creating or developing resources and capabilities
- R&D with a wide range of application across the firm
- R&D aiming at generating or guarding against disruptive technology

Decentralised R&D
- R&D activities that are less important for creating or developing resources and capabilities
- R&D with a narrow range of application within the division
- R&D aiming at generating incremental innovations

**Figure 6-4:** Possible organisational configurations for product and process innovation.

**Figure 6-5:** Model for centralisation or decentralisation of R&D according to the resource based view.

In short, theory suggests that R&D activities that are of strategic importance, have a wider applicability, or are aimed at radical or disruptive innovations should be centralised, while R&D activities that are less strategically important, have a narrower range of application, and are primarily aimed at incremental innovation should be decentralised. Illustrating this point was one manager who explained why process innovation should be decentralised to the production plants; “As [incremental] process improvements are done on existing machines – that is something every local plant know best how to do themselves”, while product innovation was centralised; “as we need to work with our customers on a strategic level”. In conclusion, the R&D organisation must be consistent with the expectations on innovation, i.e. there should be an internal ‘fit’ between strategy and structure.
Organisational affiliation

In Paper V: Innovation of process technology there is a tighter focus on process innovation. In most firms, responsibility for process innovation is generally assigned either to production or to the R&D department. By means of an industry survey in process industry Paper V studies four organisational determinants in order to ascertain whether they were related to the organisational affiliation of process innovation. For the determinants “industry category”, “size of R&D organisation”, and “intensity of process innovation” no statistical relation was found with the organisational affiliation of process innovation. The fourth determinant however, “neuiness of process innovation”, did show a statistical correlation with organisational affiliation of process innovation. This empirical evidence implies that if a firm pursues process innovations of higher newness (termed radical innovations), these will be organised within the R&D department. These survey findings were also confirmed in talks with R&D managers – one of which explained that tighter coordination in the R&D department is needed as “innovation activities in individual production units are not enough to bring about radical [process] innovations”. On the other hand, if a firm pursues process innovation with a lower level of newness (incremental innovations) these activities will be organised within the production organisation, and firms who pursue both radical and incremental innovations will have the propensity to organise these in R&D and production concurrently. The findings of the industry survey are depicted in Figure 6-6.

![Organisational belonging of process innovation](image)

**Figure 6-6:** The organisational affiliation of process innovation – findings from the industry survey.

The reason for why radical innovation is a key determinant in determining organisational design is because the R&D department and the production organisation have different goals and reward structures that support different types of activities. This notion has a long history within innovation and organisation theory originating with Burns and Stalker in 1961. For example, the R&D department is often more geared to focus on long-term goals and therefore has a propensity for more radical innovations, while the production organisation focuses more intently on incremental improvements for measurable benefits in the short term. Radicalness is a central theme within organisation theory and it is therefore satisfying to provide further empirical findings for this case.
Paper VI also focuses on discussing the pros and cons of organising process innovation either within the R&D department or the production organisation.

In short, the answer to the research question considering the organisation of intrafirm R&D organisational structures is:

The findings of this research project suggest that product and process innovation must be seen as two different activities in terms of their organisation. Furthermore, intrafirm R&D organisational structures can be organised in a several ways:

- Concerning the issue of centralisation versus decentralisation - findings suggest that “strategic importance”, “width of applicability”, and “potential disruptiveness” are factors that govern the choice between centralised or decentralised product and process innovation activities.
- Concerning the issue of organisational affiliation - findings suggest that the “degree of newness” is a factor that determines whether process innovation is assigned to R&D or production.

6.2. Conclusions

The purpose of this thesis is to explore the issue of “How can intra-firm R&D be effectively organised in process industry?” The six papers in this study have tackled this problem from different perspectives and in different ways – i.e. both in terms of theory and methods. Also, during the project, the very idea of innovation has evolved. The first case study, depicted in Paper I, saw innovation as a single concept. The subsequent case study, depicted in Paper III, and the workshop survey, depicted in Paper VI, considered technical innovation. Paper IV on the other hand considered the separation of product and process innovation – and realised that making such a distinction furthered the understanding of organisational design. Paper V goes the furthest as it specifically studies only process innovations.

While there are differences in approach, all the papers have one important characteristic in common – they all deal with the issue of context: The unique contexts of industry cause innovation in process industry to be different from other manufacturing industries. Innovation formulation processes are affected by both internal and external organisational factors. Furthermore, organisational structures are shaped by strategic factors and the type of innovations pursued. All these findings point to the importance of a thought-through R&D organisational design for conducting innovation activities within process industry firms. To borrow a concept from organisation theory – all the parts of the organisation must have a good ‘fit’. Chapter 7, IMPLICATIONS further discussed how managers can use these findings.
An underlying theme of most innovation research is that innovation is good. By that logic one may conclude that spending more on innovation is at all times better. Unfortunately, while most firms want more innovations – they have less and less to spend on making these innovations come about. Moreover, there are other ways to compete than always focusing the inventing the new. Many firms pride themselves in not being at the technological forefront but relying mainly on “proven technology”. Therefore, the importance of the intrafirm design choices should be highlighted - especially in times where cost-effectiveness is a primary organisational goal. Firms must first consider what they want out of their innovation activities, and then focus on increasing the effectiveness and efficiency of the organisation for that aim.

6.3. Reflections on the research project

A common critique of innovation management in general, that it is too focused on R&D, is presented by Radosevic (1991). He states that this narrow perspective overlooks a large amount of the innovative behaviour of organisations as “much of the innovative work at the firm level is not the result of the R&D function” (Radosevic, 1991). This is true at least concerning the research presented in this thesis; focusing especially on intrafirm R&D organisation ignores many of the firm’s other innovation activities. There are two other categories of sources for innovation: other innovation activities from within the firm, and innovation activities from outside of the firm. The issue of other intrafirm innovation activities not being counted as R&D is briefly discussed in Paper IV: Opening up intrafirm R&D, where it was exemplified by several process innovation activities being conducted within production units. For reference, Cooper (1988) states that apart from R&D the primary internal sources of R&D ideas came from sales, marketing and planning, production, other executives, and the board of directors. In discussing external sources of innovation it is a fact that many process industry firms conduct R&D outside of the intrafirm R&D organisational boundaries – even though most process industries do conduct less inter-firm R&D (joint research with external partners) relative to other manufacturing industries (as shown by Hagedoorn, 2002). However, this may be changing. Studies in pharmaceuticals have found not only that the number of inter-firm R&D partnerships increased, but also that the networks have evolved and changed over recent decades (Roijakkers and Hagedoorn, 2006). Reasons for this development are related to important industrial and technological changes in the 1980s and 1990s that have led to increased complexity of scientific and technological development, higher uncertainty surrounding R&D, increasing costs of R&D projects, and shortened innovation cycles that favour collaboration (Hagedoorn, 2002). Examples of external sources of R&D ideas are customers, contract research organisations, competitors, universities, and government agencies (see Cooper, 1988). In the light of these developments the notion of open innovation – where firms should focus on bringing in new knowledge from the outside and push their own innovations externally – has emerged (Chesbrough, 2003; Vanhaverbeke et al., 2006). Nevertheless, while the boundaries of R&D organisations are blurring managers are still struggling with their internal organisations. To understand and be able to develop
R&D one must understand the workings of the intrafirm R&D organisation. Also, this limitation is a deliberate choice by the researcher to reduce the complexity of the project.

While **Paper I: Corporate structure and R&D organisations** studied formalisation – defined as the emphasis on following rules and procedures – the relationship between informal versus formal organisational structures has not been addressed in this project. In practice however, innovations are often the fruits of informal relationships and processes not captured in this research project. One R&D manager interviewed for the project even warned that “the formal should not get in the way of the informal”. This is an important note. It should serve as a reminder to managers involved with organisational design that not everything can be controlled through formal organisational arrangements.

As this thesis warns against using research findings from other industries and other contexts too frivolously it is also necessary to put up a similar disclaimer here. The context studied here is intrafirm R&D organisations in process industry. Generalisations to other industries and different contexts concerning the results must be made with this in mind.
7. IMPLICATIONS

“For every design that displays a spark of genius or a truly new insight into social organisation, there are ten misguided efforts that reflect no more thought than a couple of sketches on napkins over lunch” (Nadler and Tushman, 1997)

The statement by Nadler and Tushman above is a provocative one. However, there is also much truth in it. Organisation change is often an ad hoc matter – often occurring as a result of events unfolding outside of the organisation. This is also the case for R&D. Major corporate changes such as mergers or new management that wishes to put their mark on the organisation are frequently the causes of organisational change in R&D – not necessarily performance issues. However, with so much information about, with so little time in which to act, and with so many variables to take into consideration, a huge load is placed on decision makers today. This thesis has focused on the decisions on which designs are based, and more than anything, this thesis accentuates the importance of context. Findings illustrate how context, in terms of industry specifics and strategic choices, can clarify some of the issues facing R&D managers in process industry.

7.1. Implications for industry

CONTEXT OF PROCESS INDUSTRY

The purpose of the study of process industry context was mainly to further academic research in the area of R&D organisation and innovation. The study indicated that the process industry is in need of somewhat different research than other sectors of the manufacturing industry. However, there are also some aspects of this study that managers can find helpful. The use of textbook solutions that are developed based on different industry logic and characteristics may have negative consequences for innovation in process industry.

“In the context of the value chain”, “production processes”, “R&D – the interplay between product and process development”, and “macro-level factors” all affect choices concerning managing and organising R&D. Understanding how these differences influence findings from other contexts may help managers assess the value of advice given.

ORGANISING R&D IN PROCESS INDUSTRY

The innovation strategy formulation process, the issue of centralisation versus decentralisation, and the organisational affiliation of process innovation are three areas where managers can be aided by this research.

Innovation strategy formulation

R&D managers concerned with innovation strategy formulation issues can use the findings of this study to evaluate their own organisations. For example, should they adhere to a positioning approach or a resource-based approach? While one manager interviewed commented that “looking too closely at the competition is dangerous” it is also a fact that market
and competitor understanding is becoming increasingly important as process industry firms try to become more customer-focused (as revealed by Chronéer, 2003). Another manager likened these new conditions to “working in a strategic draft” [translated from the Swedish: korsdrag] – simultaneously trying to balance product innovation strategies, process innovation strategies, marketing strategies, human resource strategies, and knowledge management strategies.

Whether a positioning-based or resource-based approach to innovation strategy formulation should be used is contingent on several factors. By analysing these contingencies together with the needs of the R&D organisation, managers can be helped to make better-informed decisions concerning the organisation of the innovation strategy formulation process. The important contingencies are “level of diversification”, “characteristics of industry boundaries, customers and competitors”, and the “role and organisation of R&D”. Figure 7-1 presents a guide to these contingencies.

<table>
<thead>
<tr>
<th>Contingency 1: Level of diversification</th>
<th>Contingency 2: Characteristics of industry boundaries, customers and competitors</th>
<th>Contingency 3: The role and organisation of R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resource-based approach</strong></td>
<td><strong>Positioning approach</strong></td>
<td></td>
</tr>
<tr>
<td><strong>External consistency:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product markets served</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industries served</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of customers served</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geographical area served</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many</td>
<td>Few</td>
<td></td>
</tr>
<tr>
<td><strong>Internal consistency:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relationship between diversification and tangible and intangible resources</td>
<td>Related (i.e. turbulent)</td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>Unrelated</td>
<td></td>
</tr>
<tr>
<td>Ambiguous (i.e. turbulent)</td>
<td>Unambiguous (i.e. stable)</td>
<td></td>
</tr>
<tr>
<td><strong>Continuity 2: Characteristics of industry boundaries, customers and competitors</strong></td>
<td><strong>Continuity 3: The role and organisation of R&amp;D</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Continuity 1: Level of diversification</strong></td>
<td><strong>Continuity 2: Characteristics of industry boundaries, customers and competitors</strong></td>
<td><strong>Continuity 3: The role and organisation of R&amp;D</strong></td>
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<td><strong>Continuity 1: Level of diversification</strong></td>
<td><strong>Continuity 2: Characteristics of industry boundaries, customers and competitors</strong></td>
<td><strong>Continuity 3: The role and organisation of R&amp;D</strong></td>
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<tr>
<td><strong>Continuity 1: Level of diversification</strong></td>
<td><strong>Continuity 2: Characteristics of industry boundaries, customers and competitors</strong></td>
<td><strong>Continuity 3: The role and organisation of R&amp;D</strong></td>
</tr>
</tbody>
</table>

Figure 7-1: Two approaches to innovation strategy formulation and a guide for when to use which (Larsson and Bergfors, 2006b).
Concerning the age-old question of centralisation versus decentralisation of innovation activities this thesis also provides some managerial contributions. First of all, R&D is more than product development and should be seen as also including process innovation. In the case study concerning centralisation versus decentralisation of product and process innovation it became apparent that process innovation has not always been seen as being part of the R&D organisation — even by R&D employees. This would suggest that both middle and top managers might not always take process innovation into consideration when organising R&D. This study can, by opening up the intrafirm R&D organisation, make managers more perceptive of the organisational demands of process innovation. As noted by the head of R&D at the Boliden smelter — “by losing the focus on process innovation you risk ending up with just another process engineer”. If not organised appropriately, process innovation may turn out to become little more than a solver of day-to-day operational problems.

While being careful not to make too far-reaching generalisations from a limited set of case firms, managers can use the matrix presented in Figure 7-2 to discuss and consider pros and cons for different configurations. A firm that wishes to generate more company-wide product innovations should centralise product innovation activities. A firm that wishes to promote more radical process innovations should according to theory have a more centralised organisation concerning process innovation, etc. Another way of using the results is predicting what kind of innovations will be produced given the structure of the existing intrafirm R&D organisation. It is not uncommon to hear managers complain that their R&D organisation does not generate enough breakthrough innovations. Using the findings presented in this study, managers can ask themselves whether the results they call for are in line with the way in which R&D is organised. Determining the strategic importance, width of applicability, and potential disruptiveness of the firm’s R&D activities and pairing this against the existing organisational structure is a first step towards understanding and managing R&D more effectively.

**Figure 7-2**: Possible organisational configurations for product and process innovation.
In conclusion, the R&D organisation must be consistent with the expectations of R&D, i.e. there should be an internal ‘fit’ between strategy and structure. By reflecting on the model for centralisation or decentralisation of R&D activities managers can be helped to open up their intrafirm R&D organisation and to manage R&D in a more effective manner.

**Organisational affiliation**

With regard to the organisational affiliation of process innovation, this thesis presents evidence that the degree of newness is a determinant for such organisational choices. Figure 7-3 presents these findings in a simplified matrix. R&D managers should ask themselves what type of innovations they wish the firm to pursue and then consider the pros and cons of assigning process innovation either to R&D or to Production.

![Figure 7-3: The organisational affiliation of process innovation.](image)

The pros and cons of the different organisational arrangements are fully explored in Paper V: Innovation of process technology. Here only a short summary is presented. The rationale for organising and managing radical process innovation within R&D department could be:

+ Economies of scale in research,
+ distance from everyday operations,
+ integration with product development,
+ increased strategic control,
+ longer time-frames, more risk acceptance,
+ better external relations,
+ and an organisation structure geared for innovation.

There are also some drawbacks to organising radical process innovation under R&D:

- Loss of production understanding,
- distance from actual problems,
difficulties in technology transfer,
and little learning by production.

The findings show that process industry firms who pursue incremental process innovations will predominantly organise these activities within the production organisation. There are several reasons for doing this:
+ Closeness to customers,
+ knowledge of the specific work environment,
+ increased accountability for budgets,
+ faster process innovation cycles,
+ improved technology transfers,
+ straightforward communications,
+ and an organisational structure geared towards solving specific tasks.

There are also some drawbacks to organising incremental process innovation in production—most notably being:
- Duplication of research,
- a focus on “safe” projects,
- and a loss of strategic direction.

There were a substantial percentage (12.9 percent) of the R&D managers partaking in the survey who predicted that process innovation would in the future be organised in both the R&D department and production. A reason for doing this is the possibility of having the “best of two worlds” and it is generally achieved by setting up cross-functional teams. However, a high degree of integration and coordination is necessary for this to function smoothly.

7.2. Implications for academia and further research ideas

CONTEXT OF PROCESS INDUSTRY

The workshop survey presented in Paper VI: Critical management of technology issues in process industry is very straightforward in its contribution, as it identifies and presents critical technology management issues that technology professionals believe are top concerns in process industry corporations and need to be addressed in the academic literature. The five most important issues derived in this study on the process industry are as follows;
1. Involvement of manufacturing in new product development
2. Technology core competence
3. Soft skills for technical personnel
4. Creating a conducive culture
5. Involvement of marketing groups

While many of these thematic areas are currently being researched, they are at present lacking a process industry perspective. Hence, industry context matters when it comes to establishing fruitful directions for further research.
Another objective of this study was to establish whether the ranking of research topics differs between high-tech manufacturing industry (ranked in the original survey on which the workshop survey is based) and process industry. On the one hand, process industry participants rank Involvement of manufacturing in new product development (up 16 places) and Productivity of product development activities (up 11) much higher in importance than do the high-tech participants in Scott’s original study of high-tech industries. On the other hand, Strategic planning for technology products (down 11 places), Organisational learning about technology (down 13), Cycle time reduction (down 14), and Technology trends and paradigm shifts (down 15) are ranked much lower by process industry participants than by the high-tech participants in the Scott studies. Much of this discrepancy seems to be explained by industry context factors, such as the level of intertwining of product and process development, the rate of technology development, and differing product life-cycles. This suggests that there is much more to be done in the area of exploring industry contexts.

A path for future research may be to delve deeper into the question of different industry sectoral contexts within process industry itself. Dennis and Meredith (2002) have managed to identify seven different subtypes of process industries based on their transformation systems, organised by how products are made (the diversity of materials, the movement of these materials, the equipment used, and the run time), not by specific product characteristics. These subtypes were grouped into three generic types of process industries: (1) Intermittent (fast batch, process job shop, and custom blending), (2) Continuous (multistage continuous and rigid continuous), and (3) Hybrid (stock hybrid and custom hybrid). The reason for categorising production processes into different types is because different process industry transformation systems will require different types of production control systems, different enhancement approaches, etc. (Dennis and Meredith, 2000) or, in other words, different organisational structures and processes.

ORGANISING R&D IN PROCESS INDUSTRY
Organisational affiliation
Not much research had focused on tools that firms actually use on a day-to-day basis. Tools have become the domain of management consultants. However, studying these tools is one way of getting closer to what firms actually do. As practitioners are in need of management tools and techniques that can help them structure problems and aid in decision making, Paper II: Heads or tails in innovation strategy formulation? and Paper III: A resource-based approach to the Booz Allen and Hamilton methodology show that a resource-based approach to innovation strategy formulation can be useful in an appropriate setting. The revisited Booz Allen and Hamilton methodology shows that while firmly grounded in the resource-based approach, corporations will still benefit in explicitly taking into consideration the competitive environment. Evidence from the case study suggests that when a corporation’s competitive environment becomes too complex to predict and the product markets become too many to survey, it would seem logical to retreat into the world of resources. This is one step in overcoming the antagonism between a positioning approach and a resource-based approach. Further replications of this study, either with a case-based approach or with
quantitative survey approach, will hopefully strengthen these findings or also provide additional contingencies on which to base the two methodologies.

**Centralisation**
Foremost, the case studies on centralisation depicted in **Paper IV: Opening up intrafirm R&D** show that firms may organise product and process innovation differently in terms of centralisation and decentralisation. In that sense the conventional notion of R&D organisational design, equating R&D more or less with product innovation, does not present a complete picture. This illustrates that R&D can function under dual structures, which is not apparent when R&D is considered more or less synonymous with product innovation. This study therefore advances the notion of the importance of middle-range theories of innovation – in this case that of type of innovation (product and process innovation) and that of radicalness of innovation. Thus, it can be argued that in order to further improve the model, and making it more fine-grained, the concept of stage of innovation could also be integrated. However, the reality of R&D activities in process industry is that projects shift between different product innovation and process innovation phases many times during the development process. So, while at the project level there may be a need for altering team/project structures as projects unfold, the overarching R&D organisation will be hard-pressed to deal with this complexity at a structural level. Nevertheless, questioning the simplicity of the model raises issues such as timing of project handovers, integration matters, formal versus informal organisations, departmental affiliation, etc. These issues can be addressed in future studies, for example by studying organisation at the project level.

**Innovation strategy formulation**
Concerning the organisation of process innovation **Paper V: Innovation of process technology** lends further credibility to the idea that innovation radicalness does affect organisation structure. It was found that the degree of newness determines organisational affiliation in process industry. Future research in this domain should also venture into the work processes that bring these innovations to the firm. Process innovation projects can be extremely long and it may also take a long time before a radical innovation project will provide financial returns. Understanding how these projects should be organised effectively and efficiently in process industry firms is therefore an important area for study.

While this research project attempts to distinguish process innovation from product innovation it does not make any distinction between different forms of process innovation. A literature review carried out by Barnett and Clark (1996) identified four central dimensions of technological change in the process industry: (1) *chemistry newness* – in process industry it is often the molecular or micro structure that is changed to create new material characteristics; (2) *production equipment newness* – new equipment is often required to be designed and installed; (3) *fabrication newness* – fabrication technology may have to be modified to fit the new equipment and materials; and (4) *process control newness* – new test procedures may have to be implemented, etc. Barnett and Clark argue that for all product development projects, new knowledge and capability must be developed in one or more of the areas mentioned above to enable desired improvements in product characteristics.
(Barnett and Clark, 1996). Innovation in either of these dimensions may be either radical or incremental. Further studies of process innovation may wish to further distinguish innovation along the dimensions described above as this may yield even more exact models for organising and managing innovation in process industry.

Two final notes on innovation research in general: Process innovation is very much lacking in contemporary innovation, organisation, and strategy management research. More research is definitely needed, especially as industry dynamics turn process innovations and process innovation capabilities into competitive advantages. Also, more research in organisational design at the functional and departmental level is needed simply because R&D managers ask for it. This is especially true for all aspects involving organisational performance. While the concept of performance is implicit in all organisation design there R&D managers experience difficulties when trying to measure it appropriately. Or in the words of an informant: "While we are constantly pursuing tonnes per employee out in the production plants we are ignoring efficiency issues as it relates to the rest of the corporation."
8. References


Mason, E. S. (1939). Price and production policies of large-scale enterprise, *American Economic Review*, 39, 1,


81


85


Appendix I. CASE COMPANY DESCRIPTIONS

Arla Foods
Arla Foods is Europe’s largest dairy corporation, producing and marketing branded products to end customers and supplying milked-based ingredients to industrial food producers. It has approximately 18,000 employees and an annual turnover of €5.1 billion, with 63 production plants in six countries and sales offices in 22 countries. Arla Foods uses dual strategies; focusing on both branded products, to end customers, and low-cost production, as a supplier to industrial food producers. Hence, the corporation uses differentiation as a basis for generating growth. Arla Foods conducts the major part of its R&D at three Innovation Centres and has an R&D intensity of 0.5–0.6%. Each Innovation Centre represents a specific product area and is also responsible for a number of competence areas. Altogether, the three Innovation Centres develop more than 200 new products each year.

Figure A I - 1: Schematic depiction of corporate R&D structure in Arla Foods.
**New Boliden**

New Boliden [in text referred to as Boliden] is a mining and mineral corporation focusing on mining and smelting as well as recycling of zinc, copper, gold, lead and silver. It is the fifth largest corporation in the world measured in smelting volume of zinc, and sixth in mining. Boliden has about 4,500 employees with an annual turnover of €2.0 billion and an R&D intensity of 0.9%. It has six mines in Sweden and one in Ireland; five smelting plants located in Sweden, Norway and Finland; and sales offices in three countries. The corporation focuses on overall cost leadership in mineral extraction and metal production. Eighty-five percent of Boliden’s total costs are fixed costs due to technology investments. The metals and minerals are most often sold as commodity products. The corporation therefore demands flexibility in production to help deal with the volatility of mineral and metal prices.

Boliden conducts R&D close to operating production plants. Boliden does not perform much basic research internally; it focuses primarily on development issues. Each smelting plant has its own R&D unit, whereas the mines run a central R&D department. Profitability, legislation and environmental issues are important drivers for innovation and technology. The main objective of R&D is to ensure that low-cost status is retained. Boliden does not conduct any product innovation at all, but concentrates the R&D budget on process innovation. R&D is therefore closely linked to the production process in each production plant.

*Figure A I - 2 : Schematic depiction of corporate R&D structure in Boliden.*
Billerud

Billerud is a pulp and paper corporation focusing on the production and marketing of high-quality packaging paper. It has about 2,600 employees and an annual turnover of €0.9 billion, with its own production plants in Sweden and the UK and sales offices in eleven countries. It has three paper mills in Sweden and one in the UK. Billerud is a niche player in a large and diverse industry, focusing on four areas: technical kraft paper, sack kraft paper, containerboard and market pulp.

Billerud conducts R&D at each paper mill and has an R&D intensity of 0.7%. However, the R&D unit at each mill has the overall responsibility for core areas of expertise vital to the corporation as a whole. This is to help capitalise on economies of scale in R&D even though each R&D unit is closely connected to the operations in its own paper mill. R&D is mainly linked to product innovation, and collaboration with customers and equipment and machinery suppliers is common. The main focus of R&D is to enhance product quality and to generate substantially new products, 3-5 each year.

Figure A I - 3: Schematic depiction of corporate R&D structure in Billerud.
## Appendix II. CASE INTERVIEW COMPILATION

<table>
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<tr>
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<th>Informant</th>
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<th>Year of birth</th>
<th>Function</th>
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Appendix III. PARTIAL LIST OF NON-REFERENCED CASE STUDY SOURCES

Arla Foods
MD Foods Annual Report 1999
Arla Foods, Innovation Centre Stockholm – R&D
Plan Process Teknologiprojekt ICS, Arla Foods
Nordic Innovation, Internal presentation material.
ICS Focusområden, Internal documents.
Experience from the Arla merger, Finn Bitsch, Executive Director, Conference – Milk, forward together, 12 February 2003, Conference presentation.

Billerud
Billerud Today, No.2, 2005
Billerud Environmental report 2003, March 10, 2004
Billerud, Annual Report 2001 | 2002 | 2003 | 2004 | 2005
Billerud, financial statement, January-December 2004
Billerud, Corporate Presentation 2005
Welcome to Karlsborg, Billerud informational material.
AGM 2004, Stockholm 5 May, Bert Östlund, CEO, Public presentation material
A Strategic Research Agenda for Innovation, Competitiveness and Quality of Life, European Forest Based Sector 2006.

Boliden
New Boliden Annual Report 2000 | 2001 | 2002 | 2003 | 2004 | 2005
New Boliden Interim Report, January-June 2004
Outokumpu Annual Report 2000 | 2001 | 2002 | 2003
Market analysis, Jan Johansson, President and CEO, Presentation material.
Exploration – the true R&D of Mining, Svante Nilsson, President Mining Operation, Presentation material.
Business model & strategic direction – BA Marketing and Sales, Lars-Göran Björkqvist, President Marketing and Sales, Presentation material.
Strategic direction – BA smelting operation, Jukka Järvinen, president smelting operation, Presentation material.
Integration & Synergies, Tom Niemi, deputy CEO, Presentation material.
Strategic direction, Jan Johansson, President and CEO, Presentation material.
Nya Boliden skapas, 8 September 2003, Internal presentation material.
Appendix IV. SEMI-STRUCTURED INTERVIEW GUIDE

[In Swedish – as respondents were all Swedish]
[With compressed space between questions to reduce number of pages in appendix]

Paper I
Corporate structures and R&D organisations
- Three retrospective case studies in the Nordic process industries

1. Antal människor verksamma inom FoU? 
(Hur har detta antal förändrats?)

2. Antal länder/platser där det finns FoU? 
A (Var finns FoU-centra?)

B (Har det blivit fler eller färre FoU-centran?)

3. Produkt- vs. Processutveckling? 
(Har fokus skiftat från det ena till det andra?)

4. FoU intensitet? 
(Har investeringar i FoU minskat eller ökat relativt den totala omsättningen?)

5. Grad av specialisering? 
A (Har antalet specialiserade arbetsuppgifter inom organisationen ökat/minskat?)

B (Har FoU-centran blivit mer specialiserade? Tex paper/boards osv)

6. Funktionell differentierung? 
(Har organisationen delats upp i fler eller färre funktioner/enheter?)

7. Formalisering? (Formalization)
<table>
<thead>
<tr>
<th>(Har det kommit mer/mindre regler/manualer/arbetsbeskrivningar etc?)</th>
</tr>
</thead>
</table>

8. Professionalism?
(Har medarbetare blivit bättre utbildade? En större andel doktorer/ingenjörer etc?)

9. Centralisering vs. Decentralisering av FoU?
A (Vem fattar FoU besluten; Vad som ska forskas på etc?)

B (Vem är beställare?)

10. Resursutrymme? (Slack resources)
(Finns det utrymme att forska/göra saker utanför det "absolut nödvändiga")?

11. Grad av extern samverkan?
A (Hur mycket samverkar FoU organisationen med externa organisationer?)

B (Samverkan med kunder?)

C (Samverkan med leverantörer?)

12. Grad av internationell samverkan?
(Hur mycket av FoU sker i samverkan med aktörer utanför Sverige/Danmark/England?)

13. Grad av intern samverkan? (Integration)
A (Var sker FoU? I produktion eller med marknad?)

B (Hur mycket kommunicerar det mellan avdelningar inom Arla?)

C (Spridning av kunskap mellan FoU och produktionsställen?)
D (Spridning av kunskap mellan produktionsställen?)

14. Vertikal differentiering? (Vertical differentiation)
(Hur många hierarkiska nivåer finns det inom organisationen?)

15. Innovativeness?
A (Hur bra är organisationen på FoU?)
B (Ta fram nya idéer?)
C (Lyckade projekt? Ta fram nya produkter/processer etc?)

Paper II
The locus of design
- R&D organisational design in the process industry

Vem bestämmer hur FoU organisationen är designad ”ser ut”?
A (Kommer besluten utifrån eller inifrån FoU organisationen?)
B (Vilka variabler/faktorer bestäms på ”fel” nivå?)

1. Antal människor verksamma inom FoU?
(Hur har detta antal förändrats?)
2. Antal länder/platser där det finns FoU?
A (Var finns FoU-centra?)
B (Har det blivit fler eller färre FoU-centran?)

3. Produkt- vs. Processutveckling?
(Har fokus skiftat från det ena till det andra?)

4. FoU intensitet?
(Har investeringar i FoU minskat eller ökat relativt den totala omsättningen?)
5. **Grad av specialisering?**
   A (Har antalet specialiserade arbetsuppgifter inom organisationen ökat/minskat?)
   B (Har FoU-centrana blivit mer specialiserade? Tex ost/mjölk osv)

6. **Funktionell differentiering?**
   (Har organisationen delats upp i fler eller färre funktioner/enheter?)

7. **Formaliserings? (Formalisation)**
   (Har det kommit mer/mindre regler/manualer/arbetsbeskrivningar etc?)

8. **Professionalism?**
   (Har medarbetare blivit bättre utbildade? En större andel doktorer/ingenjörer etc?)

9. **Centralisering vs. Decentralisering av FoU?**
   A (Vem fattar FoU besluten; Vad som ska forskas på etc?)
   B (Vem är beställare?)

10. **Resursutrymme? (Slack resources)**
    (Finns det utrymme att forska/göra saker utanför det "absolut nödvändiga")

11. **Grad av extern samverkan?**
    A (Hur mycket samverkar FoU organisationen med externa organisationer?)
    B (Samverkan med kunder?)
    C (Samverkan med leverantörer?)

12. **Grad av internationell samverkan?**
    (Hur mycket av FoU sker i samverkan med aktörer utanför Sverige/Danmark/England?)

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    A (Var sker FoU? I produktion eller med marknad?)
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    C (Spridning av kunskap mellan FoU och produktionsställen?)
    D (Spridning av kunskap mellan produktionsställen?)

14. **Vertikal differentiering? (Vertical differentiation)**
    (Hur många hierarkiska nivåer finns det inom organisationen?)
Appendix V. CENTRALISATION INTERVIEW GUIDE

[Compressed in appendix]

1. How is R&D organised?

<table>
<thead>
<tr>
<th>Corporate labs</th>
<th>[What do they do?]</th>
<th>[How many?]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>%</td>
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<tr>
<td>Process</td>
<td>%</td>
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</table>

<table>
<thead>
<tr>
<th>Divisional labs</th>
<th>[What do they do?]</th>
<th>[How many?]</th>
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<tbody>
<tr>
<td>Product</td>
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<tr>
<td>Process</td>
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</table>

2. How is R&D controlled?

Product

Process

3. Who makes R&D strategy?

Product

Process

4. Where are R&D projects initiated?

Product

Process

5. Where are R&D projects approved?

Product

Process
<p>| | |</p>
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<tbody>
<tr>
<td>6.</td>
<td>Where are R&amp;D projects funded?</td>
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<tr>
<td>Product</td>
<td>Process</td>
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<tr>
<td>7.</td>
<td>Is R&amp;D concentrated or dispersed?</td>
</tr>
<tr>
<td>Product</td>
<td>Process</td>
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<tr>
<td>8.</td>
<td>How has control over R&amp;D changed? 80s, 90s, 00s?</td>
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<tr>
<td>Product</td>
<td>Process</td>
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<td>9.</td>
<td>How many members are involved in decision making?</td>
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<tr>
<td>Product</td>
<td>Process</td>
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<tr>
<td>10.</td>
<td>Are “non-R&amp;D” members involved in decision making?</td>
</tr>
<tr>
<td>Product</td>
<td>Process</td>
</tr>
<tr>
<td>11.</td>
<td>How many levels are involved?</td>
</tr>
<tr>
<td>Product</td>
<td>Process</td>
</tr>
<tr>
<td>12.</td>
<td>Decisions on R&amp;D collaboration?</td>
</tr>
<tr>
<td>Product</td>
<td>Process</td>
</tr>
</tbody>
</table>
13. **Communication between units** (direct / through corp)

Product: 

Process: 

98. **Control questions:**
- Promotion of staff
- Creating new jobs
- Altering job descriptions
- Salary of staff
- Suppliers of materials
- Buying procedures
- Training of staff
- Collaboration
- Spending (capital items and other)
- Creating new departments
- Appointment of supervisory staff from outside the department

99. **Control questions**
- Centralisation dependent on…
- Radical
- Incremental
- Administrative
- Technical
- Initiation
- Implementation
Appendix VI. WORKSHOP SURVEY

Part I: General

Name: ________________________________

Organisation: __________________________

Profession: Academia  R&D Specialist  R&D Manager  General Manager

TYPES OF ORGANISATIONS:
Choose the type that best describes your corporate and R&D organisation

1. Organisation by Scientific Discipline or Technical Area

2. Organisation by Product Line

3. Organisation by Type of Activity

4. Organisation by Project

5. Matrix Organisation
Part II: Management of Technology

24 MOT ISSUES
Rate each issue from 1 to 10, with 10 being “most important”.

Issues surrounding new product development, team structure, team size, membership/composition of teams, team operations, team leader selection, need to train teams in teamwork and conflict resolution, team management, inter- and intra-team co-ordination, team control and evaluation, team reward structures, team motivation, team member access to project data bases, and types of structures for communications systems needed by teams.

1 2 3 4 5 6 7 8 9 10

2. Rewarding and Educating Technical Personnel.
Issues associated with educating, recruiting, rewarding, and retaining technology personnel who are involved in new product development (such as scientists and engineers); e.g. the need to develop more extensive rewards for good performance, encourage more persons to continuously improve their scientific/technical education, and the need for some management education and project management education for these personnel.

1 2 3 4 5 6 7 8 9 10

Issues associated with “globalisation” of high-tech product development processes, such as integration of R&D and development team activities across multiple country locations, the impact of different cultures, and dealing with the effects of protectionism and trade barriers on the transnational transfer of technology.

1 2 3 4 5 6 7 8 9 10

4. Organisational Learning About Technology.
Issues related to organisational learning and institutional memory about new technology and new product development, including how to conduct training, how to provide updating educational opportunities for technical personnel, how to accelerate organisational learning, how to accumulate and preserve organisational learning, how to systemise and maximise core competence and core technology learning that is based on experience rather than education and training, how to measure the level of core technology knowledge and increases/decreases of this level, and how to develop education and training programs for special needs such as for design for manufacture.

1 2 3 4 5 6 7 8 9 10

5. Technology Trends and Paradigm Shifts.
Issues pertaining to detecting and evaluating technology trends and paradigm shifts and convincing the company that these shifts require dramatic repositioning of the company’s technology posture, as well as to the acceptance in the marketplace of particular technologies and the future need for new kinds of products that customers do not yet say they need, e.g. the nature and structure of technology scanning and intelligence systems for early warnings, technology forecasting, and analysis methodologies to demonstrate eventual impact on the company of a paradigm shift.

1 2 3 4 5 6 7 8 9 10

6. Involvement of Manufacturing in New Product Development.
Issues about the involvement of manufacturing groups in new product development, e.g. inflexibility of advanced manufacturing systems (such as CIM), manufacturing as a bottleneck in new product development and introduction, preoccupation of manufacturing managers with their own operations which reduces the extent and effectiveness of their involvement in new product development, how to integrate these groups with the product development team, and how to foster innovative manufacturing processes.

1 2 3 4 5 6 7 8 9 10
7. Oversight of High-Tech Activities.
Issues associated with oversight of technology visions, strategies, project selection approaches, and processes and operations, such as via technology management executives committees, technology strategic audits, and corporate boards of directors.

8. Technology Core Competence.
Issues involving identification and development of technology core competencies.

Issues about the need for improved “soft skills” among project leaders, technical managers and other technically trained new product development personnel, including such soft skills as negotiating, listening, communicating, coaching, and understanding people’s motivations for work and creativity.

10. Within-Company Technology Diffusion and Transfer.
Issues involving programmes and policies to assist technology diffusion and transfer to both other technology areas (such as to manufacturing) and non-technology areas within a company.

Issues associated with defining the role of using high-tech new product development as a basis for gaining competitive advantage, e.g. establishing an explicit understanding of competitive advantage concepts among new product developers, how companies can focus new product development on competitive advantage, ways to create competitive advantage with high-tech products (such as for entry barriers), and the value of using a high rate of R&D as a strategy to discourage possible new entrants to the industry.

Issues associated with continuance vs. discontinuance of each project, involving such considerations as the uncertainty of results, management’s commitment, and funding cutbacks which may cause cancellation or cause motivation, personnel assignment and other problems at the project level.

13. Strategic Planning for Technology Products.
Issues associated with strategic and long-range planning for technology and product development, such as aligning high-tech strategies with business strategies (or vice-versa if the technology strategy should be dominant), new product introduction strategies, strategic decision-making processes, lack of understanding of technology and its roles among corporate strategic planners, lack of coherent corporate-level planning for high-tech management, failure to identify the critical success factors of a company’s technology activities, and establishing the corporation's technology climate.

Issues involved with high-tech new product development project selection, e.g. the criteria (costs/benefits, strategic necessity, etc.), how to establish a systematic approach to selection, inability of conventional financial analysis criteria to evaluate the potential of radical new technology, etc.
15. Involvement of Marketing Groups.
Issues about the involvement of marketing, market research and customer service personnel in new product
development, such as their participation in selecting research and product development projects, identifying
customer needs, defining the market timing in the introduction of new higher-tech products that will make the
company’s existing products obsolete, establishing the high-tech product family mix, and accelerating feedback
from the marketplace about customer satisfaction with the newest high-tech products.

Issues surrounding corporate senior managers’ interaction with high-tech product development, such as a need
for senior management to understand their company’s technology, a need for their long-term commitment, a
need for champions and sponsors for technology projects and embryonic products and product lines, and the
need for senior managers to take the lead in creating the corporate culture needed.

17. Establishing a “Technology Vision”.
Issues concerning the need for senior technology managers and senior corporate managers to create a “technology
vision” and communicate and “sell” this fully to the technology groups as well as to the other parts of the
company.

Issues about accelerating new product development cycles (cycle time reduction), e.g. limitations of cycle speed
benchmarks, making concurrent engineering work, the virtue of using cycle speed to permit a later start on
product development (in order to capture the most current technologies and customer needs) rather than to
introduce new products sooner.

Issues related to within-company resource allocations to high-tech product development, e.g. the overall process
for budget allocations, how different projects are prioritised, “patient capital” concerns, competing with the
information technology activities for funds, unsophisticated allocation of methodologies, and allocations among
new product projects.

20. Alliances/Partnerships Between Technology Companies.
Issues associated with choosing to participate in and managing the relationships of alliances, consortia sharing or
joint development of technology, or of external partnerships (including transnational), or issues involving
outsourcing technology development activities.

Issues involving productivity and productivity measurement of high-tech new product development activities,
e.g. success rates of new product introductions, measurement system shortcomings, and methods for improving
productivity of pure and applied research activities.
22. Creating a Conducive Culture.
Issues having to do with creating a corporate culture conducive to high-tech new product development, e.g.
establishing an internal sharing and informal networking culture, reducing within-company rivalries, gaining full
co-operation of all groups in the company, giving recognition to the importance to the company of new product
development, and elevating the importance of scientific and technical personnel.

23. Customer/Supplier Involvement.
Issues about whether and how to involve customers and/or suppliers in product development, e.g. how can
collaborating vendors be prevented from passing new technology developments along to their other customers,
circumstances in which suppliers should develop prototypes for the company or should be restricted to
contractual arrangements based on technical specifications, and a need to help suppliers upgrade their
capabilities so they can better assist the company.

24. Organisation Structure for R&D.
Issues involving which organisation structures are effective for managing R&D and for coordinating R&D with
other parts of the product development cycle.
**Part III: Innovation performance**

Do the metrics used in your organisation sufficiently capture innovation performance?  
[NO] 1 2 3 4 5 6 7 8 9 10 [YES]

**Performance Metrics**  
In the first column – select those performance metrics your R&D organisation uses today.  
In the second column – select those performance metrics that you would like to see used or better developed in your organisation in the future.

<table>
<thead>
<tr>
<th>Outputs and outcomes</th>
<th>Used today</th>
<th>Wish to see used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Products and processes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.g. number of new products/processes; New product/process success rate; Number of new patents</td>
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<tr>
<td><strong>Financial and market</strong></td>
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<tr>
<td>E.g. Sales, Profitability, Market share, Speed to market</td>
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<tr>
<td><strong>Inputs:</strong></td>
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<td></td>
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<tr>
<td><strong>People</strong></td>
<td></td>
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<tr>
<td>E.g. Number of people employed, R&amp;D intensity, Level of training/education</td>
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<tr>
<td><strong>Physical and financial resources</strong></td>
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<tr>
<td>E.g. Spending, R&amp;D intensity, Degree of slack</td>
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<tr>
<td><strong>Tools</strong></td>
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<tr>
<td>TQM, ISO etc. – e.g. Degree of use and fit</td>
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<tr>
<td><strong>Knowledge management</strong></td>
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<tr>
<td><strong>Idea generation</strong></td>
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<tr>
<td>E.g. Number of ideas, degree of newness of ideas</td>
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<tr>
<td><strong>Knowledge repository</strong></td>
<td></td>
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<tr>
<td>Formal and informal – e.g. Number of patents, Level of skills</td>
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<tr>
<td><strong>Information flows</strong></td>
<td></td>
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</tr>
<tr>
<td>E.g. Number and quality of collaborations, Extent of knowledge gathering on customers and competitors</td>
<td></td>
<td></td>
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<tr>
<td><strong>Innovation strategy</strong></td>
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<td></td>
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<tr>
<td><strong>Strategic orientation</strong></td>
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<tr>
<td>E.g. Differentiated funding, Fit between innovation goal and strategic objectives</td>
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<tr>
<td><strong>Strategic leadership</strong></td>
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<tr>
<td>E.g. Are there nominated/informal champions?</td>
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</tbody>
</table>
Organisation and culture

Culture
E.g. Responsiveness to change, Shared norms/vision, Autonomy/degree of freedom, Propensity to take risks

Structure
E.g. Flexibility, Administrative intensity (number of managers/employees), Hierarchy/degree of centralisation, Degree of formalisation, Reward systems

Portfolio management

Risk/return balance
E.g. Benefit models, Peer review

Optimisation tool use
E.g. Balance between short/long term, High/low risk, Small/large projects.

Project management

Project efficiency
E.g. Budget comparisons, Speed, Success rate

Tools
E.g. Certified processes (Stage-gate, ISO etc), Degree of use and fit

Communication
Internal and external – e.g. Number and frequency of meetings, Extent of cross-functional discussion

Collaboration
E.g. Percentage of projects in co-operation with third parties

Commercialisation

Market research
E.g. Number of customers interviewed

Market testing
E.g. Degree of customer involvement

Marketing and sales
E.g. Sales force proficiency, Distributional and promotional support, Adherence to marketing schedule
### Appendix VII. DATA FROM WORKSHOP SURVEY

| RESPONDENT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Scholar    | 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |
| Practitioner| 6 | 8 | 7 | 8 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 | 8 | 8 | 5 | 9 | 10 | 10 | 9 |

<table>
<thead>
<tr>
<th>Management of technology (MOT) issue</th>
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<tbody>
<tr>
<td>Mean value</td>
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<tr>
<td>St. Dev.</td>
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</table>
List of MOT issues

2. Rewarding and Educating Technical Personnel.
4. Organizational Learning About Technology.
5. Technology Trends and Paradigm Shifts.
6. Involvement of Manufacturing in New Product Development.
7. Oversight of High-Tech Activities.
8. Technology Core Competence.
10. Within-Company Technology Diffusion and Transfer.
13. Strategic Planning for Technology Products.
15. Involvement of Marketing Groups.
17. Establishing a “Technology Vision”.
20. Alliances/Partnerships Between Technology Companies.
22. Creating a Conducive Culture.
23. Customer/Supplier involvement.
24. Organization Structure for R&D.
Paper 1
Corporate structure and R&D organisations: three retrospective case studies in the Nordic process industries

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At a time when organisational structures are being seen as competitive tools and when R&D capabilities of firms are coming under increasing pressure, it is becoming more important to understand the complexities of the R&D organisational structure. The way R&D is organised has a substantial impact on its effectiveness and efficiency, and inappropriate organisational structures can hamper the innovativeness of R&D talent, increase the cost of output, and delay significant results. Over the past decades the process industries have seen much change in terms of both the external business environment and internal restructuring. Mergers and acquisitions as well as investments and divestments on the corporate level are also reflected by changes at the R&D level. The topic of this study is the R&D organisational structures in three selected multinational corporations in the Nordic process industries. Each of the multinationals in this study represents a different industry sector: food and beverages, mining and minerals, and pulp and paper respectively. A number of determining factors for R&D and R&D organisations have been investigated and analysed in the light of how and why corporate structures and R&D organisational structures has changed over time.

1. Introduction

This study investigates how R&D organisational structures have changed as a result of changing corporate structures. It constitutes the first part of a four-year research project entitled "Designing R&D organisations in process industry" carried out at the Centre for Management of Innovation and Technology in Process Industry.

Innovation in large firms is an important area of study because innovation and innovative activities drive economic development (Lazonick, 2002). Early on, Schumpeter noted that changes in technique and changes in productive organisations were especially important forces that drive development (Schumpeter, 1934). Another early observation is that these changes are largely shaped by large firms (Penrose, 1995). Not only has effective R&D become recognised as a primary contributor to competitive strength (Barnett and Clark, 1996; Edler et al., 2002), but also as a central determinant of long-term survival amongst firms (Utterback, 1994).

There are several reasons for choosing the R&D organisation as a starting point for studying innovation. Organisations in themselves are being seen as competitive tools (Galbraith, 1973; Scott, 1998) and the fact that R&D is at the centre of company development has been suggested by several researchers (Broehoff et al., 1997; Galbraith, 2002; Miller and Morris, 1998; Roussel et al., 1991; Teece, 1996). It is also no secret that R&D organisations in large firms are under increasing pressures relating to the nature of technological development per se, increasing internationalisation, the dynamics of the market, and internal organisational issues. A recent study by Chronéer confirms that the process industry is also very much part of this development, with an increase in mergers and acquisitions, corporate restructuring, investments and divestments as a result (Chronéer, 2005). It is therefore unfortunate that much of the literature on innovation has not looked at the process industries (Barnett and Clark, 1996).

The accelerated rate of technological progress affects R&D strategy, and increasing complexity challenges existing organisational structures (Chiesa, 2001). This development is changing the business climate, and logically the internal environment of firms operating in this environment must be changed as well. In fact, while the business environment has changed significantly the innovation processes used by firms have changed very little (Tidd, 2001). This view is supported by Miller and Morris, who write that it is not realistic to expect old organisational models to meet today’s challenges and that we must look for new models to enable effective performance (Miller and Morris, 1998). While the question of what organisational structures and management processes facilitate or inhibit innovation has been asked before (Damanpour and Gopalakrishnan, 1998; Teece, 1996) few studies have looked inside the R&D organisation (Argyres and Silverman, 2004). This study looks at how corporate structures have changed in the process industry and how the design of R&D organisations has changed as a consequence.
2. R&D organisational design in process industry

Organisational structure can be defined as “the formal allocation of work roles and the administrative mechanisms to control and integrate work activities” (Child, 1972). Looking specifically at R&D organisations, it was established early on that the way R&D is organised has a substantial impact on its effectiveness and efficiency (Lawrence and Lorsch, 1965), and that inappropriate organisational structure can hamper the deployment of R&D talent, increase the cost of output, and delay results (Roussel et al., 1991).

To correct flawed structures, the goal of organisational design is to create the best possible ‘fit’ between the specific tasks of the organisation and the context of the organisation (Mintzberg, 1999). The notion that a good fit between the organisational structure and its context will increase organisational performance is central in management and organisation design (Burton and Obel, 2004), and also forms the basis of contingency theory.

Contingency theorists assert that there is no one best way to organise, but that for every situation there are some organisational configurations that will work better than others (Drazin and Van de Ven, 1985; Galbraith, 1973). The process of achieving ‘fit’ can be either radical, making substantial changes at a single instant, or adaptive, making many incremental changes over time. However, by not adapting to change an R&D organisation will move further away from ‘fit’ towards a ‘misfit’, and eventually R&D performance will suffer. Figure 1 depicts a simple contingency model for R&D organisations, where a changing context affects R&D organisational structure and, in turn, R&D performance.

3. Context, structure and performance of R&D organisations

3.1. Contextual determinants

There are several contextual determinants of structure that have been applied in the organisational theory literature. The most common are size (Child, 1972; Pugh et al., 1968), technology (Woodward, 1965), strategy (Chandler, 1990), and environmental uncertainty (Burns and Stalker, 1961; Lawrence and Lorsch, 1967b). The total R&D intensity and product/process intensity (Lager, 2002) are other contextual determinants that have been found to affect the organisation of R&D in particular.

3.2. Structural variables

This study investigates 11 structural variables which are recognised in organisation theory and innovation literature. The variables are centralisation, formalisation, integration, functional differentiation, vertical differentiation, geographic dispersion, specialisation, professionalism, external collaboration, international collaboration, and slack. The variables were chosen because of their established impact on R&D performance.

Degree of centralisation. Centralisation concerns the locus of authority to make decisions affecting the organisation (Pugh et al., 1963). Centralisation is negatively associated with innovation, as concentration of decision-making decreases employee involvement and commitment (Damanpour, 1991).

Degree of formalisation. Formalisation distinguishes how far communication and procedures in an organisation are written down and filed (Pugh et al., 1963) and reflects the emphasis of following rules and procedures in conducting organisational activities. A low degree of formalisation and a high degree of flexibility permits openness and forces people to work together when solving problems (Damanpour, 1991).

Degree of integration. Integration is defined as the process of achieving unity among different subsystems in the organisation (Lawrence and Lorsch, 1967a). Integration often reflects the extent of communication and co-operation among organisational units or groups. Tighter integration between units allows for the cross-fertilisation of ideas, which in turn relates positively to innovation (Damanpour, 1991).

Degree of functional differentiation. Functional differentiation represents the degree to which the organisation is divided, or segmented, into different subsystems (Lawrence and Lorsch, 1967a). Differentiated units are more oriented towards their specific environment or tasks and therefore perform better (Lawrence and Lorsch, 1967a; Lawrence and Lorsch, 1967b).

Degree of vertical differentiation. Vertical differentiation represents the number of levels in an organisation’s hierarchy (Damanpour, 1991). Increasing hierarchy relates negatively to innovation, as communication between levels is more difficult (Damanpour, 1991).
innovation is inversely U-shaped, meaning that too much
Schumpeter, 1934). The relationship between slack and
innovation and innovative behaviour (Daniel et al., 2004;
unused (slack) resources in firms are a source of
reliable source of information, they show weakness if
can be a question for R&D managers (Kressens-van Drongelen and
How R&D performance is to be measured is an essential
3.3. Performance
How R&D performance is to be measured is an essential question for R&D managers (Kressens-van Drongelen and
innovation is inversely U-shaped, meaning that too much or too little slack inhibits innovation (Nohria and Gulati, 1996).

3.3. Performance

4. Research approach and case selection

The exploratory nature of this study calls for a qualitative research approach. Because this study looks at changing R&D organisational structures and their relations to changing corporate structures in the process industry, large and internationally active companies were the primary targets in case selection. In order to make industry-level comparisons, the case companies should
represent different sub-sectors of process industry. To meet these requirements Arla Foods in the food and beverage sector, Billerud in the pulp and paper sector, and Boliden in the mining and mineral sector were selected as case companies.

4.1. Case descriptions

Arla Foods. Formed through the merger between Danish MD Foods and Swedish Arla in the spring of 2000, Arla Foods is Europe’s largest dairy company with a turnover of 5.1 billion euros and almost 18,000 employees. Arla Foods is a co-operative owned by approx. 13,650 milk producers in Denmark and Sweden. With an R&D intensity of 0.5 – 0.6% Arla Foods has three R&D development centres and about 200 people working in R&D.

Billerud. Billerud is a packaging paper company with a sales turnover of around 750 million euros that employs 2,600 people in 11 countries. Billerud was formed in 2001 as a result of a major restructuring of the Swedish forest industry where two of AssiDomän’s paper mills merged with one of Stora Enso’s paper mills to create a company focused on packaging paper. In 2004 Billerud acquired a paper mill in the UK because of its focus on medical packaging. The R&D intensity is about 0.7% and R&D is mainly conducted at each of the four paper mills.

Boliden. Boliden is a mining and smelting company focusing on production of copper, zinc, lead, gold and silver. Boliden is a result of a corporate restructuring between two Nordic mining and smelting companies: Outokumpu in Finland and Boliden in Sweden. The number of employees is approximately 4,500 and the turnover amounts to approximately two billion euros annually. The Boliden plants are run as local subsidiaries, part of a greater portfolio, while the commercial organisation, mainly located in Stockholm, deals with purchasing, logistics and sales. Boliden, with an R&D intensity of 0.9% conducts most of its R&D at the mines and smelting plants.

4.2. Research method

Multiple methods of gathering data were used in the selected cases. Being a retrospective study, interviews with key informants as well as documents and archival records for triangulation were used in data collection. The interviews were conducted by a pair of researchers with informants in top management positions in the three case companies, and as the study is a historical retrospective the interviewees have all been with their companies for some time. At Arla Foods the informant was located at the R&D centre in Sweden. At Billerud two informants were interviewed at a Swedish paper mill. At Boliden the informant was located at a Swedish smelter.

To manage the huge data-load of a historical study and to focus the study on major events, a variant of the critical incident technique (CIT) was utilised. CIT focuses on significant occurrences (events, incidents, processes, or issues) identified by the respondent or the interviewer (Chell, 2004). In this study the critical incidents are major changes in the R&D organisations in the chosen case companies. During the interviews each informant was asked to list any major change in the R&D organisation that had occurred over the last decade, and these organisational changes were then discussed in light of the
contextual determinants and structural variables discussed earlier. An analysis based on CIT enables the researcher to relate context with outcomes and to look for repetition of patterns among multiple critical incidents (Chell, 2004) and among multiple cases, thus allowing for cross-case analysis (Yin, 2003).

5. Case study results

As this is a historical retrospective based on interviews at merged companies some of the analysed incidents concern the companies before the mergers.

5.1. Arla Foods

The informant at Arla Foods identified two major changes in the R&D organisation in recent times: (1) an expansion of the R&D organisation at Swedish Arla in the mid-1990s resulting from changing market conditions, and (2) a complete restructuring of the R&D organisation brought about by the merger with Danish MD Foods in 2000.

**R&D expansion.** When the dairy market changed in the mid-1990s towards a greater focus on branding and product differentiation, Arla decided to strengthen R&D capabilities by increasing the R&D intensity and, as a consequence thereof, the number of R&D employees was doubled from about 30 to about 60 in less than four years. The R&D function was seen as having a service position with respect to marketing, focusing on developing new products. However, no major changes were undertaken in the R&D organisation structure as a result of this change. See Appendix A for a summary of the structural changes.

**R&D restructuring.** On Arla’s merger with Danish MD Foods in 2000 the new company, Arla Foods, decided that it needed to restructure its R&D organisation. After the merger, Arla Foods’ R&D organisation had a staff of 200, were primarily based at three R&D centres – two in Denmark and one in Sweden. The level of R&D intensity was not subject to cost saving but was kept stable through the merger. However, the focus of R&D has changed as there has now been a shift in the dairy industry away from branding, and adding value to products, towards taking costs out of products. Although the organisation is still very product-oriented, there has been a shift towards process development after the merger. Centralisation and vertical differentiation in the R&D organisation were increased as top management took greater control over R&D and made it into a more strategic element of Arla Foods. R&D was seen as a way of building core competencies in the company. With this, the degree of formalisation with regard to work procedures, internal and external communication, external collaboration, slack resources, etc was also increased. As a result of the changes in the R&D organisation the informant reported a radical increase in R&D performance. See Appendix A for a summary of the structural changes.

5.2. Billerud

The informants at Billerud identified one major organisational change that had occurred in their R&D organisation, viz. the corporate restructuring between AssiDomän and Stora Enso in 2001 that created Billerud as a company.

**R&D restructuring.** When Billerud was created through the corporate restructuring between AssiDomän and Stora Enso, the number of people in the R&D organisation dropped sharply as all central R&D was kept as a part of AssiDomän. It was decided at the mergers between the three plants not to rebuild central R&D capabilities, as proximity to production was perceived to benefit the firm’s new focus on product development. As a result all R&D is conducted locally at plant level. However, as the R&D within Billerud came more decentralised on a unit and geographical level there was also a shift in decision-making towards being more centralised. About 80 percent of R&D is product development specified by the marketing organisation centrally, while 20 percent is carried out on behalf of the local production organisation. Even though the number of R&D units was decreased, functional differentiation was increased as each unit was given specific areas of responsibility. See Appendix A for a summary of the structural changes.

5.3. Boliden

The informant at Boliden identified one major change that had occurred in the R&D organisation. The transformation was not immediate, but part of an incremental trend of downsizing, resulting from changing internal and external conditions that affected R&D over a period of about 15 years. Another change that will be brought up here, not indicated by the informant as being a major change in the R&D organisation but still deemed as interesting is the corporate restructuring and integration between Outokumpu and Boliden.

**R&D organisational downsizing.** Boliden went through a long period of cutbacks over about fifteen years between the mid-1980s and 2000. The changing conditions of the industry as a whole can explain much of this, but during this period Boliden was also in financial difficulties that required cost-cutting in the company. During this time the R&D intensity decreased and the R&D organisation became focused on development aspects and quick-fix problem-solving. Most R&D centres were shut down during this period, so pure research is now conducted at universities. The R&D organisation has been changed in several steps in which R&D departments at plant level have merged and formalisation decreased. However, on a corporate R&D level hierarchy has increased. Even though R&D intensity decreased, the R&D performance has increased. See Appendix A for a summary of the structural changes.

**R&D integration.** At the end of 2003 Boliden and Outokumpu went through a corporate restructuring where Boliden, through a transaction, acquired Outokumpu’s zinc mining and smelting as well as copper smelting and refining operations. In return Outokumpu acquired Boliden’s copper fabrication division and technology sales business, responsible for the sale of technology for minerals, metals and chemical process industries. With the restructuring both companies became more fixed in the industry value chain – Boliden as a mining and smelting company, and Outokumpu as a copper product company and technology supplier. As part of the restructuring, Boliden and Outokumpu have agreed on
extensive technology and R&D collaboration. However, there has as yet been little or no change in the R&D organisation. See Appendix A for a summary of the structural changes.

6. Discussion and further research
From the three cases it is apparent that there are both differences and similarities in the approach to R&D organisational design. It was interesting to see that most corporate mergers and acquisitions did not affect the R&D organisation to any large extent.

The frequency of organisational change is low in all companies, and except for the restructuring at the merger of Arla Foods no company has taken an active stance for R&D organisational design. In fact, the purpose of R&D did seem to have the greatest influence on how it was organised. A strategic view of R&D as building competence causes it to being more integrated into the corporation while regarding it more as a problem-solving function make it logical to decentralise it. Highly decentralised R&D organisations have fewer problems accommodating additional R&D organisations joining the organisation as a result of mergers.

Most organisational changes in R&D were caused by necessity and not by a desire to improve R&D performance or the organisational ‘fit’. When looking at the internationalisation of the R&D organisation for example, it is evident that international collaboration is conducted to benefit R&D while geographic dispersion of R&D units is not primarily done in order benefit R&D in the first hand. Instead, the geographic dispersion of R&D units is a direct result of numerous corporate-level mergers and acquisitions. That the effects on the R&D organisations of any corporate changes will not be a priorised issue comes as no surprise, considering the low R&D intensity of all case companies. The costs of change may outweigh the perceived benefits.

In all three cases and through all major changes in the R&D organisation, the R&D performance was reported to have been improved. Returning to the simple contingency model presented in Figure 1, it was stated that changing structure would affect performance. As the case companies have all witnessed change in context, structure and performance, it would be interesting to see how they have fared compared to the theory of structural effects on innovation. In theory, both Arla Foods and Boliden have made more ‘positive’ than ‘negative’ changes in their organisational structures related to R&D performance. Billerud, on the other hand, has in theory made changes that should decrease R&D performance. There are however, many explanations for this not being the case as there are many variables to take into consideration.

Different organisational units can have different structural configurations. An area for further research is to what degree the R&D organisation can differ from other parts of the organisation that it has transactions with. To what extent does the R&D department has to ‘fit’ into corporate organisational structure?

For R&D managers in process industry some best practises concerning the design of the R&D organisation should be developed. There is much to be learned from benchmarking firms in the process industry and even the centralised firm can still affect many structural variables from within the R&D organisation. For example, the attitude towards slack is one area that opens for some interesting studies. Should it be formalised or not formalised?

It is important to recognise that changes in organisational structure do not occur of themselves and that structure itself does not determine innovation. All actual changes in an organisation are made by people who interpret the context and decide to do something about it. Structures and its determinants only mediate the human component, such as culture, attitudes, knowledge and values. For example, creativity in process industry R&D was often brought up as a central theme by the informants.

7. Conclusions and implications
The structures of R&D organisations in process industry are fairly enduring, even though the industry on a corporate level is more turbulent than ever. The changes that do occur in the R&D organisational structures are often the result of changes in other parts of the organisation. The fact that R&D does not seem to be prioritised during corporate changes points to the fact that addressing R&D organisational design in process industry more actively probably could enhance R&D performance.

8. Acknowledgements
This work has been financed by the Kempe Foundations and Jan Wallander’s and Tom Hedelius’ Foundation; their financial support is gratefully acknowledged. I also wish to express my sincere appreciation to Professor Thomas Lager for his encouraging support throughout this project. Thanks are due to Andreas Larsson for research assistance and valuable help with the case studies and William Laznick for helpful suggestions on the topic of innovation. Thanks also to industry informants Stina Blombäck, Lars-Erik Johansson, Theo Lehner, and Robert Svanberg, who devoted valuable time to this research project.

9. References


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1. In total, Schumpeter lists five causes of disturbance — increase in capital and population, changes in consumer tastes, changes in technique and productive organisation (Schumpeter, 1934).

2. Several researchers have discussed the changing nature of technology and innovation and some recurring observations by Chiesa (2001) and Teece (1996) are listed here. As uncertainty of technology and markets increases, predictions about the future are becoming more difficult. Cumulativeness of technological knowledge implies that firms must build new knowledge on old knowledge. The process of technological specialisation forces firms to concentrate on fewer technological disciplines. The irreversibility of progress eliminates the possibility of competition from older technologies. Geographical division of labour creates pockets of advanced knowledge in limited geographical areas. Path dependency of technological development compels firms to follow certain trajectories and makes it difficult to develop in areas new to the firm. The combination of knowledge from different fields forces firms to be up-to-date with increasingly dispersed disciplines.

3. The Schumpeter (1934) book on “R&D strategy and organisation” were the primary sources for the R&D structural variables used in this study.

4. For further information on the three case companies, look at Larsson’s study on strategy formulation (Larsson, 2005).

5. Bolode refers to itself as New Bolode both internally and externally to emphasise the restructuring that the organisation has gone through. However, the company is still officially named Bolode and will be referred as such in this paper.
### Appendix A: Summary of structural changes

<table>
<thead>
<tr>
<th>Period for organisational change</th>
<th>Arla Foods</th>
<th>Arla Foods</th>
<th>Billerud</th>
<th>Boliden</th>
<th>Boliden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merger between Arla and MD Foods</td>
<td>2000</td>
<td>Merger of Assi Domain and Stora Enso packaging paper mills</td>
<td>Changing environment and corporate financial problems</td>
<td>Corporate restructuring between Boliden and Outokumpu</td>
<td></td>
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<tr>
<td>Central factor behind change</td>
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<tr>
<td>Changing environment</td>
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<tr>
<td>Corporate financial problems</td>
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<tr>
<td>Merger</td>
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<td>Research/development focus</td>
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<tr>
<td>R&amp;D expansion</td>
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<td>R&amp;D restructuring</td>
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<td>R&amp;D organisational downsizing</td>
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<td>R&amp;D integration</td>
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<td>Change in...</td>
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<tr>
<td>Number of employees</td>
<td>Increased</td>
<td>No change</td>
<td>Decreased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>R&amp;D intensity</td>
<td>Increased</td>
<td>Increased</td>
<td>No change</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Research/development focus</td>
<td>No change</td>
<td>Development</td>
<td>Development</td>
<td>Development</td>
<td>No change</td>
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<tr>
<td>Process orientation</td>
<td>Product</td>
<td>Process</td>
<td>Product</td>
<td>Process</td>
<td>No change</td>
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<tr>
<td>Centralisation</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<td>more top-down</td>
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<tr>
<td>Formalisation</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Little change</td>
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<tr>
<td>Integration</td>
<td>No change</td>
<td>Increased</td>
<td>Increased</td>
<td>No change</td>
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<tr>
<td>Increased and formalised</td>
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<td>Increased esp. at local level</td>
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<tr>
<td>Functional differentiation</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>increased additional units and more specialised units</td>
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<tr>
<td>Vertical differentiation</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Increased from 2 to 4 hierarchical levels</td>
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<tr>
<td>Geographic dispersion</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Increased from 4 to 2 hierarchical levels</td>
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<tr>
<td>Specialisation</td>
<td>Decreasing as part of a larger trend</td>
<td>Decreased</td>
<td>Decreased</td>
<td>No change</td>
<td></td>
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<tr>
<td>越来越少 researchers and more generalists</td>
<td></td>
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<tr>
<td>Professionalism</td>
<td>Increasing as part of a larger trend</td>
<td>Decreased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Increased from 50 to 70 percent academics between 1990s and 2005</td>
<td></td>
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<tr>
<td>External collaboration</td>
<td>Increased</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Increased but unstructured and formalised</td>
<td></td>
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<td>Increased but more focused on a need-to-need basis</td>
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<tr>
<td>International collaboration</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
<td></td>
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<tr>
<td>Increased esp. pure research</td>
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<td>Increased prev. through R&amp;D centres</td>
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<tr>
<td>Slack</td>
<td>No change</td>
<td>Increased</td>
<td>Decreased</td>
<td>No change</td>
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<tr>
<td>Increased and formalised at 5%</td>
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<tr>
<td>Increased and more common in R&amp;D centres</td>
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<td>R&amp;D performance</td>
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Paper II
Heads or tails in innovation strategy formulation?:
Porterian or Penrosian, let context determine

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Abstract: In strategy research, resources and products can be considered two sides of the same coin. This conceptual paper turns heads into tails as it revisits the Porterian industrial economics-based Booz Allen Hamilton methodology for innovation strategy formulation from a Penrosian resource-based view. Seven propositions are generated, two distinct methodologies emerge, and four contextual factors are discussed. This paper proposes that the Penrosian methodology is more suitable in turbulent environments while the Porterian is more suitable in less turbulent environments. Furthermore, it illustrates how the resource based concept can be incorporated into a potentially very practical tool for innovation strategy formulation.

Keywords: innovation strategy; process management; strategic planning; resource-based view; industrial organisation; strategy formulation process; management tool; Porterian; Penrosian; benchmarking.

Reference to this paper should be made as follows: Larsson, A. and Bergfors, M. (2006) 'Heads or tails in innovation strategy formulation?: Porterian or Penrosian, let context determine', Int. J. Process Management and Benchmarking, Vol. 1, No. 4, pp.297–313.

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The dominant streams of strategy research from the 1980s and onwards have been the Porterian, strategic positioning approach and the Penrosian, resource-based view of strategy formulation (Ramos-Rodríguez and Ruiz-Navarro, 2004). Both views address vital management issues – the Porterian view of strategy is primarily concerned with how the corporation competes with its product and services in the product/service market, while the Penrosian view of strategy is concerned with how the corporation secure the factors needed for establishing and sustaining competitive advantage.

One of the major challenges for top management today is to avoid ending up with a business portfolio that is obsolete due to evolutionary changes in the competitive environment. Indeed, as competitive environments change and product markets become more volatile and dynamic, the accelerated rate of technological progress and complexity is constantly challenging existing organisational structures and strategies (Chiesa 2001; Edler et al., 2002). In the 1980s the Booz Allen Hamilton methodology (Pappas 1984) was developed as a tool to help companies formulate innovation strategies and it has been widely disseminated and used since. However, while the original Booz Allen Hamilton methodology is based on a positioning approach to strategy which implies focusing on product markets, claims have been made that positions in product markets are fragile and temporary sources of competitive advantage (D’Aveni, 1995). It has therefore been argued that in a dynamic environment where corporations search for continuity, this effort cannot be associated with positions in product markets but is more likely to be found in terms of the resources used for product application (Chiesa and Manzini, 1996).

It seems that the debate on whether strategy formulation should be based on resource configuration or positions in product markets has been ever present. However, this debate has provided little in terms of guidance for practitioners in choosing between the two. Birger Wernerfelt, arguably one of the fathers of the modern resource-based view, stressed that the corporation could be seen as a portfolio of resources as well as a portfolio of products, thus regarding resources and products as two sides of the same coin (Wernerfelt 1984). This paper sets out to flip that coin and turn heads into tails, exploring what would happen with a well-established tool for innovation strategy formulation if the focus were shifted to resources rather than product positions. Seven propositions are developed in response to the resource-based approach, and a new Penrosian framework for the Booz Allen Hamilton methodology is presented. The propositions and the revisited framework illustrate that the choice of following a positioning approach or a resource-based approach should be context-dependent. The paper questions some of the fundamentals of innovation strategy formulation and reveals that academia may have missed the mark with the debate. The issue is not necessarily whether a strategic positioning or resource-based approach to strategy is ultimately superior and more prosperous – rather it depends on the context-specific factors of the individual corporation. As it varies according to different contexts, strategy cannot, in the end, be taken as a universal practice.

For practitioners, this paper introduces a hands-on methodology for innovation strategy formulation based on the Penrosian resource based approach. While the Porterian positioning approach to strategy formulation has delivered hands-on methodologies for practitioners to apply, most previous research based on the resource based view has not provided tools for managers. For that reason, the paper illustrates how the resource based
concept can be incorporated into a potentially very practical tool for innovation strategy formulation.

The remainder of the paper is structured as follows. First an introduction to the positions and resource-based approach to strategy formulation is presented, followed by an introduction to the Booz Allen Hamilton methodology. The four steps of the methodology are then analysed from a resource-based view, rendering seven propositions, and the revisited methodology is presented; Finally, the revisited methodology is discussed in light of context, practical use, and further research.

2 Different ways of looking at corporations and competition

The principles of a positioning approach to strategy can be traced back to Mason (1939, 1949) and Bain (1956, 1968) and are set in the Harvard school of industrial organisation economics. The approach gained increased attention in the early 1980s, inspired by the seminal works *Competitive Strategy* (Porter, 1980) and *Competitive Advantage* (Porter, 1985) by Michael Porter. The Porterian positioning approach focuses on how corporations differ in product-market positions compared to competitors and the critical task of strategy is to determine the most favourable product market and the most favourable position in that particular product market.

The concepts of product markets and industry are central to the positioning approach to strategy. Jack Z. Sissors states that a product market is identified by a generic class of products, and refers to

“individuals who in the past have purchased a given class of products...[and] the assumption is usually made that those persons who will buy a product in the future will be very much like those who have purchased it in the past.” (Sissors, 1966, p.17)

Subsequently, an industry is identified as a bundle of similar product markets. The concept of product markets is founded on two fundamental assumptions: that each product market is distinct (there is a clarity for customers and competitors), and that competition occurs at the level of product lines and/or businesses (Prahalad and Hamel, 1990; Prahalad, 1998). However, it is argued that as business boundaries are blurring and evolving and customers and competitors are increasingly unidentifiable, existing conceptions of product markets are not a good basis for understanding competitiveness (Prahalad and Hamel, 1990; D’Aveni, 1995; Prahalad, 1998; de Toni and Tonchia, 2002), thereby shaking the fundamental assumptions of the product markets. These insights have helped give increased attention to a stream of strategy research that views the creation of competitive advantage as an inside-out process, known as the resource-based view.

The resource-based view assumes that corporations are heterogeneous because of the resources they own and control (Barney, 1991). Whereas the main objective of the positioning approach to strategy is to obtain and maintain favourable positions in product markets to earn revenues, the resource-based view sees strategy as both constrained by and dependent upon the corporation’s collection of resources (Penrose, 1959; Rumelt, 1984; Wernerfelt, 1984; Barney, 1986). The principles of a resource-based approach to strategy can be traced back to the work of Edith Penrose’s work *The Theory of the Growth of the Firm* (Penrose, 1959). Penrose argues
• that corporations will grow in the direction of their slowly-changing resources
• that the resources in the short run are both a limit to and a catalyst for growth.

The critical task in a Penrosian resource-based approach to strategy is to determine the most favourable composition of resources, in order to find the optimal configuration of product-market positions to maximise revenues over time (Grant, 1991). Resources are often classified into tangible (e.g. physical and financial resources) or intangible (e.g. competences and relations) (Haanes and Löwendahl, 1997) (See also Selznick, 1957; Hofer and Schendel, 1978; Snow and Hrebiniak, 1980; Hitt and Ireland, 1985; Winter, 1987; Leonard-Barton, 1992; Teece et al., 1997; Eisenhardt and Martin, 2000).1

3 Positions and resources: two sides of the same coin

There is evidently an interdependent and complimentary relationship between positions and resources (Mahoney and Pandian, 1992; Peteraf and Bergen, 2003). While the resource-based view is an inside-out process, the analysis of the environment is still critical since environment change “may change the significance of resources to the firm” (Penrose, 1959, p.79). In fact, Rumelt highlights the interaction between environments and resources when he suggests that strategy formulation concerns “the constant search for ways in which the firm’s unique resources can be redeployed in changing circumstances” (Rumelt, 1984, p.569). So, while the Porterian strategic positioning approach and the Penrosian resource-based view differ in their level of analysis and on the basis of how corporations achieve competitive advantage, current normative work in strategy should be oriented toward better integrating the product-market and resource-based approaches (Burgelman et al., 2004).

Corporations can either specify activities in product markets and from these infer the minimum necessary resource commitments, or by specifying a resource profile for a corporation find the optimal product-market activities (Wernerfelt, 1984). From this logic Wernerfelt concludes that resources and products are two sides of the same coin (Wernerfelt, 1984), as the corporation could be seen as a portfolio of resources as well as a portfolio of products. In the next section, heads are turned into tails as the Booz Allen Hamilton methodology is revisited with a resource-based approach perspective. The decision to rework the Booz Allen Hamilton methodology is primarily based on the fact that it is widely spread and used among practitioners, and therefore of interest to both academia and industry.

4 The Booz Allen Hamilton methodology for innovation strategy formulation

Principally, a process is a method for conducting tasks (Garvin, 1988). A process has input and output boundaries which frame the scale, scope, and objectives of the process (AT&T, 1988). As a result of a process, inputs are converted into outputs to reach defined goals. Previous work has illustrated the process of strategy development as consisting of two distinct steps; strategy formulation and strategy implementation – where the output of the first step serves as input to the second step. This is illustrated in Figure 1.
Several methodologies for strategy formulation and implementation were developed in the spirit of the positioning approach, and include contributions from academia; such as Porter (1980, 1985) and Hax and Majluf (1984) and Hax and No (1992), as well as from practitioners; such as A.D. Little (refined by Roussel et al., 1991), Booz Allen Hamilton (described by Pappas (1984)), and McKinsey (based on Foster and his work on the S-curve phenomenon (Foster, 1986)). These have been widely spread and utilised. The Booz Allen Hamilton methodology, which is the focus of this paper, deals with the first step – strategy formulation.

The Booz Allen Hamilton methodology was presented by Chris Pappas (Pappas, 1984), in the inaugural issue of the *Journal of Product Innovation Management*, at a time when the concept of ‘technology strategy’ was new to most corporations (Little, 1984). However, as ‘technology strategy’ evolved into a broader concept of ‘innovation management’ (Roussel et al., 1991; Miller and Morris, 1998), Pappas’ ideas have continued to be applied by practitioners and academics (Lauglaug, 1987; Cusumano and Elenkov, 1994; Tyler and Steensma, 1995; Collins et al., 1996; Chanaron and Jolly, 1999; Wilbon, 1999; Chiesa, 2001; Burgelman et al., 2004) as well as being taught at business schools.²

The Booz Allen Hamilton methodology aims at developing an innovation strategy by analysing the corporation’s technology vis-à-vis its business portfolio. It consists of a four-step procedure that is carried out in the following sequential order, and as illustrated in Figure 2:

- Technology situation assessment
- Technology portfolio development
- Technology and business strategy integration
- Setting technology investment priorities.

**Figure 2** The Booz Allen Hamilton methodology illustrated as part of the strategy development process
While the Booz Allen Hamilton methodology is based on a positioning approach to strategy, where the prime objective is to develop a technology portfolio that supports favourable positions in product markets, the emerging principles on which Pappas founded the methodology also encourage flipping the coin from positions to resources. First of all, Pappas assumed that innovation is not unpredictable, risky, or unquantifiable, but that the timing and direction of technology evolution can be anticipated as the steps in the innovation process leading to market commercialisation follow the same general pattern. Secondly, as technology changes and external competitive positions can be analysed, technology should be treated as a corporate asset or a ‘strategic resource’ (Pappas, 1984, p.31). The third principle states that technology priorities should dictate investments and that the congruence of technology investment and business strategy is of vital importance.

The remainder of this section will revisit the Booz Allen Hamilton methodology in the context of the resource-based view on a step-by-step basis. Through the use of propositions based on the resource-based view Pappas’ suggestions for strategy formulation are modified for the revisited methodology. Both the original Booz Allen Hamilton methodology and the revisited methodology are summarised in the discussion that follows.

**Step 1: Technology situation assessment**

The first step of the methodology consist of four phases:

- analysing the technologies currently employed in the corporation’s businesses, products and processes
- determining the importance of each technology to each specific product and/or each specific business
- reviewing the priorities that led to past and current technology investments
- scanning the external technology environment to pinpoint investment patterns of competitors.

Pappas states that the internal scan should focus on product and business levels, while the external scan should focus on technology investment patterns of competitors in each product market. In summary, Pappas suggests that corporations should:

1. scan technology on the product and business level of the corporation (internally)
2. scan the investment pattern of competitors in specific product markets (externally).

**Reply from a resource-based view to (1) and (2)**

As it seems that corporations are somewhat constrained in their ability to gain competitive advantages from tangible resources that can be acquired on a market (Dierickx and Cool 1989), many scholars have focused on corporations’ intangible, competence-based resources (Grant, 1991; Bettis and Hitt, 1995; D’Aveni, 1995; Chiesa and Manzini, 1996, 1998; Chiesa, 2001). Grant claims that competence-based resources are the most strategically significant resource of the modern corporation (Grant, 1996). However, simply looking at resources from the perspective of single products and single-product funding may inhibit the creation of long-term consistency and focus (Meyer and Utterback, 1993). This notion is based on the view that some intangible
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resources have the potential to bring access and competitive advantages to multiple product markets, which are referred to as ‘core products’ (Prahalad and Hamel, 1990). A core product can be defined as a bundle of intangible resources that form the basis for many end products. This implies that internally, corporations should focus their scan on corporate-wide compositions of resources that may form a basis for end products in the assessment of their technology situation.

Externally, corporations should scan the competitive environment on the basis of competitors’ resource positions (Grant, 1991; Bettis and Hitt, 1995), and especially those competitors’ core products (Prahalad and Hamel, 1990), rather than on product-market positions and the investment patterns of immediate competitors. The main argument for this approach is that product-market boundaries are becoming increasingly unclear and customers and competitors are more often difficult to identify (Prahalad and Hamel, 1990; Prahalad, 1998). As the greatest benefit of intangible resources is the ability to introduce unanticipated products and create new markets in which competition is lower, corporations should be observant by scanning those competitors with similar resources. Furthermore, this approach may help to avoid the consequence of emerging technological discontinuities, as these can be competence-destroying for industry incumbents (Tushman and Anderson 1986; Anderson and Tushman, 1990; Collis, 1994, Utterback, 1994).

In addition, Leonard-Barton stresses that corporations should

“scan broadly, because technological knowledge comes from a very diverse set of sources; the wider managers cast the net, the more likely a prize will be caught within.” (Leonard-Barton, 1995, p.156)

It is argued that if corporations focus too strictly on competitors only within their product market, they will risk missing the development of new ways of satisfying customer needs.

The preceding discussion leads to the following propositions:

Proposition 1: In the process of innovation strategy formulation, it is more appropriate to base the internal scan on a corporate-wide level of intangible resources than on each specific product or each specific business segment.

Proposition 2: In the process of innovation strategy formulation, it is more appropriate to focus the external scan on corporations with similarities in intangible resources than on the investment patterns of immediate competitors in each product market.

A resource-based approach to technology situation assessment might imply the following for the Booz Allen Hamilton methodology:

1 scan for resources on a corporate-wide level (internal)
2 scan the environment for corporations with the same intangible resources (external).

Step 2: Technology portfolio development

The second step in the Booz Allen Hamilton methodology is technology portfolio development. Pappas claims that the technology portfolio is a tool that can be used to “identify and systematically analyse key corporate technology alternatives and to set technology priorities” (Pappas, 1984, p.32), and he proposes that the technology portfolio should be evaluated with respect to each business segment. At this stage, two dimensions are of importance: to what degree the technology is important to existing and potential
business segments, and the corporation’s technology position in each business segment relative to its competitors. In summary, Pappas suggests that corporations should:

3. evaluate technology importance with respect to each given business segment
4. evaluate relative technology position with respect to each given business segment.

Reply from a resource-based view to (3) and (4)

Strategy selection should be based on careful evaluation of available resources (Spanos and Lioukas, 2001). One of the main insights of the resource-based approach is that not all resources of a corporation are of equal importance, and much consideration has therefore been given to identifying those that are most important. Barney (1991) sets out four conditions for resources being of importance: that they are valuable, rare, difficult to imitate, and non-substitutable. Subsequently, researchers have both developed and added to these conditions (Grant, 1991; Amit and Schoemaker, 1993; Collis and Montgomery, 1995). However, instead of looking at single resources, Prahalad and Hamel (1990) suggest that core products are a more stable basis for technology portfolio evaluation than developing a technology portfolio on the premises of technology importance and relative technology position in each single business segment. It is argued that by focusing on a single product market, a single business segment or a single product, a corporation may miss out on possible synergies and economies of scale and scope across segments and among products. Corporations which are able to transfer and utilise resources between units will gain significant advantages over those which cannot (Markides and Williamson, 1994), and focusing on resources that can be applied across a number of product markets has been shown to increase the flexibility of the corporation in end-product competition (Sanchez, 1995).

The preceding discussion leads to the following propositions:

**Proposition 3:** In the process of innovation strategy formulation it is more appropriate to evaluate the technology importance with respect to core products than to evaluate technology importance with respect to each given business segment.

**Proposition 4:** In the process of innovation strategy formulation, it is more appropriate to evaluate the relative technology position with respect to core products rather than to evaluate relative technology position with respect to each identified business segment.

A resource-based approach to technology portfolio development might imply the following for the Booz Allen Hamilton methodology:

a. evaluate the importance of intangible resources in core products
b. evaluate relative resource position with respect to core products.

**Step 3: Technology and business strategy integration**

The third step in the Booz Allen Hamilton methodology asserts that the technology portfolio should be aligned with the business portfolio in order to gain advantage in technology-related businesses. The business portfolio measures a corporation’s products in terms of positions in product markets. Selection of positions in each product market should be based on two dimensions: business segment attractiveness, which is the search for favourable product markets, and the corporation’s potential competitive position in the
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particular business segment, which signifies the ability to capitalise on each specific product market (Pappas, 1984). In summary, Pappas suggests that corporations should align technology portfolio with current business portfolio on specific business and specific product levels.

Reply from a resource-based view to (5)

There is an inherent risk in basing business attractiveness on positions in product markets, as these are based on the buying behaviour of previous customers (as described by Sissors (1966)). Christensen (1997) observed that corporations who become too focused on existing customers and scanning existing markets may fail to launch the next generation of products that are based on new technology and that they, in a sense, risk being held captives by their customers. Therefore, integrating the technology portfolio with the business portfolio based on a positioning approach as suggested by Pappas may entail some limitations on both innovation strategy and business strategy, and may lead to poor decisions on what businesses the corporation should be in. Instead of viewing technology simply as determining the current opportunities of the corporation, as in the positioning approach to strategy formulation, Itami and Numagami (1992) propose that there need not be such a static relationship between innovation and strategy. They argue that current technology may influence future strategy, just as current strategy can also influence future technology. Itami and Numagami trace the origin of this research back to Penrose (1959) and Chandler (1962), where path dependency among accumulated resources from past business activities becomes the driving force for further potential for growth.

The preceding discussion leads to the following proposition:

**Proposition 5:** In the process of innovation strategy formulation, the relationship between technology and business strategy should be characterised by a dynamic relationship rather than a static one.

A resource-based approach to technology and business strategy integration might imply the following for the Booz Allen Hamilton methodology:

- a dynamic alignment between technology portfolio and business portfolio focused on specific intangible resources and core products.

**Step 4: Setting technology investment priorities**

The fourth step in the Booz Allen Hamilton methodology is setting technology investment priorities. A key question that arises at this stage of the process is what investments devoted to technology are required to achieve corporate strategic objectives. Pappas (1984) claims that the answer can be found in the portfolio analysis made in the previous stage, and that technology investment options should be generated on the basis of relative technology positions as compared to competitors in specific product markets. The aim is to identify resource requirements in order to commit resources to each specific business, and in the end to each specific product. In summary, Pappas suggests that corporations should identify and commit investments to specific businesses and identify and commit investments to specific products.
Reply from a resource-based view to (6) and (7)

It is suggested that the competitive environment demands more flexibility than ever before (Bettis and Hitt, 1995; D’Aveni, 1995; Sanchez, 1995; Danneels, 2002). From a strategy formulation standpoint, this implies that top management has to loosen the degree of detail in planning in order to survive (Quinn, 1980; Mintzberg and Waters, 1982; Mintzberg, 1994; Andersen, 2004). In bridging these trends, some degree of stability in strategy formulation may be gained by focusing on resources rather than positions in specific product markets and specific businesses. This is due to the stability that resources provide compared to positions in product markets (Prahalad and Hamel, 1990; Grant, 1991; Bettis and Hitt, 1995; Chiesa and Manzini, 1996, 1998; Chiesa, 2001). As the resources that a corporation possesses are slow to change (Penrose, 1959), evolutionary (Ahuja and Katila, 2004), and path dependant (Helfat, 1994), while technological discontinuities may appear seemingly out of nowhere (Tushman and Anderson, 1986; Anderson and Tushman, 1990; Utterback, 1994), it becomes increasingly important to focus investments on intangible resources and guard against technological discontinuities rather than investing for temporary positions in product markets. Or, in the words of Markides and Williamson, “simply exploiting existing strategic assets will not create long-term competitive advantage” (Markides and Williamson, 1994, p.164).

The preceding discussion leads to the following propositions:

**Proposition 6:** In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific intangible resources are met rather than to ensure that investments are committed to each specific business.

**Proposition 7:** In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific core products are met rather than to ensure that investments are committed to specific products.

A resource-based approach to setting technology investment priorities might imply the following for the revisited Booz Allen Hamilton methodology:

- identify and commit investments to ensure that requirements for specific intangible resources and core products are met.

5 A revisited methodology for innovation strategy formulation

In revisiting the Booz Allen Hamilton methodology with a resource-based approach as opposed to a positioning approach, several changes to the original methodology have been suggested in the propositions. These changes are summarised below.

In the original methodology – illustrated in Figure 3 – internal and external scanning, evaluation of portfolios, aligning technology and business, and investment decisions emphasise positions in product markets and focus on end products.
A resource-based approach implies that corporations should strive to keep flexibility in product markets by focusing on their resources rather than on positioning in product markets. The revisited methodology based on a resource-based approach – illustrated in Figure 4 – emphasises innovation strategy formulation based on intangible resources and core products in order to gain a competitive advantage. All the four steps in the methodology reflect this change in perspective.

### Figure 3
The original Booz Allen Hamilton four-step methodology for innovation strategy formulation

<table>
<thead>
<tr>
<th>Step 1: Technology situation assessment</th>
<th>Step 2: Technology portfolio development</th>
<th>Step 3: Technology and business strategy integration</th>
<th>Step 4: Setting technology investment priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan</td>
<td>Evaluate</td>
<td>Align</td>
<td>Invest</td>
</tr>
<tr>
<td>• Internal (I)</td>
<td>• Technology importance (TI)</td>
<td>• Align technology portfolio with current business portfolio</td>
<td>• Identify investment requirements</td>
</tr>
<tr>
<td>• External (E)</td>
<td>• Relative technology position (RTF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative to</td>
<td></td>
<td>The needs of the business strategy</td>
<td>Each specific product in each specific product market</td>
</tr>
<tr>
<td>• (I) Specific product and specific business</td>
<td>• (TI) Specific business segment compared to competitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• (E) Investment patterns of competitors</td>
<td>• (RTF) Positions compared to competitors</td>
<td></td>
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</table>

Source: As interpreted from Pappas (1984)

### Figure 4
The revisited Booz Allen Hamilton four-step methodology for innovation strategy formulation

<table>
<thead>
<tr>
<th>Step 1: Technology situation assessment</th>
<th>Step 2: Technology portfolio development</th>
<th>Step 3: Technology and business strategy integration</th>
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<td>Scan</td>
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<tr>
<td>• Internal (I)</td>
<td>• Technology importance (TI)</td>
<td>• Dynamic interaction between technology and business portfolio</td>
<td>• Identify investment requirements</td>
</tr>
<tr>
<td>• External (E)</td>
<td>• (RTF) Relative technology position</td>
<td></td>
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<tr>
<td>Relative to</td>
<td></td>
<td>The needs of the business strategy</td>
<td>For each identified core product</td>
</tr>
<tr>
<td>• (I) Resources</td>
<td>• (TI) Specific resources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• (E) Similarities in resource composition</td>
<td>• (RTF) Core products</td>
<td></td>
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</tbody>
</table>

### 6 Discussion and further research

When crafting innovation strategy, managers ultimately have to deal with a central paradox, viz. that the amount of flexibility that the competitive environment imposes is often in conflict with the degree of stability that the organisation requires. The two interpretations of the Booz Allen Hamilton methodology presented here are somewhat different in this respect; where the original methodology emphasises a detailed approach in terms of product markets, the revisited methodology is less precise in that sense, but at the same time more flexible. In responding to the original methodology presented by Pappas (1984) the resource-based approach has highlighted some contexts where the revisited methodology may be more suitable. The four main contingencies that have become evident from theory are the nature of the competitive environment, the impact of technological discontinuities, the characteristics of resources used, and the number of product markets served by the corporation. Each is discussed in turn.
Competitive environment. The revisited methodology seems to be more suitable when the environment is turbulent and competitors are numerous and difficult to identify. Scanning and evaluating competitors in this environment is time-consuming and difficult. By focusing on resources, a corporation will not have to follow fast-moving markets to the same extent, thus decreasing information load.

Technological discontinuities. If the resources that a corporation builds on are slow and difficult to change, the revisited methodology may prove better for innovation strategy formulation. Path dependency implies that companies are stuck with what they have, and that focusing on product-market positions will not guard against technological discontinuities. However, guarding against discontinuities is more important if they are likely to revolutionise the industry: if they are not, a positioning approach may serve better.

Resources. If the corporation has intangible resources that can be utilised in a variety of product markets the revisited methodology will probably be a more suitable choice. If there are no or few synergies in employing resources over a variety of markets, the original methodology is probably more suitable.

Product markets. If the corporation is present in a large number of product markets, it is more difficult to organise and manage the business portfolio; this implies that the revisited methodology may be better under such conditions. The revisited methodology also simplifies the extension of resources over multiple markets. However, if the corporation operates in only a few product markets, managing the business portfolio will be less difficult. In this case a positioning approach will suffice, and the original methodology will be more effective for innovation strategy formulation.

In moving forward from a conceptual paper it is clear that empirical work is needed to test the propositions in an actual industrial context. Nevertheless, this paper hints at some avenues for further research worthy of note. Future research should focus more on generating propositions that pit different theoretical lenses against each other, preferably in the same empirical setting. This is the best way to bridge the gap between theory and practice and to uncover interesting contingency variables that managers can absorb and assimilate into their own context. Studying different contexts using different theoretical approaches makes any fruitful cross-comparisons difficult, so if academia wishes to advance the debate between Porterian strategic positions and Penrosian resources, working in one contextual setting is the best way to proceed. One of the major goals in strategy research is to understand the sources of competitive advantage. It is commonly argued that corporations obtain competitive advantage by implementing strategies that exploit their internal resources, through responding to environmental opportunities, while neutralising external threats and avoiding internal weaknesses (Barney, 1991). However, most research related to the achievement of competitive advantage has either focused on isolating a corporation’s external analyses of opportunities and threats in the competitive environment (for example, Porter, 1980, 1985) or internal analyses of strengths and weaknesses (for example, Penrose, 1958). In order to deliver hands-on tools to managers, one promising avenue for future research would be to combine the two methodologies into a hybrid methodology – a methodology which both addresses the resources (that is, internal strengths and weaknesses) as well as products (that is, external opportunities and threats). In other words, although the Porterian approach and the Penrosian approach diverge with how competitive advantage is achieved, managers are in need of methodologies which address both internal and external factors simultaneously.
7 Conclusions and implications for practice

Strategy is only as good as the information from which it is derived, so relying on an inappropriate set of strategy tools may hamper a corporation’s ability to compete in a dynamic environment. In revisiting the Booz Allen Hamilton methodology, this paper has shown that the context is critical when choosing between a Porterian or Penrosian approach to strategy. In short, one is not automatically better than the other, and it is suggested that corporations, on the basis of their corporate internal and external context, will benefit differently from the revisited and the original methodology. In summary, corporations in blurring and dynamic competitive environments where technological discontinuities are likely to be devastating, who have numerous end-products, and who employ core products over several markets, are more likely to benefit from the Penrosian methodology. It would almost seem that the complexity of such an environment forces a corporation to retreat into resources. On the other hand, corporations who compete in a less dynamic environment, where technological discontinuities are not likely to revolutionise the industry, who have fewer end-products to care for, and where intangible resources are not related to a multitude of different product markets, are better served by the original methodology.

This paper suggests that much of the previous debate, which focused on whether certain corporate resources or favourable positions within a market give the best explanation for corporate growth and competitiveness, actually misses the mark. Corporations, and their managers who wish to know what actions they can take to avoid ending up with obsolete business portfolios, are not interested in abstract debates. Therefore, this paper attempts to take the debate to a more concrete level by saying not only that ‘it depends’, but also saying ‘when’ and ‘why’ it depends. Faced with the two methodologies, corporations are forced to rethink the foundations on which they formulate innovation strategy. They must decide what and where to scan, on which tools to rely, and how they evaluate and align technology and business within the corporation. Finally, resulting investments must then be matched correctly. In this sense corporations can use the original and revisited methodologies as checklists to audit their current tools and techniques for scanning. If the corporations are able to achieve a correct fit, they will find that the quality of information on which they derive their strategies will be better suited to their strategising needs.

While this paper is simplistic in its approach and in flipping the coin from positions to resources with respect to the Booz Allen Hamilton methodology, this proved to be a rewarding endeavour, as the change in perspective acts as a lever to better understand organisations. It also illustrates that the resource-based approach can be utilised in constructing hands-on management tools, even tools that address the environment.

Acknowledgements

This work has been financed by the Kempe Foundations; their financial support is gratefully acknowledged. We also wish to express our sincere appreciation to Professor Thomas Lager for his encouraging support throughout this project. Thanks are due to Professor Henrich R. Greve for helpful suggestions and we are grateful to the editors and two anonymous reviewers for their insightful comments for the final paper.
References


Heads or tails in innovation strategy formulation?


Heads or tails in innovation strategy formulation?


Notes

1By this classification, a multitude of various concepts that have emerged, such as core competence (Prahalad and Hamel, 1990; Leonard-Barton, 1992), capabilities (Grant, 1991), distinctive competence (Selznick, 1957; Snow and Hrebiniak, 1980; Hitt and Ireland, 1985), dynamic capabilities (Teece et al., 1997; Eisenhardt and Martin, 2000), strategic assets (Winter, 1987) and resource deployment (Hofer and Schendel, 1978), are part of the broader categories of intangible and tangible resources. For the purpose of this paper however, we need not concern ourselves with the debate within these concepts, but only focus on the basic premises of the resource-based approach.

2While technology strategy formulation is a vital task of innovation management, it would be more appropriate nowadays to equate ‘technology strategy’ in Pappas’ sense with ‘innovation strategy’. Furthermore, the way the term ‘corporate strategy’ is used by Pappas is more commonly denoted as ‘business strategy’, see Hofer and Schendel (1978). In these two minor details, the methodology will therefore not be presented as in the original paper.
Paper III
A resource-based approach to the Booz Allen and Hamilton methodology: exploring new directions for practice

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Abstract: Two major streams in strategy research are the strategic positioning approach and the resource-based approach to strategy formulation. However, resources and products can be considered as two sides of the same coin, implying one view is not necessarily superior to the other. In this paper, the well-known Booz Allen and Hamilton methodology for innovation strategy formulation, originally based on a strategic positioning approach to strategy, is revisited with a resource-based approach to strategy. Eight propositions are investigated through case studies conducted in two multinational corporations. It shows that both the established methodology and the revisited methodology are used in multinational corporations today. Case analyses indicate that there are three contingencies that shape the structure of innovation strategy formulation processes – level of diversification; characteristics of industry boundaries, customers and competitors and Role and organisation of R&D. In the light of these results new directions for practice and managerial implications are explored.

Keywords: innovation strategy; strategic planning; resource-based view; industrial organization; management tool.


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1 Introduction

In the 1980s, strategic management scholars showed increased attention to the fact that innovation can be considered a powerful competitive weapon. Most of the early strategy research on innovation was based on a positioning approach to strategy whose principles can be traced back to industrial organisation in economics, developed by Mason (1939, 1949) and Bain (1956, 1968). The positioning approach focuses on market structure and positioning within industries, to help find the most favourable product-market and the most favourable position in that particular product-market.

In the early days of research on innovation strategy formulation, several methodologies were developed in the spirit of the positioning approach. However, recent research has argued that as business boundaries are blurring and evolving customers and competitors are more often unidentifiable, existing conceptions of product-markets are not a good basis for understanding competitiveness (D’Aveni, 1995; De Toni and Tonchia, 2002; Prahalad and Hamel 1990) and as a result, it is commonly argued that innovation strategy formulation should originate from internal resources rather than positions in product markets (Chiesa, 2001; Chiesa and Manzini, 1996). Unfortunately, in this stream of research, known as the resource-based approach to strategy, less attention has been paid to the fact that practitioners are in need of management tools and techniques that can help them structure problems and make decisions.

For that reason, the goal of this paper is to introduce a new management tool derived from the resource-based view and to explore how management tools actually are used today. In order to do this, a widely used tool, the Booz Allen and Hamilton methodology (Pappas, 1984) is revisited with a resource-based approach to strategy formulation (Larsson and Bergfors, 2006). Eight propositions are investigated in two multinational corporations. This paper contributes to innovation management and strategic management knowledge in three areas. Firstly, it provides descriptive data on innovation strategy formulation of multinational corporations. Secondly, it indicates that corporations of today either focus on positions or resources in the work-process of innovation strategy formulation. Finally, it sheds light upon key aspects that help explain why corporations choose to focus on either positions or resources in the work-process of innovation strategy formulation.

2 Theoretical background

2.1 Positioning approach

The contemporary positioning approach to strategy is very much influenced by the work of Porter (1980, 1985). To Porter, the ultimate goal of the firm is to find an attractive relative position, within an attractive product-market, in an attractive industry. Either this position can arise from the selection of a cost base lower than the competition or from the firm’s ability to differentiate its offerings and command a premium price that exceeds the accumulation of the extra costs. According to Porter, industry structure affects the sustainability of firm performance, whereas positioning of end products reflects the firm’s ability to establish advantage over its competitors.

Corporations sell their variety of end products in various product-markets. A product-market is identified by a generic class of products (Sissors, 1966). Sissors points out that product-markets are “referring to individuals who in the past have
purchased a given class of products... the assumption is usually made that those persons who will buy a product in the future will be very much like those who have purchased it in the past” (1966, p.17).

In addition, two fundamental assumptions are made in the positioning approach. Firstly, it is assumed that the product-market is distinct (there is a clarity of customers and competitors). Secondly, it is assumed that competition occurs at the level of product lines and/or businesses.

2.2 Resource-based approach

The principles of a resource-based approach to strategy can be traced back to Edith Penrose’s work *The Theory of the Growth of the Firm* (Penrose, 1959). Penrose argues 1 that corporations will grow in the direction of their slowly changing resources and 2 that the resources in the short run are both a limit to and a catalyst for growth.

Barney defines resources as all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness (Barney, 1991). Resources can be classified into tangible and intangible resources (Haanes and Löwendahl, 1997).

Corporations can either specify activities in product-markets and from these infer the minimum necessary resource commitments, or by specifying a resource profile for a firm find the optimal product-market activities (Wernerfelt, 1984). From this logic, (1984) Wernerfelt concludes that resources and products are two sides of the same coin as the corporation could be seen as a portfolio of resources as well as a portfolio of products. Furthermore, he argues that it is possible to identify a corporation’s optimal product-market configuration by specifying its resource profile.

3 The Booz Allen and Hamilton methodology

The Booz Allen and Hamilton methodology was presented by Pappas (1984) at a time when the concept of ‘technology strategy’ was new to most corporations (Little, 1984). However, as ‘technology strategy’ evolved into a broader concept of ‘innovation management’ (Miller and Morris, 1998; Roussel et al., 1991) Pappas’ ideas have continued to be applied by practitioners and academics as well as being taught at business schools.

The methodology aims at developing an innovation strategy by analysing a corporation’s technology vis-à-vis its business portfolio. It consists of a four-step procedure that is carried out in the following sequential order:

1 technology situation assessment

2 technology portfolio development

3 technology and business strategy integration and

4 setting technology investment priorities.
3.1 Step 1: Technology situation assessment

The first step of the methodology consists of internal and external scanning. Pappas states that the internal scan should focus on product and business levels, while the external scan should focus on technology investment patterns of competitors in each product-market. Consequently, Pappas suggests that corporations should:

1. scan technology on the product and business level of the corporation (internally)

and

2. scan the investment pattern of competitors in specific product-markets (externally).

3.1.1 Reply from a resource-based view to (1) and (2)

While resources form the basis for corporations' ability to compete (Barney, 1991; Knott, 2003; Rumelt, 1984; Wernerfelt, 1984), simply looking at resources from the perspective of single products and single-product funding may inhibit the creation of long-term consistency and focus (Meyer and Utterback, 1993). This notion is based on the view that a bundle of intangible resources have the potential to bring access and competitive advantages to multiple product markets through end-products, referred to as 'core products' (Prahalad and Hamel, 1990). This implies that internally, corporations should focus their scan on corporate-wide compositions of intangible resources that may form basis for end-products in the assessment of their technology situation.

Corporations should scan the competitive environment based on competitors' resource positions (Bettis and Hitt, 1995; Grant, 1991) and especially those competitors' core products (Prahalad and Hamel, 1990), rather than on product market positions and investment patterns of immediate competitors. This approach may help to avoid the consequence of emerging technological discontinuities, as these can be competence-destroying for industry incumbents (Anderson and Tushman, 1990; Collis, 1994; Tushman and Anderson, 1986; Utterback, 1994). Besides, Leonard-Barton stresses that corporations should "scan broadly, because technological knowledge comes from a very diverse set of sources, the wider managers cast the net, the more likely a prize will be caught within" (Leonard-Barton, 1995, p.156). If corporations focus too strictly on competitors only within their product-market, they will risk missing the development of new ways of satisfying customer needs.

Proposition 1: In the process of innovation strategy formulation, it is more appropriate to base the internal scan on intangible resources than basing it with respect to each specific product or each specific business segment.

Proposition 2: In the process of innovation strategy formulation, it is more appropriate to focus the external scan on corporations with similarities in intangible resources than focusing on investment patterns of immediate competitors in each product market.

A resource-based approach to technology situation assessment might imply the following for the Booz Allen and Hamilton methodology:

1. scan for resources on a corporate-wide level (internal) and

2. scan the environment for corporations with the same intangible resources (external).
3.2 Step 2: Technology portfolio development

The second step is technology portfolio development. Pappas claims that the technology portfolio is a tool that can be used to ‘identify and systematically analyse key corporate technology alternatives and to set technology priorities’ (1984, p.32) and he proposes that the technology portfolio should be evaluated with respect to each business segment. In summary, Pappas suggests that corporations should:

(3) evaluate technology importance with respect to each given business segment and
(4) evaluate relative technology position with respect to each given business segment.

3.2.1 Reply from a resource-based view to (3) and (4)

As a business segment is a collection of product-markets within an industry (Sissors, 1966), the evaluation of technologies with respect to business segments gives rise to islands of knowledge about the technology requirements of the corporation only with respect to these product-markets, but no knowledge about the distance between the islands (i.e. possibilities for synergies and economies of scale). Therefore, Prahalad and Hamel (1990) suggest that core products are a more stable basis for technology portfolio evaluation than developing a technology portfolio on the premises of technology importance and relative technology position in each single business segment.

Proposition 3: In the process of innovation strategy formulation it is more appropriate to evaluate the technology importance with respect to core products than to evaluate technology importance with respect to each given business segment.

Proposition 4: In the process of innovation strategy formulation, it is more appropriate to evaluate the relative technology position in respect to core products rather than to evaluate relative technology position with respect to each identified business segment.

A resource-based approach to technology portfolio development might imply the following for the Booz Allen and Hamilton methodology:

1 evaluate the importance of intangible resources in core products and
2 evaluate relative resource position in respect to core products.

3.3 Step 3: Technology and corporate strategy integration

The third step asserts that the technology portfolio should be aligned with the business portfolio in order to gain advantage in technology-related businesses. In Pappas’ example, the business portfolio measures a corporation’s products in terms of positions in product-markets and according to Pappas, selection of positions in each product-market should be based on two dimensions: business segment attractiveness, which is the search for favourable product-markets and the corporation’s potential competitive position in the particular business segment, which signifies the ability to capitalise on each specific product-market (Pappas, 1984). Pappas suggests that corporations should:
(5) Align technology portfolio with current business portfolio on specific business and specific product levels.

3.3.1 Reply from a resource-based view to (5)

There is an inherent risk in basing business attractiveness on positions in product-markets, as these are based on the buying behaviour of previous customers (Prahalad, 1998; Prahalad and Hamel, 1990). Observed to FOUND that corporations who become too focused on existing customers and scanning existing markets may fail to launch the next generation of products that are based on new technology and that they, risk being held captives by their customers (Christensen, 1997). Furthermore, it is argued that there is an inherent current customers technology may influence future strategy; just as current strategy can also influence future technology (Itami and Numagami, 1992). Itami and Numagami trace the origin of this research back to Penrose (1959) and Chandler (1962), where path dependency among accumulated resources from past business activities becomes the driving force for further potential for growth.

Proposition 5: In the process of innovation strategy formulation, the relationship between technology and business strategy should be characterised by a dynamic relationship rather than a static relationship.

A resource-based approach to technology and business strategy integration might the following for the Booz Allen and Hamilton methodology:
1 A dynamic alignment between technology portfolio and business portfolio focused on specific intangible resources and core products.

3.4 Step 4: Setting technology investment priorities

The fourth step concerns the setting of technology investment priorities. In short, Pappas suggests that corporations should:

(6) identify and commit investments to specific businesses and
(7) identify and commit investments to specific products.

3.4.1 Reply from a resource-based view to (6) and (7)

It is suggested that the competitive environment demands more flexibility than ever before (Bettis and Hitt, 1995; Danneels, 2002; D'Aveni, 1995; Sanchez, 1995) but some degree of stability in strategy formulation may be gained by focusing on resources rather than positions in specific product-markets and specific businesses. This is due to the stability that resources provide compared to product-markets. While the resources that a corporation possesses are slow to change (Penrose, 1959) and path dependant (Helfat, 1994) and technological discontinuities may appear seemingly out of nowhere (Anderson and Tushman, 1990; Tushman and Anderson, 1986; Utterback, 1994), it becomes increasingly important to focus investments on intangible resources and guard against technological discontinuities rather than investing for temporary positions in product-markets. Markides and Williamson note that also ‘simply exploiting existing strategic assets will not create long-term competitive advantage’ (Markides and Williamson, 1994, p.164).
Proposition 6: In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific intangible resources are met rather than to ensure that investments are committed to each specific business.

Proposition 7: In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific core products are met rather than to ensure that investments are committed to specific products.

A resource-based approach to setting technology investment priorities might imply the following for the revisited Booz Allen and Hamilton methodology:

1. Identify and commit investments to ensure that requirements for specific intangible resources and core products are met.

3.5 A reworked model for innovation strategy formulation

In revisiting the Booz Allen and Hamilton methodology with a resource-based approach as opposed to a positioning approach several changes of the original methodology have been suggested in the propositions. In the original methodology (illustrated in Figure 1) internal and external scanning, evaluation of portfolios, aligning technology and business, and investment decisions emphasise positions in product-markets and focus on end-products. This approach is more suitable in non-dynamic competitive environments.

Figure 1 The original Booz Allen and Hamilton four-step methodology for innovation strategy formulation

<table>
<thead>
<tr>
<th>Step 1: Technology situation assessment</th>
<th>Step 2: Technology portfolio development</th>
<th>Step 3: Technology and business strategy integration</th>
<th>Step 4: Setting technology investment priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan</td>
<td>Evaluate</td>
<td>Align</td>
<td>Invest</td>
</tr>
<tr>
<td>• Internal (I)</td>
<td>• Technology importance (TI)</td>
<td>• Align technology portfolio with current business portfolio</td>
<td>• Identify investment requirements</td>
</tr>
<tr>
<td>• External (E)</td>
<td>• Relative technology position (RTP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• (I) Specific product and specific business</td>
<td>• (TI) Specific business segment</td>
<td>The needs of the business strategy</td>
<td>Each specific product in each specific product market</td>
</tr>
<tr>
<td>• (E) Investment patterns of competitors</td>
<td>+ (RTP) Positions compared to competitors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: As interpreted from Pappas (1984).

A resource-based approach implies that corporations should strive to keep flexibility in product-markets by focusing on the corporation’s resources rather than focusing on positioning in product-markets. The revisited methodology based on a resource-based approach (illustrated in Figure 2) emphasises innovation strategy formulation based on intangible resources and core products in order to gain a competitive advantage. This approach seems to be more suitable in a dynamic environment.

3.5.1 Summary and response from previous propositions

Literature on the resource-based view of the firm has exemplified some contexts where the revisited methodology may be more suitable for innovation strategy formulation. The four main contingencies that have become evident from theory are; the nature of the competitive environment, the impact of technological discontinuities, the characteristics of resources used and the number of product-markets served by the corporation.
In blurring and highly competitive environments, where competitors are numerous and difficult to scan, the revisited methodology is theoretically more suitable as focusing on resources is more stable. As resources are path dependent and slow to change, corporations who are susceptible for discontinuous technological changes should use the revisited methodology. If the nature of the intangible resources possessed by a corporation are such that they can be utilised across a wide variety of product applications the revisited methodology is more useful. If the corporation is active within a large number of product-markets focusing on resources makes it easier to extend intangible resources over multiple markets and also make it easier for the corporation to uncover new product-markets. In these cases, the revisited methodology would be more helpful than the original.

**Figure 2** The revisited Booz Allen and Hamilton four-step methodology for innovation strategy formulation

Based on the commonly held view of the increasingly dynamic nature of technology and innovation; including increased competition, greater turbulence, shortening life-cycles and increased globalisation (Chiesa, 2001; Teece, 1996), it would seem as if the revisited methodology ought to be better for innovation strategy formulation.

**Proposition 8:** In the process of innovation strategy formulation, the revisited Booz Allen and Hamilton methodology is more suitable than the original methodology.

### 4 Research method and case descriptions

In exploring a phenomenon such as innovation strategy formulation processes in action and within its real-life context inside the organisation a case based approach is a promising venture – especially since the theoretical propositions state that the internal and environmental contexts affect the phenomenon to be studied (Yin, 2003). Because this study focuses on innovation strategy the R&D organisation within two firms, Arla Foods and Billerud, were chosen for the case studies. The rationale behind the case selection is further developed in the subsequent section.

The studies were conducted in Sweden over a period of 12 months and are mainly based on semi-structured interviews with informants in top management positions at Arla Foods and Billerud who were all personally involved in innovation strategy formulation. At Arla Foods three informants were located at an R&D unit in Sweden. At Billerud two informants were interviewed at a Swedish paper mill. As the unit of analysis is the strategy formulation process within the R&D organisation the data from the interviews have been integrated with further case data collected via annual reports, internal reports and internal strategy documents to avoid relying solely on the opinion of
individuals (Yin, 2003). The interviews and further data collection were conducted as a team by two investigators who kept separate case protocols. Final analysis, as well as data collection, was conducted with the theoretical propositions as orientation. This means that the focus of the analysis has been on the steps of the strategy formulation process and the contingencies suggested by theory. By iterating between theory and data, that is, returning to the cases to find more information on specific issues and contingencies, we believe that we have reached the theoretical saturation advocated by Eisenhardt (1989). Finally, as suggested by Yin (2003), individual case reports were prepared and sent to the informant for validation to support the reliability of the case findings.

4.1 Case descriptions

In order to explore the contextual variables in greater depth and conduct cross-case analysis two cases were selected for this study, Arla Foods and Billerud. They were selected on several bases:

1 Both corporations are part of the process industry – Arla Foods is in the food and beverage sector and Billerud is in the pulp and paper sector. That the production process is centred around raw materials also means that they share several fundamental characteristics in R&D as well (Barnett and Clark, 1996; Dennis and Meredith, 2000).

2 Though they may be defined as low-tech, both firms rely heavily on their R&D organisation to bring new products to market and improve manufacturing processes. Furthermore, both corporations’ R&D intensity is comparable to each other and to their respective industry averages (0.8% for the food and beverage industry and 0.7% for the pulp and paper industry (Lager 2002)).

3 Both corporations are multinationals as they conduct R&D and have production plants in more than one country and sales offices in more than ten countries.

4 It was determined that except for shared characteristics from being multinational process industry firms Arla Foods and Billerud were different in respect to the nature of their competitive environment, type and number of products and customers and type of technologies used. This allows for making comparisons on the contingencies revealed by the propositions.

4.1.1 Arla Foods

Arla Foods is Europe’s largest dairy corporation with a turnover of USD 6.4 billion and 21,000 employees, with its own production plants in eight countries and sales offices in 23 countries. It produces and markets branded products to end customers as well as supplying milk-based ingredients to industrial food producers. Hence, it sells both fast-moving consumer products (such as fresh milk, yoghurt, creams, cooking products, cheese, butter and spreads) and commodity products (such as retail packed milk powder, sweeteners and milk proteins). The industrial customers include corporations from a variety of industries, such as nutrition, dairy, meat, beverage, ice cream and pharmaceutical. While Arla Food’s portfolios of businesses are unrelated in terms of customers, distribution channels and merchandising, this multidivisional and diversified corporation is glued together by the use of the same raw material for almost
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all its products, viz. milk. Depending on product-market and industry characteristics Arla Foods uses dual generic competitive strategies, both differentiation and cost leadership.

Arla Foods has an R&D intensity of 0.5–0.6% and conducts R&D at three innovation centres. Development takes place in project teams comprising staff from production, marketing and innovation, whereas basic research is often carried out in conjunction with universities or other external research institutes. Of the internal R&D, about 90% is carried out in conjunction with marketing and about 10% is carried out in conjunction with production. The three innovation centres are involved in an annual centralised work process of innovation strategy formulation. In all, the innovation centres develop more than 200 new products each year.

4.1.2 Billerud

Billerud is a pulp and paper corporation with a sales turnover of around USD 1.0 billion that employs 2600 people. It has production plants in two countries and sales offices in 11 countries. Billerud is a niche player in a large and diverse industry, focusing primarily on two packaging paper segments: kraft paper and containerboard. Hence, Billerud uses differentiation focus as its generic competitive strategy. Billerud does not convert pulp into consumer products (finished products): its customers are exclusively manufacturers of paper-based packaging.

The main focus of Billerud’s R&D is to enhance product quality and to generate substantially new products. The R&D intensity is about 0.7% and the corporation develops 3–5 new products each year. There are no centralised R&D departments, so each production plant conducts its own R&D. The process of innovation strategy formulation is also mainly decentralised. Top management advises on product development concerns, whereas process development concerns are treated more or less in isolation at each production plant.

5 Findings from the case studies

Proposition 1: In the process of innovation strategy formulation, it is more appropriate to base the internal scan on intangible resources than basing it with respect to each specific product or each specific business segment.

Arla Foods supports an internal scan based on a corporate-wide set of intangible resources. A scan based on each specific product or each specific business is considered nearly impossible for such a highly diversified corporation due the vast amount of information it would be necessary to process about different products and markets. A centralised process of innovation strategy formulation is unfit to handle the extensive amount of information that is necessary when competing in many product-markets but works fine when scanning on the level of intangible resources. The, in many cases, short product-life cycles also make it difficult to conduct scanning based on products.

Billerud, on the other hand, supports an internal scan based on each specific end product or each specific business. Billerud formulates separate innovation strategies for each paper-mill, which makes it difficult to assess the complete set of intangible resources for the corporation as a whole. In addition, because Billerud uses a differentiation focus strategy, they have fewer products to scan.
Proposition 2: In the process of innovation strategy formulation, it is more appropriate to focus the external scan on corporations with similarities in intangible resources than focusing on investment patterns of immediate competitors in each product-market.

Arla Foods supports an external scan based on similarities in intangible resources. Arla Foods’ competitive environment is characterised by blurring industry boundaries, ever-changing customer preferences with frequent horizontal moves in the value chains (e.g. retailers introducing own labels and producing milk-based products), with often unidentifiable competitors as a result. Intangible resources, often originating from R&D, are considered the best competitive weapon available; therefore, it is important to scan for potential competitors who show similarities in intangible resources.

Billerud supports an external scan based on investment patterns of immediate competitors in each product-market. Billerud’s competitive environment is characterised by clear industry boundaries, with competitors easily identifiable. In addition, Billerud uses a differentiation focus strategy, primarily focusing on just two segments of the packaging industry (kraft paper and containerboard), making the competitive environment perspicuous.

Proposition 3: In the process of innovation strategy formulation it is more appropriate to evaluate the technology importance with respect to core products than to evaluate technology importance with respect to each given business segment.

Arla Foods supports evaluation of technology importance with respect to intangible resources for core product. As Arla Foods develops more than 200 new products annually, for numerous business segments, it chooses to evaluate technology importance with respect to a total of seven identified ‘focus areas’ (e.g. shelf-life, health and packaging). These focus areas make up the foundation of necessary intangible resources for most business segments.

Billerud supports evaluation of technology importance with respect to each business segment because it competes in very few business segments. Hence, it is possible to immediately determine technology importance with respect to each business segment.

Proposition 4: In the process of innovation strategy formulation, it is more appropriate to evaluate the relative technology position in respect to core products rather than to evaluate relative technology position with respect to each identified business segment.

Arla Foods supports evaluation of the technology portfolio with respect to relative technology position in each identified business segment. It uses a competence-gap analysis to determine its technology position in each business segment. As one R&D manager at Arla Foods said: “As it ultimately is about conquering a business segment with end products, there is no reward in finishing second; therefore, we have to know what we are up against and where we stand in terms of technology in each business segment”.

Billerud supports evaluation of the technology portfolio with respect to relative technology position in each identified business segment with the same basic arguments as in Proposition 3, that is, that there is no need for core products because of the low degree of diversity in both business segments and technology.

Proposition 5: In the process of innovation strategy formulation, the relationship between technology and business strategy should be characterised by a dynamic relationship rather than a static relationship.
Arla Foods supports the notion that there is a dynamic relationship between technology and business strategy. At Arla Foods the work processes of both innovation strategy formulation and business strategy formulation are centralised. Both strategy processes are run simultaneously and therefore facilitate a dynamic relationship. The role of R&D is to drive innovation strategy to make it easier for Arla Foods to conceptualise new products and to enter new markets.

Billerud supports the notion of more a static relationship between technology and business strategy and stresses that the innovation strategy should respond to the needs of the business strategy. Business strategy formulation is centralised and conducted at corporate headquarters whereas innovation strategy formulation is decentralised and conducted at each paper-mill. Business demands drive innovation strategy in such a way that R&D delivers technical solutions for product requirements. Corporate headquarters also advises on product development concerns, which is used as input to each paper-mill’s process of innovation strategy formulation.

Proposition 6: In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific intangible resources are met rather than to ensure that investments are committed to each specific business.

Arla Foods considers it is more appropriate to commit investments to ensure competence requirements for specific core products. Each of its seven focus areas contains intangible resources which are the bases for corporate-wide product development. The investments in focus areas are conducted with the use of ‘strategic buckets’ (Cooper et al., 1998) to ensure that intangible resource investments in different focus areas do not compete with each other.

Billerud considers it more appropriate to ensure that resources are committed to each specific business with the basic arguments that the low degree of diversity in both business segments and technology does not entail investments in intangible resources used for a broad range of products.

Proposition 7: In the process of innovation strategy formulation, it is appropriate to commit investments to ensure that requirements for specific core products are met rather than to ensure that investments are committed to specific products.

Arla Foods supports committing investments to specific core products. The need for specific products is not dealt with directly in the work process of innovation strategy formulation, but rather it is up to the innovation centre to create a wellspring of knowledge from which the diversified business units can drink when needed. However, the main goal is not just investing for current product application, but building intangible resources and core products that can be applied in future uses.

Billerud supports committing investments to each specific product with the same basic arguments as in Propositions 3, 4 and 6, that is, that there is no need for core products because of the low degree of diversity in both business segments and technology. In an industry where production alterations imply heavy investments and require extensive lead-time for implementation, any move by competitors will require development time and therefore make countermoves possible for industry incumbents.

Proposition 8: In the process of innovation strategy formulation, the revisited Booz Allen and Hamilton methodology is more suitable than the original methodology.
A resource-based approach to the Booz Allen and Hamilton methodology

Arla Foods supports the revisited methodology for innovation strategy formulation.
Billerud supports the traditional methodology for innovation strategy formulation.

Table 1 summarises the findings of propositions in the case studies. The findings show that Arla Foods supports the revisited, resource-based, Booz Allen and Hamilton methodology, whereas Billerud supports the original, positioning-oriented, Booz Allen and Hamilton methodology. It is clearly showed that that both multinational corporations are consistent in using either a resource-based or a positioning approach to innovation strategy formulation.

**Table 1** Summary of the findings with respect to each proposition

<table>
<thead>
<tr>
<th>Proposition</th>
<th>Arla Foods</th>
<th>Billerud</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Internal scan</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>2 – External scan</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>3 – Tech. importance</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>4 – Relative tech. importance</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5 – Aligning strategies</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>6 – Invest in resources</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>7 – Invest in core products</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>8 – Revisited methodology</td>
<td>B</td>
<td>A</td>
</tr>
</tbody>
</table>

*Note: A = Original Booz Allen and Hamilton methodology based on a positioning approach to strategy; B = Revisited Booz Allen and Hamilton methodology based on a resource-based approach to strategy.*

6 Discussion of the results

The case studies indicate that there seem to be several contextual grounds for either adhering to the original Booz Allen and Hamilton methodology or following the reasoning of the revisited methodology. Three overarching contingencies have been identified; the level of diversification; the characteristics of industry boundaries, customers and competitors and the role and organisation of R&D.

6.1 Level of diversification

The case-findings illustrate that the level of diversification is an important factor in deciding on an innovation strategy methodology. The level of diversification can be analysed from two main points of view (Chiesa and Manzini, 1997); either from an external perspective, which focuses on the product-markets and industries entered, the products offered and the customers and geographical area served or an internal perspective which focuses on the relationships between diversification and tangible and intangible resources.

In the case of Arla Foods’ external perspective it can be considered highly diversified as in terms of product-markets served, as it sells both fast-moving consumer products (such as fresh milk, yoghurt, cream, cooking products, cheese, butter and spreads) and commodity products (such as retail packed milk powder, sweeteners and milk proteins) to industrial customers in a variety of industries (such as nutrition, dairy, meat, beverage,
ice cream and pharmaceuticals) spread out geographically all over the world. However, internally, Arla Foods is highly focused on a few central focus areas (e.g. core products and intangible resources) which are valuable in a many product-markets. Hence, the sheer number of end-products and different product-markets suggests that Arla Foods cannot support a positioning approach. Assessing each product and product-market in terms of positions would be too time-consuming, especially in the light of some cases of extremely short product life-cycles.

Externally, Billerud is competing in a few product-markets, with few product offerings, and has only one type of customers, manufacturers of paper-based packaging, while 81% of sales are made within Europe. Internally, Billerud has a somewhat consistent collection of intangible resources in R&D. Hence, in terms level of diversification, Billerud seem to have the option to either focus on positions or resources in the process of innovation strategy formulation.

6.2 Characteristics of industry boundaries, customers and competitors

The characteristics of the environment was suggested by the resource-based approach as being an important reasoning for switching perspective from positions to resources. In a positioning approach to strategy, it is assumed that each product-market is distinct, hence, customers and competitors are identifiable and competition occurs at the level of product lines and/or businesses (Sissors, 1966). However, these assumptions are not valid in the case of Arla Foods. As an example, Arla Foods experiences blurring industry boundaries as retailers introduce their own labels and produce their own milk-based products. Hence, backward integration (Porter, 1985) is used by retailers to get around intermediate producers, such as Arla Foods, while at the same time integrating forward to reach end customers through retail-owned-brands. As a fact, industry boundaries are blurring as former customers are becoming competitors.

On the other hand, the case of Billerud does not experience the same turbulent competitive environment. Hence, the underlying assumptions made in a positioning approach, still hold in the corporate context of Billerud and are, therefore still, a solid starting point for strategy formulation. In the case of Billerud, the perceptions of quality constantly changes for Billerud’s customers and therefore gradually demand more complex products. This has got to do with trends in packaging of consumer products (such as coated paper for carrier bags and fashion bags). Arla Foods introduces about 200 new products each year while competitors and customers remain, more or less, ambiguous. Hence, Arla Foods competitive environment, is characterised by weakly defined industry boundaries and where competition is mostly played out on the ability to generate new products or market combinations.

6.3 The role and organisation of R&D

In the case of Arla Foods, innovation is seen as a powerful competitive weapon which can influence business and corporate strategies. As both the work-process of innovation strategy formulation and the R&D function are centralised while the competitive environment is turbulent, a dynamic interaction between innovation and business strategies is encouraged by top management. As Arla Foods develops about 200 new products each year, it is not possible to evaluate each specific product development project with respect to the business portfolio. Furthermore, as intangible resources
change more slowly than projects or product lines, evident in the case of Arla Foods, it must be extremely difficult and time consuming, to capture an attractive relative position in a product-market without having the suitable intangible resources already available as the competitive environment is turbulent. Instead, R&D is used as a wellspring of knowledge for the business portfolio to capitalise on and be driven by. This is one reason for why Arla Foods supports a dynamic interaction between innovation and business strategy. Billerud, on the other hand, uses several decentralised work-processes of innovation strategy formulation, conducted at each paper-mill, while the work-process of business strategy formulation is centralised and conducted at corporate headquarters.

Hence, in the case of Billerud, R&D responds to the needs of the business portfolio in terms of product development and to the needs of each paper-mill in terms of process development. The alignment between business and technology strategy is therefore more commonly centred on the demands of business strategy.

In summary, the role and organisation of R&D, along with the other two identified contingencies, seem to heavily influence if positions or resources is the basis in innovation strategy formulation.

7 Conclusions and further research

Not much research had focused on tools that firms actually use on a day-to-day basis. Tools have become the domain of management consultants. However, studying these tools is one way of getting closer to what firms actually do. While practitioners are in need of management tools and techniques that can help them structure problems and aid in decision making, this paper shows that a resource-based approach to innovation strategy formulation can useful in an appropriate setting. The revisited Booz Allen and Hamilton methodology shows that while firmly grounded in the resource-based approach, corporations will still benefit in explicitly taking into consideration the competitive environment. We have found evidence to suggest that when a corporation’s competitive environment becomes too complex to predict and the product-markets become too many to survey, it would seem logical to retreat into the world of resources.

The case study also shows that both the revisited methodology, based on a resource-based approach to strategy and the traditional methodology, based on a positioning approach to strategy, are used in corporations today. In addition, it shows that a corporation focuses almost exclusively on either resources or positions in the process of innovation strategy formulation; hence, a mixture of the two approaches does not exist in this study. However, this does not automatically imply that the possibility of hybrids existing is excluded.

It is indicated that the choice between the methodologies is affected by three key aspects

1. the level of diversification
2. the characteristics of industry boundaries, customers, competitors and
3. the role and organisation of R&D.

In that sense, this paper highlights the importance of adjusting to the internal context as well as the external context when choosing a suitable methodology for innovation strategy formulation. The question is not whether focusing on resources or positions is
It is worth mentioning that the two methodologies presented in this paper are not intended to function as the sole basis for innovation strategy formulation. Instead, they can be used as an overarching framework and as a starting-point for discussion.

7.1 Limitations and further research

The goal of this study has been to expand and generalise theory from propositions on strategy formulation processes. The limitations of case studies, especially the difficulties of making scientific generalisations from case results, imply that replications of the study will provide valuable additional knowledge on strategy formulation processes. Further work either deepening the existing cases or expanding the study to include complementary case firms may yield additional contingencies or more knowledge on the contingencies previously described. The contingencies found in this study may also be confirmed in quantitative studies.

The process industry is considered a mature industry. It is possible that newer and more dynamic industries will provide different contingencies. Exploring the two models of strategy formulation across industries may lead to the discovery of other contingencies. Also it is possible that as resource configurations (financial, physical, incremental, etc.) that firms use differ across firms and industries so will the formulation processes.

At the end of the day, researchers and managers want to know how all this relates to performance – or simply: which firms fare better? While theory suggests that there must be a fit between strategy formulation process and context this relation should be explored further.

In conclusion, any additional studies, whether they are deepening case studies of quantitative investigations, should focus more on performance as a dependent variable.

8 Managerial implications

As practitioners are in the need of normative and hands-on management guidelines, the aim of this section is to provide practical guidance. In this paper, a revisited methodology for innovation strategy formulation is presented and three contingencies are identified. These three contingencies are important for practitioners to take into consideration when choosing between a positioning or resource-based approach to the Booz Allen and Hamilton methodology. Evidence show that there is a clear need for adopting an approach consistent with the corporate internal context and competitive environment. Firstly, it is indicated that level of internal and external diversification influences appropriate approach. Hence, if a corporation is present in many product-markets, with a wide range of customers, wide geographical coverage and have a compact bundle of resources it adheres to the revisited, resource-based, methodology. A positioning approach is favoured if a corporation is present in only a few product-markets, with a limited set of customers. Secondly, if a corporation experiences a turbulent competitive environment with blurring industry boundaries as customers, competitors are hard to identifiable while horizontal and vertical activity in the value chain is volatile; the
A resource-based approach to the Booz Allen and Hamilton methodology seems to adhere to the revisited methodology. A positioning approach is favoured when the corporation is active in a less dynamic environment. Finally, a resource-based approach to innovation strategy formulation is favoured when the corporation expects R&D to drive business strategy. On the contrary, a positioning approach is favoured when R&D is more often driven by business strategy.

The three contingencies and the most appropriate methodology for innovation strategy formulation are summarised in Figure 3 below. The original and revisited methodology along with the illustration provided below can be used for communicative purposes among managers from market-oriented functions, such as sales and marketing and technology-oriented functions, such as R&D and production. Where many management tools of today are very detailed and multifaceted, which makes them difficult to implement, the straightforward nature of the original and revisited Booz Allen and Hamilton methodology implies that they can be used as a first step towards a more detailed and structured approach to innovation strategy formulation.

![Two approaches to innovation strategy formulation and when to use which](image-url)

**Contingency 1: Level of diversification**

- **External consistency:**
  - Product markets served
  - Industries served
  - Type of customers served
  - Geographical area served

- **Many** | **Few**

- **Internal consistency:**
  - Relationship between diversification and tangible and intangible resources

- **Related** | **Unrelated**

**Contingency 2: Characteristics of industry boundaries, customers and competitors**

- **External factors:**
  - Industry boundaries
  - Identifiable customers
  - Identifiable competitors
  - Movement in value chains

- **Ambiguous** (i.e. turbulent) | **Unambiguous** (i.e. stable)

**Contingency 3: The role and organisation of R&D**

- R&D is expected to:
  - at all times drive business strategy
  - be driven by business strategy
Acknowledgements

This work has been financed by the Kempe Foundations and Jan Wallander’s and Tom Hedelius’ Foundation; their financial support is gratefully acknowledged. The authors also wish to express their sincere appreciation to Henrich R. Greve and Torben J. Andersen for their insightful comments and Thomas Lager for valuable assistance.

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Note

By this classification, various concepts such as core competence (Leonard-Barton, 1992; Prahalad and Hamel, 1990), capabilities (Grant, 1991), distinctive competence (Hitt and Ireland, 1985; Selznick, 1957; Snow and Hrebiniak, 1980), dynamic capabilities (Eisenhardt and Martin, 2000; Teece et al., 1997), strategic assets (Winter, 1987), resource deployment (Hofer and Schendel, 1978), to name a few, are all part of the broader categories of intangible and/or tangible resources. For the purpose of this paper however, we need not concern ourselves with the debate within these concepts (Foss, 1998), but will simply focus on the basic premises of the resource-based approach.
Paper IV
OPENING UP INTRAFIRM R&D: INSIGHTS FROM THE ORGANISATION OF PRODUCT AND PROCESS INNOVATION

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This paper focuses on strategic management of intrafirm industrial R&D. It opens up the R&D organisation by separating product and process innovation and exploring these in terms of the structural variable of centralisation versus decentralisation. Case studies of three multinational firms, representing food and beverage, mining and minerals, and pulp and paper industry sectors reveal that dual structures may exist within the R&D organisation; one for product innovation and one for process innovation. Consequently it is suggested that the conventional notion of R&D organisational design, equating R&D more or less with product innovation, does not present a complete picture for many firms. Furthermore, based on the resource based view and the case studies this paper proposes that strategic importance, width of applicability, and potential disruptiveness of product and process innovations are related to the organisation structure of intrafirm R&D. These findings are discussed in terms of implications for effectively managing industrial R&D and a matrix illustrating different configurations of intrafirm R&D is presented as a tool for better understanding the organisational structuring of product and process innovation.

1. Introduction

For many firms innovation is an important business driver. This being the case, managers are hard pressed to design effective organisational structures to support these activities – which unfortunately - also are widely known to be difficult to organise and manage. While the question of what organisational structures and management processes facilitate or inhibit innovation has been explored before [e.g. Damanpour (1991); Damanpour and Gopalakrishnan (1998)] few studies have investigated the internal structure of the research and development (R&D) organisation itself [Argyres and Silverman (2004)].

From a internal structure viewpoint the question of centralisation versus decentralisation of R&D is a key issue when organising innovation activities, and it has a long history of research in organisation theory [e.g. Ford and Slocum (1977); Mintzberg (1999); Pugh et al. (1963)] and innovation management [e.g. Burns and Stalker (1961); Chiesa (2001); Damanpour and Gopalakrishnan (1998); Zaltman et al. (1973)]. However, research focusing on the centralisation-innovation link has devoted very little attention on the differences between product and process innovation. In fact, much of the prior research in organising innovation within firms has failed to recognise the significance of the type of innovation that the firm pursues. While the broader distinction between administrative and technical innovation has previously been dealt with [starting with Daft (1978)] not much research has
explored the differences between product innovation and process innovation. Since researchers have historically focused mainly on product innovation [Pisano and Wheelwright (1995)] the lack of distinction between product and process innovation have often created confusion both in academic research as well as in operational performance of industrial R&D [Lager (2002b)]. As empirical research suggest that product and process innovation is related with different organisational structures [Cohen and Klepper (1996); Lager and Hörte (2005); Utterback and Abernathy (1975)] this study will separate these types:

- **Product innovation** is defined as development driven by a desire to improve the properties and performance of finished products. Objectives of product innovation may be to develop new products, improve product properties, improve product quality etc. [Lager (2002a)].
- **Process innovation** is defined as development driven by internal production objectives. Such objectives may be reduction of production costs, higher production yields, improvement of production volumes, environment-friendly production etc. [Lager (2002a)].

The aim of this study is to open up the intrafirm R&D organisation by studying the organisation of both product and process innovation activities. The study explores differences in organisational structure by focusing on the concept of centralisation as a measure of this differentiation.

2. **Centralisation, decentralisation, and innovation**

2.1 **Defining centralisation and decentralisation**

Centralisation has been defined in a variety of ways although most refer to the distribution of power and the degree to which decision making and authority is concentrated at a single point within the organisation [e.g. Duncan (1976)]. When most decisions are made hierarchically, that organisation is often said to be centralised, while in a decentralised organisation more decisions are delegated to subordinate personnel or units. However, there are three common uses of centralisation concepts; vertical (the dispersion of power down the chain of authority), horizontal (the extent to which non-managers control decision processes), and physical (concerning the location of facilities, people and objects) [Mintzberg (1999)].

Much of the research concerned with the centralisation-decentralisation-innovation link focuses at the unit level and on the internal structural characteristics that promote innovativeness [Damanpour and Gopalakrishnan (1998)]. Negative effects of centralisation on employee motivation, initiative, commitment, and collaboration were found to affect the organisations propensity to innovate [Daft (1978); Damanpour (1991); Duncan (1976); Mintzberg (1999); Zaltman et al. (1973)]. Because of these internal consequences of centralisation early organisational researchers believed that firms would become more organic, i.e. more decentralised, as time went by and innovation rates and scientific knowledge increased [e.g. Burns and Stalker (1961)]. However, empirical research has not been able to support these claims. Instead there has been a tendency of R&D going back and forth between centralised and decentralised structures [Edler et al. (2002); Eto (1991); Hirsch-Kreinsen (2005); Roberts (1995)]. Rather than being part of an evolutionary development the shifts in centralisation and decentralisation of corporate and divisional R&D seem to be linked to a shifting view of strategy and organisation [Chiesa (2001); Roussel et al. (1991)].

This study uses the concept of vertical centralisation to distinguish between centralised and decentralised R&D in such a way that R&D activities that are being controlled from higher up in the firm hierarchy are considered being centralised, while R&D activities controlled at a lower organisational level are considered decentralised. This definition implies that the internal organisational complexity of the R&D organisation as such is not the main focus – but rather the locus of decision making concerning R&D activities within the firm as a
whole. Although the centralisation and decentralisation are not absolute term, but rather two ends on a continuum (Corporate and divisional R&D can take several forms along this continuum as illustrated by Chiesa [(2001)] and Argyres and Silverman [(2004)]) they will be treated as such in this study.

Because the link between strategy and organisation structure is well founded in management research [e.g. Chandler (1962)] this study will apply a resource based view to formulate a framework for centralisation and decentralisation of R&D.

2.2 Centralisation, decentralisation and the resource based view

The resource based view suggests that firms grow and remain competitive because they are able to exploit of their unique resources [Barney (1991); Penrose (1959); Wernerfelt (1984)] and capabilities [Leonard-Barton (1992a); Teece et al. (1997)]. The critical task in the resource-based approach to strategy is to determine the most favourable composition of resources [Grant (1991)] and to continuously create new and develop existing capabilities [Leonard-Barton (1992a)]. For many firms the R&D organisation has a central role in managing and developing resources.

When applying the logic of the resource based view to the question of centralisation versus decentralisation of R&D several aspects are discussed (and illustrated in figure 1);

- **Strategic importance:** Central to the resource based logic is that certain resources (and capabilities) are more important than others. In light of the importance that R&D has on the creation and development of resources and capabilities, and in turn on competitiveness, it is understood that corporate level strategy [Grant (1991); Teece et al. (1997)] and top management [Amit and Schoemaker (1993)] must address these issues. This is supported by further studies which find that senior management plays an important role in building capabilities [Verona (1999)] and by Leonard-Barton who says that, as the emphasis on organisational learning over immediate output is critical for long term competition, R&D should be consciously managed for continuous organisational renewal [Leonard-Barton (1992a)].

  **Proposition 1:** The resource based view suggests that R&D activities that are more important for building resources and capabilities within the firm should be under corporate control. R&D activities which are not central for building resources and capabilities can be decentralised.

- **Width of applicability:** Prahalad and Hamel argue that a corporation should be built around a core set of competencies by which a firm can get access to a wide variety of markets [Prahalad and Hamel (1990)]. Core competencies are unique combinations of resources which have longer life spans than individual products or technologies and can be used in many end products. Product and process innovation projects draw on these core capabilities, but are also used to develop the capabilities themselves [Leonard-Barton (1992)]. However, if these synergies are to be captured across businesses corporate R&D needs to play an active role in managing them [Chiesa (2001); Markides and Williamson (1996)]. This view is supported by Argyres and Silverman who in studying R&D organisational structure in relation to competencies and knowledge in more detail found that firms in which R&D is centralised tend to pursue R&D that has a greater and broader impact on future technological development [Argyres and Silverman (2004)].

  **Proposition 2:** The resource based view suggests that R&D activities that aim at wider application within the firm or achieving a broader set of knowledge or competencies should be centralised. R&D activities with a narrow range of application should be decentralised.

- **Potential disruptiveness:** The notion that resources are slow to change is central in the resource based view [Penrose (1959)]. There is a path dependence in the resources and
capabilities that a firm can utilise [Helfat (1994); Teece et al. (1997)] which means that firms may not be able to respond to changes in the manner or the speed that they may intend. Given that, any disruptive technology (i.e. technology that overturns existing dominant technology) has the potential of severely disturb profitability for incumbent firms [Anderson and Tushman (1990); Christensen (1997)]. Therefore, being able to generate fundamentally different, i.e. radical, innovations or guarding the firm from discontinuities may be critical for long-term survival (Fiol points out that resources and capabilities must constantly change and that competitiveness is as likely to be derived from the ability to destroy and rebuild specialised resources over time [Fiol (2001)]). Studies of radical innovation has found that these were more likely to occur in centralised structures [Ettlie et al. (1984)] and separated from ongoing business activities [Rice et al. (1998)] while incremental innovation on the other hand benefit from being decentralised. Also, guarding against technological discontinuities by scanning the environment is also facilitated by centralised R&D as these structures have the potential to scan more broadly [Argyres and Silverman (2004); Leonard-Barton (1995)] and better monitor scientific development [Ahuja and Katila (2004)].

**Proposition 3:** The resource based view suggests that R&D activities that build on previous research and aims at making incremental changes should be decentralised. R&D activities aiming at creating or guarding against disruptive innovations should be centralised.

![Centralisation or decentralisation of R&D diagram](image)

**Figure 1:** Model for centralisation or decentralisation of R&D according to the resource based view.

### 2.3 Framework and research purpose

While the model proposed in figure 1 is generic, and thus explanatory for all types of innovation activities, there is a need to differentiate between product innovation and process innovation. To achieve this aim, the model for centralisation or decentralisation of R&D proposed by the resource based view is used as a foundation for a framework based on the distinction of product and process innovation (figure 2).
Instead of viewing the R&D as being either centralised or decentralised the distinction between product and process innovation allows us to consider several organisational possibilities (depicted in figure 3). In viewing product innovation and process innovation as separate activities within a firm this implies that there are nine possible organisational configurations. Product innovation can be organised either in a centralised or decentralised fashion, as can process innovation. However, there is also the possibility that a firm does not have any in-house product innovation and/or process innovation activities.

![Figure 2: Framework for studying centralisation and decentralisation as relating to product and process innovation.](image)

The aim of this study is to explore differences in organising R&D within a firm in terms of product innovation and process innovation. In order to achieve this aim the concept of centralisation or decentralisation of decision making of key R&D activities is used as a measure of this differentiation. If there are structural differences in the way intrafirm R&D is organised, this study will ascertain if these can be explained by the framework model based on the resource based view.

3. Method

3.1 Research method

A case based approach was used as this study of centralisation versus decentralisation of product and process innovation in R&D organisations is explorative [see Eisenhardt (1989);}

![Figure 3: Possible organisational configurations for product and process innovation.](image)
Yin (2003)]. The case study interviews were conducted with informants in top management positions in Swedish process industry firms between 2004 and 2006 by a pair of researchers who kept separate case protocols. The data from the interviews were integrated and triangulated with further case data collected via annual reports, internal reports and internal strategy documents. Final analysis and concluding data collection was conducted with the theoretical framework based on the resource based view as orientation. By iterating between theory and data, i.e. returning to the cases to find more information on specific issues and contingencies, we believe that we have reached the theoretical saturation advocated by Eisenhardt [(1989)]. Finally, as suggested by Yin [(2003)], individual case reports were prepared and sent to the informant for validation to support the reliability of the case findings.

3.2 Case selection and descriptions

Three cases were selected from the process industry; Arla Foods in the food and beverage sector, Billerud in the pulp and paper sector, and Boliden in the mining and smelting industry. An important aspect that makes the process industry a suitable context of studying centralisation and decentralisation in terms of product and process innovation is that process innovation often constitutes a large share of R&D spending compared to other manufacturing industry [Lager (2002a)] and that product innovation is enabled by process innovation [Barnett and Clark (1996); Lim et al. (2006)]. Process industry firms can therefore be expected to have both product and process innovation activities organised internally. While it has been shown that mature and low-tech firms have difficulties being innovative for organizational reasons [Dougherty and Hardy (1996)], recent studies have also found that process industry firms frequently change their R&D organisations [Hirsch-Kreinsen (2005)] which suggests that these firms are acting to improve organisational efficiency and effectiveness.

The specific firms in this case study were selected on several bases:

1) R&D is considered a key activity and the selected firms rely heavily on their R&D organization to bring new products to market and improve manufacturing processes.

2) The selected firms can be viewed as being typical in their respective industry sector [mining and smelting - Eltringham (1998); pulp and paper - Phillips (2000); food and beverage - Trail and Grunert (1997)] while the R&D intensity of the selected firms is also equivalent to the respective industry averages [see Lager (2002a)].

3) All firms are alike in the sense that they are considered as multinationals as they all conduct R&D and have dispersed production plants in more than one country.

Arla Foods. Arla Foods is Europe’s largest dairy company with a turnover greater than USD 7.8 billion and roughly 20,000 employees. Arla Foods is a co-operative owned by approx. 13,650 milk producers in Denmark and Sweden. With an R&D intensity of 0.5 – 0.6% Arla Foods has three R&D centres and about 200 people working in R&D.

Billerud. Billerud is a packaging paper company with a sales turnover of USD 960 million that employs 2,600 people in 11 countries. Production is concentrated to four paper mills in Sweden and the UK. The R&D intensity is about 0.7% and R&D is mainly conducted at each of the four paper mills. In total, around 50 employees work with product and process development.

Boliden. Boliden is a mining and smelting company focusing on production of copper, zinc, lead, gold and silver. The number of employees is approximately 4,500 and the turnover amounts to approximately USD 2.8 billion annually. The Boliden plants are run as local subsidiaries, part of a greater portfolio, while the commercial organisation, mainly located in
Stockholm, deals with purchasing, logistics and sales. Boliden, with an R&D intensity of 0.9% conducts most of its R&D at the mines and smelting plants.

4. Results from the case studies

4.1 Arla Foods
At Arla Foods today about 85% of the R&D budget is concerned with product innovation. However, the share of process innovation has been increasing as the cost focus in the dairy industry has become more prominent.

Product innovation
Arla Foods is divided into three autonomous divisions; Nordic, International and Ingredients were each division has a research centre. The R&D unit of the Nordic division conduct product innovation concentrated on fresh milk and desserts, the international division on cheese and butter and the ingredients division on milk powder. Each research centre is also responsible for knowledge creation within general areas (such as knowledge around shelf-life, packaging, health etc.). A multitude of different end-products are then based on these general knowledge areas as over 200 new products are launched each year. The R&D director at Arla Foods Nordic explained it as while “marketing focuses on how we can beat competitors here and now R&D is preoccupied with winning the war”. The knowledge creation takes place in product innovation as product development projects are used to spur and accumulate knowledge within the general areas. The knowledge created in a research centre is spread to the other research centres through workshops and formal meetings.

Process innovation
At the onset of the case study Arla Foods devoted limited attention to process innovation. Some projects were done locally but mostly Arla Foods relied on the suppliers of production technology to come up with solutions to its process technology needs. As process innovation is an important enabler for product innovation this is a strategically important issue. However, the number of large production technology suppliers to the diary industry is limited to three actors, all of which have been unwilling to come up with process innovations which satisfy the needs of Arla Foods. For this reason, Arla Foods have now decided to internally establish a function which works exclusively with process innovation. The aim is to develop knowledge which can be spread to its 63 production plants world-wide. The intention is that new products can be extracted out of the existing production plant, through process innovation, and to reduce costs of production significantly. By pooling resources process innovation can become more efficient and better at “driving technological development” and managing large and “difficult” projects.

4.2 Billerud
At Billerud about 50% of the R&D budget is focused on product innovation and 50% is focused on process innovation. In general the focus at Billerud has shifted more towards product innovation while process innovation has become more of a short-term issue than before.

Product innovation
When the case studies were initiated in 2004, new product development projects were initiated autonomous at each paper mill. However, while understanding customers has always been a focus at Billerud, product innovation initiatives were most commonly initiated by technicians and claims were made that the new products lacked market-orientation. Therefore, during the course of the case study, top management decided to organise product innovation
activities into three “Business areas” (Market Pulp, Packaging Boards, and Packaging & Speciality Paper) with the intention of becoming better at understanding the customer and the customers’ industry value chain. According to the head of R&D at Billerud Karlsborg “the main objective [of the new organisation] is to build this competence”.

Product innovations are initiated through a number of segment teams which contain members of R&D, technical customer support, and sales, in total 5 or 6 employees. The focus of the teams is centred on a number of specific end products (such as sack paper, white liner, and medical containers) which in turn are based on broad product areas (such as Kraft paper or containerboard). Each team consist of appropriate experts’ regardless of organisational belonging. Hence, while the members of the segment teams are geographically dispersed their competencies are pooled for specific projects. Their activities are coordinated by four annual product innovation meetings where the teams and a corporate innovation advisory board participate. The corporate innovation advisory board settle on a broad frame for resource allocation among future areas of product innovation and an overall strategy for product innovation is crafted on the basis of business segment attractiveness.

Process innovation
Concerning process innovation the head of R&D at Billerud Karlsborg states that the objective of each production plant “is to develop what we already have – and that we do best ourselves”. Consequently, process innovation is conducted, more or less in isolation, at each paper mill as it deals mostly with incremental activity carried out close to each production plant (i.e. improving efficiency of existing paper machines). Hence, each production plant is autonomous on process innovation as each plant is kept responsible for production yields and production volumes. There is no formalised cross-plant coordination and no formal routines for knowledge sharing on process innovation. Instead, issues concerning process innovation are handled through informal networks. An interesting comment from an employee in technical customer support was that “when we talk about innovation at Billerud, we generally talk about innovation activities related to the development of new products… not activities related to innovation in the production processes”.

4.3 Boliden

Product innovation
Boliden does not conduct any product innovation. The smelters extract and produce predetermined basic metals (such as zinc, copper, gold and lead) out of ore. The challenge for Boliden is to produce the same commodity product with varying quality of input materials.

Process innovation
At Boliden each production plant is autonomous with respect to process innovation. The objective of R&D is to make everyday improvements in the continuous production process and therefore many of the R&D employees are attached to a certain part of the production line and decisions are made locally over a cup of coffee. The aim of process innovation in Boliden is according to head of R&D at the smelter in Rönnskär to “make incremental process innovations to the existing production process” and to do this Boliden has “chosen to work with proven technology”. The main drawback of decentralised process innovation as identified by Boliden is the lack of long term dedication and that “we don’t know what we are doing in 10 years”. Another drawback is “as most of the R&D employees are working very close to the production process we have to avoid ending up with yet another production engineer… the autonomous R&D employees should contribute with process improvements which are more significant and long-term than the ones that the production engineer deliver”.
5. Discussion of findings and suggestions for further research

Through analysis of the case firms it was found that product innovation and process innovation may be organised differently within the same R&D organisation. In a sense, the R&D organisation may have dual structures, at least in terms of centralisation and decentralisation (these findings are presented in figure 4). This finding sets the study apart from much previous research that has not differentiated between product and process innovation. The case studies also indicated that different aims for product innovation and process innovation derived in the propositions were related to the structural organisational choices of the studied cases.

At Arla Foods both product and process innovation is now centralised. Product innovation is centralised primarily to build knowledge and competence in general areas. This competence is then applied when developing a multitude of different products based on these knowledge areas. Process innovation is primarily centralised in order to manage the development of more long-term and more radical process innovation projects.

At Billerud, where knowledge about customers is important, product innovation is centralised while process innovation is decentralised. Product innovation is concerned with building competence concerning customers and the industry value chains, and by pooling resources centrally Billerud aims at developing a wider range of products. Process innovation is mainly concerned with incremental innovations and optimising existing production technology and processes.

At Boliden there is no product innovation, only decentralised process innovation. The reason for decentralisation is to make everyday incremental improvements aimed at cutting costs in the continuous production process. As each plant is run independently there is little incentive to pursue innovations with broader areas of application.

It seems as if the rationales for organising product and process innovation uncovered in the case studies were consistent with the predictions of the framework based on the resource based view. The organisational changes that occurred during the study period further illustrated that as the rationale for innovation changed within the case firms so did the organisational structure.
As the propositions that came out of the framework were supported by the case studies the matrix presented above can be used to discuss several implications of the study findings. While being careful not to make too far-reaching generalisations from a limited set of case firms managers can use the matrix to consider what configuration is most suitable for the kind of innovation, in terms of product and process innovation, which the firm wishes to pursue. A firm that wishes to generate radical process innovations should according to theory have a more centralised organisation concerning process innovation, etc. Another way of using the results is predicting what kind of innovations will be produced given the structure of the existing intrafirm R&D organisation. It is not uncommon to hear managers complain that their R&D organisation only generates incremental innovations and not enough breakthroughs. Based the findings presented of this study, managers can ask themselves whether the results they call for are in line with the way in which R&D is organised. Determining the strategic importance, width of applicability, and potential disruptiveness of the firm’s R&D activities and pairing this against the organisational structure is a first step towards managing R&D more effectively.

In the case studies it became apparent that process innovation has not always been seen as being part of the R&D organisation – even by R&D employees. This would suggest that both middle and top managers might not always take process innovation into consideration when organising R&D. This study can, by opening up the intrafirm R&D organisation, make managers more perceptive of the organisational demands of process innovation. As noted by the head of R&D at the Boliden smelter – “by losing the focus on process innovation you risk ending up with just another process engineer”. If not organised appropriately process innovation may turn out to become little more than a solver of day-to-day operational problems.

This study focuses on intrafirm R&D. However, a great deal of R&D takes place outside of the intrafirm R&D organisation, particularly in the process industries [Hirsch-Kreinsen et al. (2005)] – either in networks with other firms or in external research institutes. The make-
or-buy question of internal resource development versus external resource acquisition is a central issue in the resource based view. So, while the study’s focus is on the intrafirm organisational structure the findings can also be used to discuss external sourcing issues. For example, it is argued that knowledge created through intrafirm R&D affect the ability for corporations to recognize the value of new information, assimilate it, and apply it to commercial ends [Cohen and Levinthal (1990)]. This concept of absorptive capacity, argues that by having already developed knowledge in an area, a corporation knows more precisely what additional information it will require to be able to effectively exploit any new advances that may materialize. The way in which intrafirm R&D is organised will therefore also affect the way a firm acquires and integrates external resources and competences. The initial findings of this study can be used to further explore the relationship among intrafirm product and process innovation, technological acquisitions, and interfirm R&D. Investigating the determinants for certain combinations of the degrees of centralization of product and process innovation, and how they might link to the underpinning efforts to develop competencies and competitive advantage will advance academic understanding of organising innovation and help managers make more informed decisions.

This study touches on two middle-range theories of innovation – that of type of innovation (product and process innovation) and that of radicalness of innovation. However, it does not take into account the concept of stage of innovation (for a thorough discussion of middle-range theories see Damanpour and Gopalkrishnan [(1998)])). It can be argued that in order to further improve the model, and making it more fine-grained, the concept of stage of innovation could also be integrated. However, the reality of R&D activities in process industry is that projects shift between different product innovation and process innovation phases many times during the development process. So, while at the project level there may be a need for altering team/project structures as projects unfold, the overarching R&D organization will be hard-pressed to deal with this complexity at a structural level. Nevertheless, questioning the simplicity of the model raises issues such as timing of project handovers, integration matters, formal versus informal organisations, departmental belonging etc. In a sense this is but a first step in opening up the intrafirm R&D organisation.

6. Conclusions and managerial implications

Foremost, these case studies show that firms may organise product and process innovation differently in terms of centralisation and decentralisation. In that sense the conventional notion of R&D organisational design, equating R&D more or less with product innovation, does not present a complete picture. This illustrates that R&D can function under dual structures, which is not apparent when R&D is considered more or less synonymous with product innovation.

The study also accentuates the importance of a firm’s demands on innovation and show how these demands can be linked with the structure of the organisation. The resource based view proposes that managers need to ask what kind of innovations the organisation is looking for in terms of product innovation and process innovation. Depending on the degree of strategic importance, width of applicability, and potential disruptiveness of R&D activities the firm must make choices concerning the centralisation or decentralisation of product and process innovation. In practice, this implies that R&D activities that are of strategic importance, have a wider applicability, or are aimed at radical or disruptive innovations should be centralised; while R&D activities that are less strategically important, have a narrower range of application, and are primarily aimed at incremental innovation should be decentralised. In conclusion, the R&D organisation must be consistent with the expectations of R&D - i.e. there should be an internal fit between strategy and structure. By reflecting on
the model for centralisation or decentralisation of R&D activities managers can be helped in opening up their intrafirm R&D organisation and help in managing R&D in a more effective manner.

7. References


Paper V
Innovation of process technology
Determinants for organisational design

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Process innovation in the process industries traditionally accounts for a fairly large share of the company’s total development resources, but has nevertheless not received much attention in academic studies. As a part of a larger research project concerning various aspects of process development in the process industries, the future organisational affiliation of process development has been investigated in an exploratory survey to R&D managers in European process industry. In the process industries, the R&D organisation is often still a part of a functional company organisation where internal organisational barriers are overcome by cross-functional development teams. In such organisations the alternative functional affiliations may be with the R&D organisation, with the production organisation, or both. The results of the survey reveal that, out of several possible determinants, only the degree of newness of the company’s total process innovation project portfolio shows significant correlations to organisational affiliation. The results are discussed in terms of pros and cons of organising process development in different parts of the functional organisation and in cross-functional teams.

1. Introduction
Confronted with shorter product life cycles, increasingly fragmented markets, technological change, and continuous customer demands for ever better quality products at lower prices, many firms see innovation as the best source of survival. Or, as put by Hayes et al.: “In today’s increasingly competitive global markets, a firm cannot survive for long if it is shackled with inadequate capacity, run-down and poorly located facilities, and outdated and uncompetitive process technologies” (Hayes et al., 1996, p.97). While this puts more pressure on the R&D organisation it is also clear that we must address the organisational design aspects of R&D. As old organisational models for R&D cannot be expected to meet new challenges (Miller and Morris, 1998), this study focuses on the determinants for the future organisational affiliation of process innovation in European process industry firms.

Process innovation can be defined as development driven by internal production objectives (Lager, 2002a). The focus of process innovation can therefore be said to be on internal customers, and the objectives may be reduction of production costs, higher production yields, improvement of production volumes, environment-friendly production, etc. Product innovation, on the other hand, can be defined as development driven by a desire to improve the properties and performance of finished products (Lager, 2002a). The focus is on the needs of external customers and objectives of product innovation may be to develop new products, improve product properties, improve product quality, etc. Process innovations constitute some of the most important activities and decisions that a firm will make, as committing to process architecture will affect the company for a long time to come. Ford’s decision to adopt the assembly line as a process for producing automobiles not only changed the cost structure of the industry – it also committed Ford to a trajectory of lower-cost, high-volume production of standard models. This later allowed other manufacturers, such as GM, to attract customers by offering product variations
In the process industries a fairly large share of a company’s total investment in R&D is spent on process innovation (Lager, 2002a). Historically, managers and researchers have focused predominantly on product innovation and ignored process innovation (Pisano and Wheelwright, 1995; Lager, 2002b; Lu and Botha, 2006). In fact, a recent review found that only about one percent of empirical studies in the field of innovation management studied process innovations (Becheikh et al., 2006). Nevertheless, process innovation is becoming more important in today’s increasingly dynamic marketplace because of a need for cost-cutting, increased quality, and productivity issues (Hayes and Wheelwright, 1984; Ettlie and Reza, 1992; Skinner, 1992; Lu and Botha, 2006). Additional rationales to focus on process innovations include:

- **Accelerating time-to-market** through more effective production systems (e.g. Gold, 1987; Pisano and Wheelwright, 1995; Pisano, 1997).
- **Enhancing product functionality and customer acceptance** by altering the performance of a product through minimal changes in the production process (e.g. Tushman and Nadler, 1986; Pisano and Wheelwright, 1995). This includes features such as consistency, purity, size, weight, reliability, environmental impact, etc – factors that we often describe as quality.
- **Extending proprietary (exclusive) positions.** Competitive cost structures and production processes hidden behind closed doors are more difficult for competitors to imitate than the products themselves (e.g. Pisano and Wheelwright, 1995; Schroeder et al., 2002; Ornaghi, 2006).

Process innovation is thus an important area in the future, both for commodity producers and producers of more functional products. Nevertheless, process innovation, like all other activities in industry, calls for continual adaptation to new circumstances and continual improvement to remain competitive. Shifting external and internal demands and conditions compel firms to try new ways of organising and managing their process innovation activities. One way to improve the performance of process innovation might be through a better understanding of how to organise process innovation in an efficient and effective manner.

In the process industries, the R&D organisation is often still a part of a functional company organisation where internal organisational barriers are overcome by cross-functional development teams. In those cases process innovation can be organised in either the R&D department, the production organisation, or both. However, while organisational theory has addressed the concept of innovation and structure on numerous occasions, it has rarely done so at the functional level (Twomey et al., 1988) and not specifically at R&D organisational level (Cardinal, 2001; Argyres and Silverman, 2004). Also, organisation research has tended to emphasise process issues (e.g. communication, decision making) rather than organisational structural issues (Gopalakrishnan and Damapour, 1997) so R&D managers have very little guidance on designing organisations with respect to the organisational affiliation of process innovation. This study focuses on innovation of process technology and some variables that might determine the organisational affiliation of these activities. The empirical base is firms in the European process industry.

2. **Theoretical framework**

2.1. **Organising industrial R&D**

The study of innovation and the study of organisation have always been closely coupled. Some of the early and most notable studies in organisation also commented on the link between organisation structure and innovation. Examples include Burns and Stalker (1961), who found that organic organisations (decentralised and less formalised) are better suited for innovation, while mechanistic organisations (hierarchical and more formalised) maximise efficiency; Lawrence and Lorsch (1967), who concluded that integration between differentiated departments is generally required for successful innovation; and Woodward (1965) who noted that changes in production technology affected the organisational structure of firms. In fact, many of the new organisational forms being used today were born out of the needs of innovation. The concept of interdisciplinary project teams traces its roots back to the problems faced in developing new products, where there was a need for a temporary well-coordinated effort involving many different parts of the organisation (Allen, 2001). The complexity of product development activities, especially the need for technical specialists to communicate with their peers, was also what prompted the Boeing Company to come up with the matrix organisation in the 1960s (Allen et al., 2004). “Skunk works” (often used to describe an autonomous group within an organisation working on independent
The bringing together of individuals and groups is the basic function of an organisation. In that way, organisations can create benefits of scale through specialisation, shared support and the control of shared resources (Williamson, 1981; Nadler and Tushman, 1997, p.64). The structure of an organisation is also often defined in terms of groupings – as the “internal differentiation and patterning of relationships” (Thompson, 1967, p.51), or as the “sum total of the ways in which its labour is divided into distinct tasks and then its co-ordination is achieved among these tasks” (Mintzberg, 1999). The work of Gulick and Urwick (1937) has led to identification of five different bases on which units of organisations could be grouped or separated:

1) **Common purpose or contribution to the larger organisation.** This is often referred to as functional departmentalisation (Nohria, 1995) and the advantage of this type of grouping is obtaining efficiencies from consolidating resources and people with shared skills and knowledge.

2) **Common processes.** As different processes requires particular skills, departmentalising by process offers a basis for homogeneous arranging of work activities.

3) **Particular clientele.** Departmentalisation by customers groups on the basis of a common set of needs or problems of specific customers or markets.

4) **Particular geographical area.** Specific local characteristics or the fact that physical separation makes centralised control more difficult are two reasons for creating departments based on geographical areas.

5) **Departmentalisation by product.** A fifth common motivation for departmentalisation is to place functions needed to make and market a particular product under one executive. This type of organisational structure evolved with the emergence of large diversified firms (depicted by Chandler, 1962) to provide increased autonomy for managers.

The difficulty in departmentalising an organisation lies in the fact that a complex organisation is often faced with several options on how to organise. A firm may perform many activities through a multitude of processes to produce different products for different customers on a variety of markets and geographic areas. This leads the organisation to question not on which criterion to departmentalise, but which criterion should be given priority (Thompson, 1967, p.57). Also, these priorities may change over time, compelling the organisation to change its structure as well (Lawrence and Lorsch, 1967). While most firms adhere to some form of functional departmentalisation, it is not uncommon that mixed forms are used (Chiesa, 2001). Matrix organisations, cross-functional teams and other forms of integration are used to gain benefits from different groupings simultaneously.

As previously stated, innovation is a complex activity to manage, and there is no one structure that can meet all needs. In fact, different situations call for different forms of design, and there are a variety of factors upon which design decisions are contingent (Nadler and Tushman, 1997, p.63). As a result, a number of different organisational structures have been used in R&D over the years, “unfortunately with very little real basis for choosing among them” (Allen, 1984, p.218). It is therefore a principal task for researchers to try to find some reliable and useful basis for organisational design. Organisational affiliation is in that respect an important issue to be addressed.

Concerning the innovation of process technology within a company, there are basically three ways of organising these activities in process industry companies (see Figure 1):

i) Process innovation can be organised and managed within the R&D department together with product innovation activities;

ii) Process innovation can be organised and managed within the production organisation;

iii) Process innovation activities can be organised both within the R&D department and the production organisation.
2.2. Organisational determinants for organising process innovation

Pisano (1997, p.155) noted that there were no previous studies linking project performance with organisational structures for process innovation. However, in his work on pharmaceutical and biotechnology companies he identified two models for organising process and product R&D. Pisano labels these as the integrated model, which describes process innovation organised in R&D, and the specialised model, which describes process innovation organised in both R&D and production – with a handover in between. However, considering how product and process innovation is defined in this paper, the process innovation activities that Pisano sees taking place in R&D (process chemistry, analytical chemistry, molecular biology, kilo lab, biochemistry, and protein chemistry) (see Pisano, 1997, pp.156-157) are actually more akin to product innovation, as they deal with product properties. Thus, in the specialised model process innovation can actually be said to be organised in production. Studying the integrated and specialised models, Pisano found several differences in process innovation lead times and costs. While these results were not statistically significant at conventional levels, they suggest that there are pros and cons to organising process innovation either in the R&D department or in production.

So, taking a step back, what are the variables that determine organisational structure? There are several contextual determinants of structure that have been applied in the organisational theory literature, of which the most common have been size (see Pugh et al., 1968; and more recently Evangelista and Mastrostefano, 2006), technology (see Woodward, 1965; Thompson, 1967), strategy (see Chandler, 1990), and environmental uncertainty (see Burns and Stalker, 1961). These factors determine organisational structure, and in turn, the organisation’s proficiency at innovation. There have also been many attempts to link innovation propensity with different structural determinants (see Damanpour, 1991 for a review), as well as with different organisational structures and processes (see Teece, 1996; see Damanpour and Gopalakrishnan, 1998).

The general research questions for this study are stated as follows:

1. What are the determinants for selecting the organisational affiliation of process development in process industry?
2. What are the advantages/disadvantages of the different organisational affiliations?

Four determinants for organisational affiliation of process innovation have been explored and tested in this study. The hypotheses are that there is an association between the variable process development organisational affiliation and the four independent variables: industry category, size of R&D organisation, process innovation intensity and newness of process innovation (Figure 2).

Organisational determinants

I - Industry category
II - Size of R&D organisation
III – Process innovation intensity
IV – Newness of process innovation

Organisational affiliation of process innovation

- R&D department
- Production organisation
- Both

Figure 2: Determinants for organisational affiliation of process innovation

I - Industry category versus organisational affiliation of process innovation

Refining petroleum is very different from developing new milk products, and mining and smelting copper is very different from producing pharmaceuticals. While some see process industry as being homogeneous, there is a great diversity within the process industry concerning technology, input materials, products, and customers (Dennis and Meredith, 2000). It is apparent that the process industry is made up of a diverse group of industry sectors, each using different sets of product and process technologies. Looking within the firm, Woodward (1965) showed that the complexity of technology used in different industries affected the structural organisational features of firms within those industries.

As the intensity and way in which firms compete with each other differs between industries, so does firm strategy and organisation. Different competitive priorities require different operating priorities, so different approaches to process innovation are taken by different firms. Some focus on lowering costs, some focus on being able to switch production quickly, some focus on delivering high quality goods (see Porter, 1980). So, even within the same industry, companies differ in the way they conduct process innovation. In some industry sectors competition is more focused on product uniqueness, i.e. bringing differentiated products to customers. Here firms need to focus on product and process integration to facilitate new product development and accelerate time-to-market, etc. (Pisano and Wheelwright, 1995). In other industries competition is more focused on cost leadership, i.e. keeping production costs as low as possible. Here firms need to focus on minimising cost in the production process and also making sure that production processes are difficult to imitate (Pisano and Wheelwright, 1995). Although many process industries nowadays try to avoid being commodity producers competing on cost, and instead produce more functional products with higher margins (as illustrated by Chronéer, 2003), the opposite development also occurs. An industry that was previously very much focused on differentiating products was the chemical industry. However, international competition, patent expirations, and developments in process technology have “commoditised” what were previously specialty products (see Felch, 2002). This has created a higher level of competition on production efficiency and production factors, such as capital and personnel.

In conclusion, process industry sectors are dissimilar in terms of core technology and competitive factors. These sectorial differences may affect the organisational affiliation of process innovation.

Research question 1: Does the industry category of the company relate to the organisational affiliation of the innovation of process technology?

II - Size of R&D organisation versus organisational affiliation of process innovation

The relationship between firm size and innovation has been central in innovation research for a long time. It is often stated that larger organisations have more resources which provide critical mass and more access to slack resources – both beneficial to innovation (Camisón-Zornoza et al., 2004). Large firms are also able to take on bigger risks from unsuccessful innovations. However, the formalised and bureaucratic structures often associated with big organisations may hamper the innovative climate, and in many cases smaller firms are better at adapting to their environment and making changes (Tushman and O’Reilly,
Previous studies on overall firm size and type of innovation have found that larger firms do more process innovation (Cohen and Klepper, 1996). The logic is that larger firms benefit more from process innovation due to economics of scale in production, i.e. the more production output a firm has, the larger the return will be on any successful investments in process technology.

How the organisation of process innovation should relate to the size of the R&D department has not been specifically studied, but in terms of functional differentiation it has been appreciated that increasing organisational size gives rise to increasing subdivision of responsibilities (Lawrence and Lorsch, 1967). That is, if an organisation becomes too large and complex to handle, it makes sense to let different parts of the organisation specialise in different areas. While this implies that product and process innovation could be organised separately, it does not state whether they should be separated within the R&D department or production. Pisano (1997, p.158) hypothesises that firm size affects the organisational affiliation of process innovation. He proposes that it is not economically feasible for smaller firms to divide process innovation activities within the firm. Instead, he suggests that an integrated approach, where process innovation is organised within R&D, is more efficient as people can be reallocated between different projects more easily.

In conclusion, there seems to be support for the notion that size could affect the organisational affiliation of process innovation.

Research question 2: Does the size of the R&D department relate to the organisational affiliation of the innovation of process technology?

III - Process innovation intensity versus organisational affiliation of process innovation

Firms differ in their emphasis on product or process innovation for providing competitive advantage and as a consequence invest relatively more or less resources in process innovations than other firms. Lager (2002a) defines process innovation intensity as the firm’s share of R&D spent on process innovation, and while a previous study on process innovation intensity not only showed not only differences between industries, it also revealed a high dispersion of process innovation intensity within each industry sector (Lager, 2002a).

Previous discussion of process innovation intensity have largely focused on relating it with other determining factors such as firm size, strategy, and industry maturity. As illustrated earlier, one reason for a firm to engage more in process innovation is the size of the firm and the potential effects on output – where firms with larger output have more to gain on process innovations (Cohen and Klepper, 1996). Furthermore, firm strategy is determined by industry competitiveness – where a focus on cost leadership leads to adopting process innovations (Porter, 1980). Finally, Utterback (1994) proposes that industry maturity affects the relative amount of product and process innovation being undertaken within firms. As industries become more mature and dominant designs and industry standards emerge, firms as a rule focus more on process innovations stimulated by production-related factors.

Thus, while general issues of process innovation intensity have been discussed, the specific relation between process innovation intensity and organisational affiliation has yet to be determined.

Research question 3: Does the process innovation intensity of the organisation relate to the organisational affiliation of the innovation of process technology?

IV - Newness of process innovation versus organisational affiliation of process innovation

There are different views on what constitutes newness as it relates to innovation. The Oslo Manual classifies innovations as either “new to the firm”, “intermediary” (new to a particular market or region), or “new to the world” (OECD, 2005). Another way of classifying the degree of newness is to vary innovations along a continuum from “incremental” to “radical” (Ettlie et al., 1984). Radical innovations are those that produce fundamental changes in the activities of the organisation and represent a large departure from existing practices, while incremental innovations are those that result in a lesser degree of change. In a previous study by Lager (Lager, 2002b) it was found that the distribution of resources for process development leaned more towards development that can be classified as improvements of the existing production process than development geared towards breakthrough process technology.
Research findings suggest that radical innovations require technical knowledge and slack resources normally available to larger and more complex organisations (Damanpour, 1996). This is because organisations pursuing radical innovations need to be able to raise the human and technical resources necessary and absorb the higher cost of failure of such innovations. Other studies of radical innovation have found that it was more likely to emerge in centralised structures (Ettlie et al., 1984) and when separated from ongoing business activities (Rice et al., 1998). The R&D department and the production organisation have different goals and reward structures that support different types of activities. The R&D department is geared to focus on long-term goals and therefore has a propensity for more radical innovations (Utterback, 1994), while the production organisation focuses more often on incremental improvements for measurable benefits in the short term. This view echoes that of Lawrence and Lorsch (1967), who propose that the more organic (decentralised and less formalised) R&D department is better at achieving uncertain tasks, such as radical innovations, while a more mechanistic (hierarchical and more formalised) production organisation is better geared to certain tasks such as incremental innovation. Nevertheless, a more recent study on innovation in pharmaceutical industry suggests that incremental and radical innovation should not necessarily be managed differently (Cardinal, 2001).

In conclusion, there seems to be evidence that the organisational affiliation of process innovation may be related to the degree of newness of process innovation.

**Research question 4:** Does the degree of newness of process innovation relate to the organisational affiliation of the innovation of process technology?

### 3. Methodology

The results presented in this paper build on a previous research project on the development of process technology in Process Industry. In that project a survey was conducted among R&D managers in European Process Industry during 1999. The following intentional type of definition of process industry that was used in this study characterises this industry in a descriptive manner: “Process industry is production industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow.” The survey included a lengthy (8-page) questionnaire concerning various aspects of process development. The total questionnaire was pilot-tested on three R&D managers before being distributed to 327 R&D managers in European process industry with a focus on Swedish process industries. Since the Swedish sample included nearly all process industries, making it close to a census, the discussion of significance is in that context irrelevant. The sample for the survey and the further conduct of the survey are described in the Appendix.

The question in the survey was as follows:

*Will process development work in the company belong in the future to the organisation for R&D or Production?*

The part about organisational affiliation in the survey was small. Nevertheless, the specific research question about organisational affiliation was studied in relation to many other variables in this study: *industry category, size of R&D organisation, process innovation intensity, and newness of process innovation.* These independent variables are discussed below.

**Industry category**

Industries that are proposed to be included in process industry have been selected from the NACE system (NACE, 1996) and clustered for this study in six categories, as *Mining & Mineral Industry, Food & Beverage Industry, Pulp & Paper Industry, Chemical Industry, Basic Metal Industry, and Other Process Industry* (see Table 1). Those groups of industries can be broken down in more detail into sub-groups. Chemical Industry, for example, can be further divided into Paint Industry, Industry for Basic Chemicals, etc.

**Table 1:** Categories of process industry based on NACE.
### Categories

<table>
<thead>
<tr>
<th>Categories</th>
<th>NACE Codes</th>
<th>NACE Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining &amp; Mineral Industry</td>
<td>CB 13</td>
<td>Mining of metal ores</td>
</tr>
<tr>
<td></td>
<td>CB 14</td>
<td>Other mining and quarrying</td>
</tr>
<tr>
<td></td>
<td>DI 26</td>
<td>Manufacture of other non-metallic mineral products</td>
</tr>
<tr>
<td>Food &amp; Beverage Industry</td>
<td>DA 15</td>
<td>Manufacture of food products and beverages</td>
</tr>
<tr>
<td>Pulp &amp; Paper Industry</td>
<td>DE 21</td>
<td>Manufacture of pulp, paper and paper products</td>
</tr>
<tr>
<td>Chemical Industry</td>
<td>DF 23</td>
<td>Manufacture of coke, refined petroleum products and nuclear fuel</td>
</tr>
<tr>
<td></td>
<td>DG 24</td>
<td>Manufacture of chemicals and chemical products</td>
</tr>
<tr>
<td></td>
<td>DH 25</td>
<td>Manufacture of rubber and plastic products</td>
</tr>
<tr>
<td>Basic Metals Industry</td>
<td>DJ 27</td>
<td>Manufacture of basic metals</td>
</tr>
<tr>
<td>Other Process Industry</td>
<td>DJ 28</td>
<td>Manufacture of fabricated metal products, except machinery and equipment</td>
</tr>
<tr>
<td></td>
<td>DJ 37</td>
<td>Recycling</td>
</tr>
<tr>
<td></td>
<td>E 40</td>
<td>Electricity, gas, steam and hot water supply</td>
</tr>
<tr>
<td></td>
<td>E 41</td>
<td>Collection, purification and distribution of water</td>
</tr>
</tbody>
</table>

### Size of R&D organisation

There are several ways in which to measure the variable “size” (e.g. number of employees, financial resources, sales, physical capacity). However, the number of employees, as used in this study, is the most common measure used (Camisón-Zornoza, Lapiedra-Alcamí et al. 2004).

### Process innovation intensity

The process innovation intensity is the proportion of R&D expenditures spent on process innovation – that is, the total annual expenditure on process innovation divided by its total annual expenditure on R&D (Lager, 2002a).

### Newness of process innovation

Newness of process innovation is measured on two scales – *newness of process to the company production system* (low, medium, and high) and *newness of process to the world* (low, medium, and high) (Lager, 2002b) – illustrated in Figure 3. The R&D managers were asked to approximate the percentage of annual process innovation expenditures that fell within each section of the matrix.

![Figure 3](image)

Figure 3: Matrix for classification of newness of process innovation in process industry.
4. Research findings

The statistical findings concerning the research questions 1 to 4 are briefly presented below.

4.1. Industry category versus organisational affiliation of process innovation

Table 2: Future organisational affiliation of process innovation for different categories of process industry

<table>
<thead>
<tr>
<th>Classification of industry category in this study</th>
<th>Future organisational affiliation of process innovation</th>
<th>R&amp;D</th>
<th>Production</th>
<th>Both</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining &amp; Mineral Industry</td>
<td></td>
<td>72.7%</td>
<td>27.3%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Food &amp; Beverage Industry</td>
<td></td>
<td>27.8%</td>
<td>61.1%</td>
<td>11.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Pulp &amp; Paper Industry</td>
<td></td>
<td>33.3%</td>
<td>44.4%</td>
<td>22.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Chemical Industry</td>
<td></td>
<td>77.8%</td>
<td>14.8%</td>
<td>7.4%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Basic Metal Industry</td>
<td></td>
<td>31.8%</td>
<td>45.5%</td>
<td>22.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Other Process Industry</td>
<td></td>
<td>52.4%</td>
<td>33.3%</td>
<td>14.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>50.9%</td>
<td>36.1%</td>
<td>13.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The null hypothesis that the two variables are independent were tested with a Pearson chi-squared test. The result indicates that the null hypothesis cannot be rejected, and hence that the two variables are independent (pvalue=0.023).

4.2. Size of R&D organisation versus organisational affiliation of process innovation

Table 3: Future organisational affiliation of process innovation for total number of company employees in R&D

<table>
<thead>
<tr>
<th>Total number of company employees in R&amp;D</th>
<th>Future organisational affiliation of process innovation</th>
<th>R&amp;D</th>
<th>Production</th>
<th>Both</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low (0-11)</td>
<td></td>
<td>43.5%</td>
<td>56.5%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Low (12-44)</td>
<td></td>
<td>61.5%</td>
<td>23.1%</td>
<td>15.4%</td>
<td>100.0%</td>
</tr>
<tr>
<td>High (45-150)</td>
<td></td>
<td>51.7%</td>
<td>34.5%</td>
<td>13.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Very high (151 or more)</td>
<td></td>
<td>50.0%</td>
<td>25.0%</td>
<td>25.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>52.0%</td>
<td>34.7%</td>
<td>13.3%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The null hypothesis that the two variables are independent were tested with a Pearson chi-squared test. The result indicates that the null hypothesis cannot be rejected, and hence that the two variables are independent (pvalue=0.097).
4.3. Process innovation intensity versus organisational affiliation of process innovation

Table 4: Future organisational affiliation of process innovation for different process innovation intensity

<table>
<thead>
<tr>
<th>Proportion of R&amp;D expenditures spent on process innovation</th>
<th>Future organisational affiliation of process innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D</td>
</tr>
<tr>
<td>0-40 percent</td>
<td>55.2%</td>
</tr>
<tr>
<td>41-70 percent</td>
<td>46.4%</td>
</tr>
<tr>
<td>71-100 percent</td>
<td>57.1%</td>
</tr>
<tr>
<td>Total</td>
<td>53.0%</td>
</tr>
</tbody>
</table>

The null hypothesis that the two variables are independent was tested with a Pearson chi-squared test. The result indicates that the null hypothesis cannot be rejected, and hence that the two variables are independent (p-value=0.916).

4.4. Newness of process innovation versus organisational affiliation of process innovation

The variable newness of process innovation is two-dimensional; varying from “low” to “high” on the scales of “new to the company production system” and “new to the world”. The matrix in Figure 4 depicts the annual expenditures of the surveyed firms on these scales. Mean values are shown as large figures; the figures in parenthesis are the denominations for the different matrix areas.

![Figure 4: Newness of process innovation - Distribution of company annual expenditures on innovation of process technology among areas of the process matrix (average figures for all companies).](image)

Since the variable newness is two-dimensional it was decided to create a new variable using the matrix in a different mode. Referring to the process innovation newness matrix, the distribution of process development in the areas 11, 12 and 21 was added to create a new variable called “Newness of process innovation”. The average distribution of process innovation to this area for all companies is 51% of the total matrix. This variable was then further categorised into four groups by the distribution to the quartiles. The new variables are:

- Very high newness < 32.5%;
- High newness 32.5 – 50.0%;
- Low newness >50% - 70%;
- Very low newness >70%.

In Table 4 the new variable has been cross-tabulated against the variable “Future organisational affiliation”
Table 5: Future organisational affiliation of process innovation for different degrees of newness of process development

<table>
<thead>
<tr>
<th>Newness of process innovation</th>
<th>Future organisational affiliation of process development</th>
<th>R&amp;D</th>
<th>Production</th>
<th>Both</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high (&lt;32.5%)</td>
<td>66.7%</td>
<td>19.0%</td>
<td>14.3%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>High (32.5-50.0%)</td>
<td>63.0%</td>
<td>29.6%</td>
<td>7.4%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Low (&gt;50.0%-70.0%)</td>
<td>52.4%</td>
<td>38.1%</td>
<td>9.5%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Very low (&gt;70.0%)</td>
<td>6.3%</td>
<td>68.8%</td>
<td>25.0%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>50.6%</td>
<td>36.5%</td>
<td>12.9%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

The null hypothesis that the two variables are independent was tested with a Pearson chi-squared test. The result indicates that the null hypothesis can be rejected, and hence that the two variables are not independent (pvalue=0.008). The structure of the association can be summarised as follows: in the category “Very High” and “High” newness of process innovation we find an over-representation of companies organised in R&D compared to the expected number. In the category “Very Low” newness of process innovation we find an over-representation of companies organised in production compared to the expected number.

5. Discussion

This study tested four organisational determinants to ascertain whether they were related to the organisational affiliation of process innovation in process industry firms. For the determinants Industry category, Size of R&D organisation, and Intensity of process innovation no statistical significances were found with the organisational affiliation of process innovation. The fourth determinant, however – Newness of process innovation – did reveal a statistically significant result. This finding suggests that newness of process innovation is a determining factor for future organisational affiliation amongst R&D managers in process industry.

5.1. Organising for radical or incremental innovation in process industry

The findings propose that if a firm pursues process innovations of high or very high newness (we will label these as radical innovations for the rest of the discussion), these will be organised within the R&D department. On the other hand, if a firm pursues process innovation with a very low level of newness (we label this as incremental innovations), these activities will be organised within the production organisation. There are also a number of firms which pursue both radical and incremental process innovations and that organise these activities in both R&D and production. Figure 5 depicts these organisational design choices in a three-by-three matrix, with the variables newness and organisational affiliation on the two axes.

---

1 Regarding the assumptions of the test: four cells in the contingency table (out of 12) have expected counts less than 5. The smallest expected count is 2.07. Agresti (1990) states that a minimum expected value of 1 is permissible as long as no more than about 20% of the cells have expected values below 5. Hence, there seem to be some violations to the assumptions of the test, but nevertheless there is a tendency in the data.
5.2. Pros and cons of organising radical process innovation in the R&D organisation

The findings show that firms who wish to pursue *radical* process innovations will tend to organise this activity within the R&D department. The rationale for organising and managing radical process innovation within R&D department could be:

- **Economies of scale in research.** Economies of scale are reached by pooling technical expertise, scientific knowledge and other resources within R&D. Ettlie et al. (1984) found that the growing number of technical specialists seems to promote the adoption of advanced technology. Pooling staff also simplifies knowledge-sharing among research professionals and makes it easier to attract new talented employees to process innovation.

- **Distance from everyday operations.** Being organised within R&D means that R&D employees can detach themselves from the everyday operations and everyday problems of the production plant. Another aspect of keeping distance is that radical process innovations often involve big changes in how work is done in the production organisation. If process innovation is organised under production, there might be less chance that it will bring forth innovations that change the immediate working environment. However, if process innovation is organised under R&D, it will not be thus constrained. Studying metal-makings, Moors and Vergragt (2002) found that a high degree of technical and organisational intertwining often complicates the implementation of more radical innovations.

- **Integration with product development.** Conducting process innovation within R&D makes closer integration with product innovation and other R&D activities more straightforward. This is especially important for firms where product specifications cannot just be “thrown over the wall” for process development, or whose product development and production process development processes are intertwined as in the pharmaceutical industry (see Pisano, 1997; Lim et al., 2006).

- **Strategic control.** Organising process innovation activities under R&D makes strategic control over these activities easier. For example, Chiesa (2001) suggests that the more centralised a function, the easier it is to control for strategic direction. If process innovation is organised under production, it is more likely that production and process control issues will have higher priority than strategic innovation goals.

- **Longer time-frames.** R&D departments usually have a longer time horizon for investments than production (Lawrence and Lorsch, 1967, p.36). Production is more focused on completing projects with immediate pay-back.

- **Risk acceptance.** Production units are less inclined to make large investments with uncertain payback. However, radical innovations are by nature uncertain and are better nurtured where short-term goals do
not compromise long-term undertakings. R&D often has different budget constraints than production, which encourages risk-taking to a higher extent.

+ **External relations.** External contacts are important for bringing new knowledge into the firm (Cardinal, 2001). Studies in steelmaking suggest that heterogeneous and externally-oriented relations facilitate the development of radical innovations (Moors and Vergragt, 2002, p.295). Managing external contacts is often easier to do from the R&D department.

+ **Organisation structure.** R&D is often seen as less hierarchical, less formalised, and with a culture that permits free thinking. These organic organisations are geared towards uncertain tasks such as pursuing radical innovations (Lawrence and Lorsch, 1967, p.31).

There are also some drawbacks to organising radical process innovation under R&D:

- **Loss of production understanding.** When the R&D professionals have less knowledge of the production processes, they may have more difficulty in conceiving new radical ideas. In short, they do not know what the customer needs in terms of process innovations, and in these cases R&D can often be seen as an “ivory tower” (Chiesa, 2001).

- **Distance from actual problems.** R&D personnel too separated from the actual production processes do not see problems as they arise.

- **Technology transfer.** When a new process is developed, the technology transfer and project handovers may be more difficult if it has been developed outside of the production unit that has to implement it. Apart from purely technical issues, there are also organisational issues to overcome. For example, changes in technology may call for new skills and changes in systems and procedures for production control and scheduling. New organisation structures may be required. Furthermore, the “not invented here” syndrome may hinder process innovations originating from R&D from being adopted in production.

- **Learning.** When an organisation focuses its process innovation efforts before the launch of a product, most of the learning is done by process developers in the R&D laboratories. However, many organisations emphasise learning by doing through production experience, and therefore most learning takes place on the shop floor (Hayes et al., 1996, p.104).

### 5.3. Pros and cons of organising incremental process innovation in the production organisation

The findings show that process industry firms who pursue incremental process innovations will predominantly organise these activities within the production organisation. There are several reasons for doing this:

+ **Closeness to customers.** The production organisation is the customer of process innovations developed within the firm. Being organised in production close to the customers means that process innovations can pick up on emerging needs and unique production characteristics (Cardinal, 2001). This encourages the alignment of innovation projects and production needs.

+ **Knowledge of the specific work environment.** Knowledge of the work environment and the production processes used will facilitate process innovation. The firm must continually use the plant as a source of knowledge, or process R&D employees may lose the specific knowledge of that environment (Pisano, 1997, p.279).

+ **Increased accountability for budgets.** As production is continually measured by key performance indicators, there is little room for big spending. As a result, innovation work within production is typically more fiscally responsible. Simply put, if an organisation is being measured on costs, it will focus innovation work on cutting these.

+ **Faster process innovation cycles.** Production often focuses on projects that deliver immediate outcomes.

+ **Improved technology transfers.** Handing over technology and implementing new innovations in the production process is simplified when development work is carried out within the production unit. Problems can be solved on-site by people who understand the context.
+ Straightforward communications. Studies show that while radical project success is facilitated by cross-functional teams, incremental projects are easily burdened by information overload created by cross-functionality (Cardinal, 2001)

+ Organisational structure. Production is often seen as a mechanistic organisation, where work is more closely supervised and formalised, and whose main objective is to solve specific tasks (Lawrence and Lorsch, 1967).

There are also some drawbacks to organising incremental process innovation in production:
- Duplication of research. Research efforts may be duplicated across production plants when each production unit only looks out for itself. When process innovation is conducted in production, the close focus on specific problems may mean that vital ideas and technologies are not communicated to other parts of the organisation.
- Focus on “safe” projects. Being measured on success of projects and cutting costs in production will drive innovation to choose simple and safe projects over more difficult but also potentially more rewarding projects.
- Loss of strategic direction. When development projects are chosen on a project-by-project basis based on production needs, there is a risk of long-term objectives being overshadowed. Hayes et al. argue that process technology choices should not be solely the domain of technical and financial specialists: “Even if each individual investment decision seems sound from a technical and financial standpoint, they may still not fit with the company’s operating strategy” (Hayes et al., 1996, p.99)

5.4. Organising process innovation within R&D and production simultaneously

A substantial percentage (12.9 percent) of the R&D managers partaking in the survey predicted that process innovation would in the future be organised in both the R&D department and production. Separating different types of innovative activities in different organisational units could imply organising radical process innovations under R&D while incremental process innovations are simultaneously organised under production. This can offer the firm a possibility of having the “best of both worlds”, as pointed out by Clark and Fujimoto (1991, p.123): “Effectiveness of process engineering depends as much on the ability to interact with product designers and the factory as it does on technical skills.” However, there are also several difficulties concerning integration and communication issues. The differences between R&D and production are not easily overcome. For example, a high degree of integration is necessary to inform R&D employees about technical problems that they might be able to overcome and to acquaint production personnel with new processing techniques that could be introduced (Lawrence and Lorsch, 1967, p.45). Also, R&D and production must agree on what technological innovations are possible and desirable.

Many firms employ cross-functional teams in process as well as product innovation. In a sense, the decision of organising process innovations can be taken on a project-by-project basis. Some projects may be more suited for being run jointly with production, while others need the resources and special expertise found in the R&D department. Based on the degree of newness ranging from incremental to more radical, and referring to the results from the survey and theory, the advantages of locating process innovation projects to the R&D organisation might be to give a good environment for more long-term process innovation activities of a more radical character. The advantage of assigning process innovation projects to production might be to facilitate incremental development by making it easier to transfer results direct to production. All this implies that the departmental affiliations may be less important than the organisation of efficient work-processes for process development transcending departmental demarcation lines. The shift from a strict departmental organisation to multifunctional teams managed by project managers is a clear trend for product innovation in other manufacturing industries (see Clark and Fujimoto, 1991). The importance of establishing multifunctional structures and modes of collaboration for process development and production is still relevant, because the departmental organisation will probably survive for some time in process industry as some sort of organisational backbone even in the future, although the focus will be more on work processes, in this case the “process development process”.
6. Implications and further research

This study provides further empirical evidence that there is a relationship between the organisation of innovation and the degree of newness of the innovations pursued. A study of European process industry showed that those with more radical process innovation will organise it in R&D, while those with more incremental innovation will organise it in production. The study found no significant relation between organisational affiliation and the other organisational determinants; industry category, size of R&D, and process innovation intensity. This suggests that newness is a major determinant for organising process innovation in process industry.

Future research should endeavour to overcome some of the empirical limitations of this study. A problematic methodological issue is that the study relies on a single respondent to address organisation-level questions. Future research might seek the views of multiple organisation members to reduce the potential for common method variance. Another issue is the fact that future organisational affiliation is related to the current distribution of process innovation spending from time to time. If innovations take time to develop and the “radicalness” of an innovation can only be determined ex post (after the fact), longer time frames may be deemed necessary for studying the issue of organisational affiliation and any measure of innovation effectiveness. A final note on the empirical limitations is the issue of response rates of non-Swedish companies. More effort should be applied to elicit answers also from this group of respondents in the future – see the Appendix for response rates in different geographical areas.

Product and process innovation in process industry is characterised by intertwinement of development work. During a process innovation project there are often several shifts between different product innovation and process innovation phases during the development process. The project may therefore cross over between R&D and production many times during its progress. Studying not only functional organisations but also work processes for process innovation to explore how such projects can be organised is another important option for future research. Longitudinal mini-case studies that can follow projects through their different phases may be a potentially rewarding way forward.

While this study distinguishes process innovation from product innovation it does not make any distinction between different forms of process innovation in process industry. In a literature review carried out by Barnett and Clark (1996) four central dimensions of technological change in the process industry were identified: (1) Chemistry newness – in process industry it is often the molecular or microstructure that is changed to create new material characteristics; (2) Production equipment newness – new equipment often needs to be designed and installed; (3) Fabrication newness – fabrication technology may have to be modified to fit the new equipment and materials; and (4) Process control newness – new test procedures may have to be implemented, etc. Barnett and Clark argue that for all product development projects, new knowledge and capability must be developed in one or more of the areas mentioned above to enable desired improvements in product characteristics (Barnett and Clark, 1996). Innovation in any of these dimensions may be categorised along the scale from incremental to more radical. Further studies of product and process innovation may wish to further distinguish innovation along the dimensions described, as this may yield even more exact models for organising and managing innovation in process industry.

7. Acknowledgements

This work was partly financed by the Kempe Foundations – both during the original survey and during recent follow-up work; their financial support is gratefully acknowledged. Many thanks go to Mats Nyfjäll (Statisticon) who aided with statistical data analysis. Input from discussions with R&D management staff in process industry is highly appreciated. We also sincerely thank all companies who participated in this survey.

8. References


Appendix – conduct of the survey:

Pilot testing
The total questionnaire was pilot tested on three R&D managers before being distributed to 327 R&D managers in European process industry with a focus on Swedish process industries.

Data gathering
The questionnaire was sent out to R&D managers in the companies concerned. All questionnaires were sent to a specific person who had been identified as the respondent. The Swedish part of the survey was carried out as follows: telephone contact for checking data and confirming participation; mailing questionnaire; fax reminders; telephone reminders; final fax reminder. The Nordic and European survey was carried out as follows: mailing the questionnaire; new mailing after new information (e.g. new contact person or new address); fax reminder; final fax reminder. The response rates are given in Table A.1.

Table A-1: Response rates for industry survey

<table>
<thead>
<tr>
<th></th>
<th>Sweden</th>
<th>Other Nordic countries</th>
<th>Other European countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number contacted beforehand</td>
<td>109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of mailings</td>
<td>99</td>
<td>80</td>
<td>148</td>
</tr>
<tr>
<td>Number of responses</td>
<td>79</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Response rate (%)</td>
<td>72</td>
<td>23</td>
<td>11</td>
</tr>
</tbody>
</table>
Paper VI
Critical management of technology issues in process industry

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Critical management of technology issues in process industry

Abstract
R&D managers face problems of different kinds according to which industry they work in, and are therefore in need of research on differing topics. Research has shown that process industry differs from other manufacturing industry. The aim of this study is to identify those Management of Technology topics that technology professionals and experts on Swedish process industry felt to be in greatest need of improvement. Twenty-four MOT issues related to product development, derived in a previous study, were rated by 21 respondents in a workshop survey for a response rate of 84%. The study indicates that “Manufacturing Involvement in New Product Development” is considered the highest-priority MOT issue. Also, six major discrepancies are discussed in the light of industry context characteristics. It is indicated that the process industry require a different research agenda than high-tech manufacturing industry.

Introduction
“Strategic management as a field of inquiry is firmly grounded in practice and exits because of the importance of its subject” - Rumelt, Schendel, and Teece, [1], p.9.

Management researchers must therefore take pains to focus on issues and phenomena that concern practitioners. As innovation is an integral part of corporate success, the management of technology (MOT) is an area where there is a need to focus research on the actual problems and issues facing managers in their everyday operations. In this respect, studies and rankings of MOT issues is an effective way of ensuring that innovation and management research is on track with what managers need. However, R&D managers’ experiences and problems vary depending on the context in which they operate, and they are therefore in need of research on different topics. Earlier studies on rankings of MOT issues have predominantly focused on industries which are considered high-tech with rapid technological change (e.g. [2-6]). No earlier study has exclusively investigated and ranked MOT issues with respect to the part of manufacturing industry known as process industry:

“Process Industry is a part of Manufacturing Industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow” [7].

The process industry consists of pulp and paper, mining and mineral, food and beverage, and chemical industry, among others. Although these industry sectors are generally considered mature, they rely heavily on their R&D organisation to bring new products to market and improve manufacturing processes [8]. While they are an important employer in Western countries, previous studies have indicated that the process industry differs in many respects from other manufacturing industry, and from assembled high-tech products in particular [9-13]. For this reason one would expect process industry experts to give priority to research on MOT issues which differ from those of assembly-type high-tech industry.

This study draws upon a previous study conducted by Scott [4] in which 24 MOT issues were ranked in order of importance (The issues are described individually in Appendix
These issues formed the basis of a workshop survey that was distributed among process industry R&D managers and experts. The aim of the study was to establish which MOT issues are considered most critical to undertake further research on. A second aim is to explore whether there are any discrepancies between high-tech manufacturing and process industry and try to explain these by contextual factors.

The study strongly indicates that Manufacturing Involvement in New Product Development is considered the highest-priority MOT issue. In summary, the five most important derived in this study are as follows: Involvement of Manufacturing in New Product Development, Technology Core Competence, Soft Skills for Technical Personnel, Creating a Conducive Culture, and Involvement of Marketing Groups.

Concerning the second aim, the study found several discrepancies between the rankings of MOT issues in process industry and previous studies of high-tech manufacturing. In order to explore the context of process industry the issues which have shifted most compared to the Scott studies are analysed in terms of industry context in the discussion section. These are: Involvement of Manufacturing In New Product Development (up 16 steps), Productivity of Product Development Activities (up 11 steps), Strategic Planning for Technology Products (down 11 steps), Organizational Learning about Technology (down 13 steps), Cycle Time Reduction (down 14 steps), and Technology Trends and Paradigm Shifts (down 15 steps). Understanding these discrepancies will further the understanding of management of technology in process industry.

As the context of process industry is considered under-researched [13], this study will aid researchers in deciding on future research directions in the area of MOT in the process industry. It thus indicates that the process industry is in need of somewhat different research than other sectors of manufacturing industry. The unique characteristic of the non-assembled, mature, low-tech industries thus requires a different research agenda. Hence, industry context really matters when it comes to establishing fruitful directions for further research.

MOT issues – past research and a unique context

Previous studies on MOT issues

It is often argued that increased global competition and rapid technological change periodically change the perspective on how to manage R&D [14-16]. Despite that, industries and firms still struggle with how to reconcile the rival pressures associated with improving cost efficiency and how to diversify in order to capture a competitive edge. Several studies have therefore been conducted with a view to identifying and capturing MOT issues in need of further research. In these studies, the objective has either been to map out fruitful directions for future research [2-6] or to establish best practice [17-21].

However, most studies in this stream of research have investigated a broad industry cross-section in order to obtain wide applicability across industry boundaries (e.g. [17, 19, 21-23] or focused on industries considered high-tech (e.g. [2-6, 18, 20]). Also, studies have often been conducted solely on a US sample (e.g.[17, 18, 20-23] or included a significant amount of US respondents (e.g.[2-6, 19]. Besides, evidence has shown that findings from Europe and the USA diverge significantly in evaluation scores of some MOT issues [2]. Table 1 gives a summary of these previous MOT studies.
However, depending on their contextual environment, practitioners and industry experts might disagree on a few counts with how the studies above were conducted. That is, they might oppose the assumption that what works in other industries also works in their own. This could be due for example to industry characteristics such as whether their corporation (1) is considered low-tech or high-tech, (2) delivers services, assembled products or non-assembled products, (3) whether it is primarily a business-to-business or business-to-consumer corporation (e.g. position in the value chain) or (4) is located in Asia, Western/Eastern Europe, the USA, etc. Hence, some would argue that the characteristics of their industry would inhibit cross-fertilisation.

In the series of papers by Scott on high-tech assembled industries [2-6], targeting practitioners, experts, and academic researchers, an exhaustive set of major MOT problems was identified and then ranked in order of importance relative to the others. Through the use of a DELPHI study (an iterative questioning process) Scott managed to identify and rank 24 MOT issues [4](Table 2). The studies by Scott demonstrated that strategic planning for technology products and issues associated with strategic and long-range planning for technology-product development were the most important problem to address in the field of management of technology [2, 4].

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**Table 1. Methodological considerations in previous studies on critical MOT issues and best practice**

<table>
<thead>
<tr>
<th>Study</th>
<th>Sampling frame</th>
<th>Method</th>
<th>Respondents</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalone (1995)</td>
<td>Broad industry cross-section</td>
<td>mq</td>
<td>North America/US only</td>
<td>Memors of PDMA</td>
</tr>
<tr>
<td>Cooper, Edgett and Kleinschmidt (2001)</td>
<td>Broad industry cross-section</td>
<td>cs/mq</td>
<td>North America/US only</td>
<td>All US firms conducting product dev. &amp; members of IFI (Institut of Industrial Research Institute), Washington D.C.</td>
</tr>
<tr>
<td>Cooper and Kleinschmidt (1995)</td>
<td>Broad industry cross-section</td>
<td>mq</td>
<td>Europe and North America</td>
<td>Chemical, materials, communications, equipment, machinery, electric, food, automobile parts, services, manufactured goods, high-tech, low-tech, mixed, business-to-business, business-to-consumer, mixed</td>
</tr>
<tr>
<td>Griffin (1997)</td>
<td>Broad industry cross-section</td>
<td>mq</td>
<td>US only</td>
<td></td>
</tr>
<tr>
<td>Gupta and Wilemon (1996)</td>
<td>Broad industry cross-section</td>
<td>mq</td>
<td>North America/US only</td>
<td>Technology-based corporations</td>
</tr>
<tr>
<td>Scott (1998)</td>
<td>High-tech industry</td>
<td>Dm</td>
<td>Predom. North America but also world-wide</td>
<td>Assembled high-tech products</td>
</tr>
<tr>
<td>Scott (1999)</td>
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</tr>
<tr>
<td>Scott (2001a)</td>
<td>High-tech industry</td>
<td>Dm</td>
<td>Predom. North America but also world-wide</td>
<td>Assembled high-tech products</td>
</tr>
<tr>
<td>Scott (2001b)</td>
<td>High-tech industry</td>
<td>mq/cs</td>
<td>US only</td>
<td>Assembled high-tech products</td>
</tr>
<tr>
<td>Song and Montoya-Vélez (1998)</td>
<td>High-tech industry</td>
<td>mq/cs</td>
<td>US only</td>
<td>Development of radical vs. Incremental products</td>
</tr>
<tr>
<td>Spivey et al. (1997)</td>
<td>High-tech industry</td>
<td>mq/cs</td>
<td>US only</td>
<td>US Department of Defense, single firm</td>
</tr>
</tbody>
</table>

mq = mail questionnaire  
cs = case studies  
Dm = DELPHI method
Table 2: Ranking of critical MOT issues [4].

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Management of technology and innovation issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strategic Planning for Technology Products.</td>
</tr>
<tr>
<td>2</td>
<td>New Product Project Selection.</td>
</tr>
<tr>
<td>3</td>
<td>Organizational Learning About Technology.</td>
</tr>
<tr>
<td>4</td>
<td>Technology Core Competence.</td>
</tr>
<tr>
<td>5</td>
<td>Cycle Time Reduction.</td>
</tr>
<tr>
<td>6</td>
<td>Creating a Conducive Culture.</td>
</tr>
<tr>
<td>7</td>
<td>Coordination and Management of New Product Development Teams.</td>
</tr>
<tr>
<td>8</td>
<td>Technology Trends and Paradigm Shifts.</td>
</tr>
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<td>9</td>
<td>Involvement of Marketing Groups.</td>
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</tr>
<tr>
<td>15</td>
<td>Within-Company Technology Diffusion and Transfer.</td>
</tr>
<tr>
<td>16</td>
<td>Using High-Tech for Competitive Advantage.</td>
</tr>
<tr>
<td>17</td>
<td>Involvement of Manufacturing in New Product Development.</td>
</tr>
<tr>
<td>18</td>
<td>Globalization of Product Development Processes.</td>
</tr>
<tr>
<td>19</td>
<td>Resource Allocations to High-Tech Activities.</td>
</tr>
<tr>
<td>20</td>
<td>Establishing a ‘Technology Vision’.</td>
</tr>
<tr>
<td>21</td>
<td>Productivity of Product Development Activities.</td>
</tr>
<tr>
<td>22</td>
<td>Rewarding and Educating Technical Personnel.</td>
</tr>
<tr>
<td>23</td>
<td>Project Continuance/Discontinuance.</td>
</tr>
<tr>
<td>24</td>
<td>Oversight of High-Tech Activities.</td>
</tr>
</tbody>
</table>

The study in this paper is based on Scott’s [4] study on critical MOT issues related to new product development in high-tech firms. However, it does not cover high-tech assembly-type manufacturing industry, but rather a set of manufacturing industries known as process industry. Next, the characteristics of process industry are compared with the characteristics of other sectors of manufacturing industry.

Context: Process industry

The effects that the industry context has on an individual organisation are often difficult to assess [24, 25]. However, industrial differences must be taken into account in applying research findings to real-world problems. While the process industry has characteristics that set it apart from other manufacturing industry, much of this seems to be missing in the innovation literature [13]. However, a large research project conducted by the Royal Swedish Academy of Engineering Sciences (IVA) generated a list of key characteristics that distinguish process industry from other manufacturing industry [26]. A summary of the findings in the IVA study is shown in Table 3 and discussed below.
**Table 3: Process industry versus other manufacturing industry**

<table>
<thead>
<tr>
<th>Input materials and position in the value chain</th>
<th>Manufacturing industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diverging flow (raw materials and intermediate goods produce different types of products)</td>
<td>Converging flow (fewer products, but large variation possible)</td>
</tr>
<tr>
<td>Often homogeneous products</td>
<td>Heterogeneous products</td>
</tr>
<tr>
<td>Based on raw materials and natural resources</td>
<td>Based on intermediate goods (components and subsystems)</td>
</tr>
</tbody>
</table>

**Production process**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous production</td>
<td>Batch production</td>
</tr>
<tr>
<td>Highly automated</td>
<td>Varying degree of automation</td>
</tr>
<tr>
<td>High-tech production</td>
<td>Varying degree of technology level in production</td>
</tr>
<tr>
<td>Less labour intensive – often capital intensive</td>
<td>Labour intensive – varying degree of capital investments</td>
</tr>
<tr>
<td>Generally very energy intensive</td>
<td>Comparatively low energy usage</td>
</tr>
<tr>
<td>Process control is necessitated by variable compositions of incoming raw materials</td>
<td>Even quality of intermediate goods (quality and measurements) require different type of process control</td>
</tr>
</tbody>
</table>

**R&D - interplay between product and process innovation**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product and process development difficult to separate</td>
<td>Product and process development possible to separate</td>
</tr>
<tr>
<td>Product variety achieved through small modifications of production process</td>
<td>Product variety achieved through altered or separate production processes</td>
</tr>
<tr>
<td>R&amp;D more focused on process innovation</td>
<td>R&amp;D more focused on product innovation</td>
</tr>
<tr>
<td>Develops few new products</td>
<td>More often develops new products</td>
</tr>
</tbody>
</table>

**Macro-level factors**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroeconomic sensitivity (exchange rates, interest rates)</td>
<td>Varying degree of sensitivity to macroeconomic factors</td>
</tr>
<tr>
<td>Highly dependent on political decisions (energy, environment etc)</td>
<td>Lesser dependence on political decisions</td>
</tr>
<tr>
<td>High net export value</td>
<td>Lesser and varying degree of net export value</td>
</tr>
<tr>
<td>Environmental demands a driver for product and process development</td>
<td>Environmental demands are important but are not a driver for company development</td>
</tr>
</tbody>
</table>

**Input materials and typical position in the value chain**

One of the key points is that process industry production is based on a diverging flow of materials and intermediate goods. This means that a few materials are used for a variety of products. Other manufacturing industry, on the other hand, is viewed as a converging flow, where different materials and intermediate goods are assembled into a few products (albeit with the option of many variations). Furthermore, process industry products are often homogeneous rather than heterogeneous as is the case for assembled products. Finally, the products are often based on raw materials and natural resources rather than intermediates. This implies that most process industry corporations are suppliers to producers of assembled goods and are therefore situated upward in the supply chain, several steps from the end consumer.

**Production process**

A key characteristic of process industry production is that it is continuous rather than being based on batches as in the case of assembled products. The production process runs around the clock, and is often highly automated and technically sophisticated. Consequently, it is less labour-intensive and more capital-intensive (due to large investments in production technology) compared to less automated and less capital-intensive assembly-type manufacturing. And because production shut-downs and start-ups are extremely expensive and investments in existing production technology are large, process innovation activities have historically focused on evolutionary or incremental process improvements, while major breakthroughs have occurred in infrequent large steps [11, 27]. Also, the production process is generally very energy-intensive, as most sectors in the process industry (such as pulp and paper, mines and minerals) typically
refine raw materials into semi-finished products. Another aspect of using raw materials as inputs is that strict process control is necessary because of the variable composition of the incoming materials. This is not the case in other manufacturing industry, where the quality of intermediate goods is uniform.

R&D – the interplay between product and process development
A major feature of R&D in the process industry is the interplay between process development (driven by internal production objectives) and product development (driven by a desire to improve the properties and performance of finished products). On one hand, production ramp-up (the period between completion of development and full capacity utilisation) is complicated, as new products usually go direct from the R&D laboratory to full-scale production [10]. Hence, in process industry, it is more difficult to gradually increase production volume from trial batches to full-scale production. Also, unlike the case with assembled products, it is difficult to separate product development from process development because the existing production system must be able to switch to a new product without causing major disruptions in the continuous production process. On the other hand, modifications to the production process (i.e. process development) frequently bring about unexpected changes in the characteristics of the end product [10]. Consequently, in process industry, product development activities and process development activities are intertwined [28], and extensive intra-firm collaboration between R&D and production is therefore needed. Another aspect of the intertwining of process and product development is the connection between product modifications and the production process. In process industry, product variety is achieved through small modifications of the production process, while other manufacturing industry achieves product variety through altered or separate production processes. Moreover, process industry differs from manufacturing industry in general, and high-tech manufacturing in particular, with respect to what proportions of its innovation activities are classed as product or process development [9, 11]. High-tech firms focus more on product development, while process industry firms focus comparatively more on process development. As a result, process industry firms (with some exceptions) develop fewer new products than other manufacturing industry.

Macro-level factors
Process industry can also be distinguished from other manufacturing industries with regard to some key macro-level factors. As many Swedish process industry corporations produce commodity products, they are sensitive to exchange rates; they export semi-finished goods but do not import much in the way of raw materials, as they often are self-sufficient in that respect (iron ore, timber etc.)[26]. They are also very sensitive to interest rates, as their production plants require large investments, while profitability in many sectors of the process industry is cyclic (e.g. pulp and paper, mines and minerals). Hence, sectors of the process industry (chemical, pulp and paper, mines and minerals) are highly dependent on political decisions related to the above-mentioned issues. Furthermore, process industries are also dependent on political decisions concerning energy and environmental issues. Consequently, environmental demands are often drivers for product and process development [29], for instance to respond to new pollution legislation.
**Method**
This study aims at identifying critical MOT issues in the process industry. To meet these aims, a survey was conducted among managers and experts on innovation in process industry.

**Survey method**
The survey was carried out as an integrated part of a workshop for R&D managers from various sectors of Swedish process industry and academics specialising in innovation in process industry firms. The topic of the workshop was “Management of Innovation and Technology in Process Industry”, and it was held in Luleå, Sweden, on 16th May 2006. The workshop is an annual executive forum, by invitation only, for discussions on management of innovation and technology in process industry. The questionnaire was completed in a secluded lecture hall where the respondents had access to two academic researchers who could assist when needed.

**The questionnaire**
The questionnaire used in this survey is based on the results of the Scott DELPHI studies. It consists of the 24 management-of-technology issues identified and described by Scott [4]. The 24 issues, together with the comments from the participants in the Scott studies, were presented to the respondents. The issues were placed in random order.

**Participants and response rate**
The questionnaire was distributed to 25 participants at the workshop. Twenty-one completed the questionnaire, for a response rate of 84%. The 21 participants represented a total of fourteen organisations and institutions. Out of these 21, the respondents were divided between 16 industry participants and five academic researchers focusing on MOT in process industry. The 16 industry participants, comprising R&D managers and senior technology officers, represented the following sectors of the process industry: Pulp and Paper, Food and Beverage, Mining and Mineral and the Basic Metal. The participants, moreover, are a homogeneous group as their firms and industry sectors produce non-assembled products, are located high in the value chain (i.e. business-to-business) and are considered mature (see section “Previous studies on MOT issues”). In addition, the participants’ firms have annual turnovers ranging from approx. EUR 700 million and upwards, and have production plants and R&D units in more than one geographical location.

**Scale and ranking of items**
A Likert scale ranging from 1 (least important) to 10 (most important) was used to rate the issues – the same measurements as used in Scott’s studies. Ranking is based on the statistical averages calculated for each issue.
Critical management of technology issues in process industry

Methodological reflections
This is not meant as a replication of Scott’s DELPHI studies. Instead, it picks up from Scott’s studies to explore what MOT issues are ranked as important in process industry today. As there has been a considerable time lag between the Scott studies and this survey there is little point in making industry comparisons. However, it can be used as a starting point to discuss contextual differences between process industry and high-tech manufacturing. The central issue of any survey is the question of sample and sample size. An objection to this study could be that the sample is neither large nor wide enough to represent the process industry as a whole. However, while one industry sector is missing (chemical industry), the sample covers a homogeneous group of process industries (For a discussion on NACE codes and process industry see previous work by Lager [7]). The sample is therefore deemed representative of the Swedish process industry as a whole. Furthermore, the fact that the participants in the workshop are considered experts – i.e. with a solid understanding of the issues concerning innovation in the process industry – in part makes up for the small sample size in terms of quality of the answers. As the object was not to make a census of what managers in process industries think, but rather to enquire into what the critical MOT issues may be, a small and well-informed group of respondents is preferable to a larger group that may not be as well informed. Also, the fact that the respondents had access to researchers for questions while conducting the survey also added to the quality of the answers, as any ambiguities or misunderstandings could be avoided.

Because it draws on the 24 MOT issues that Scott derived in previous studies, there is a possibility that this study may have missed one or more issues that R&D managers in process industry consider important. However, none of the participants voiced this opinion. As one of the objects of the survey was to map future research areas in innovation management on behalf of the research centre in which most firms at the workshop have a stake, it must be assumed that all respondents answered the questionnaire on the basis of their actual MOT research needs.

Findings
The rankings of the critical MOT issues are presented in Table 4 together with the average score and standard deviation. Participants rated each MOT issue on a scale of 1-10, with 10 as the highest importance rating. The standard deviation increases somewhat as the averages decrease, suggesting greater agreement of the top issues.
Table 4: Critical issues in the management of innovation and technology in process industry

<table>
<thead>
<tr>
<th>Rank</th>
<th>Management of technology and innovation issue</th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Involvement of Manufacturing in New Product Development</td>
<td>8,700</td>
<td>1.341</td>
</tr>
<tr>
<td>2</td>
<td>Technology Core Competence</td>
<td>8,238</td>
<td>1.044</td>
</tr>
<tr>
<td>3</td>
<td>Soft Skills for Technical Personnel</td>
<td>8,143</td>
<td>1.652</td>
</tr>
<tr>
<td>4</td>
<td>Creating a Conducive Culture</td>
<td>8,000</td>
<td>1.974</td>
</tr>
<tr>
<td>5</td>
<td>Involvement of Marketing Groups</td>
<td>7,952</td>
<td>1.396</td>
</tr>
<tr>
<td>6</td>
<td>New Product Project Selection</td>
<td>7,857</td>
<td>1.389</td>
</tr>
<tr>
<td>7</td>
<td>Senior Managers’ Involvement in Technology</td>
<td>7,857</td>
<td>0.963</td>
</tr>
<tr>
<td>8</td>
<td>Customer/Supplier involvement</td>
<td>7,476</td>
<td>1.832</td>
</tr>
<tr>
<td>9</td>
<td>Coordination and Management of New Product Development Teams</td>
<td>7,476</td>
<td>1.965</td>
</tr>
<tr>
<td>10</td>
<td>Productivity of Product Development Activities</td>
<td>7,429</td>
<td>1.912</td>
</tr>
<tr>
<td>11</td>
<td>Within-Company Technology Diffusion and Transfer</td>
<td>7,333</td>
<td>1.390</td>
</tr>
<tr>
<td>12</td>
<td>Organization Structure for R&amp;D</td>
<td>7,289</td>
<td>2.472</td>
</tr>
<tr>
<td>13</td>
<td>Strategic Planning for Technology Products</td>
<td>7,289</td>
<td>2.452</td>
</tr>
<tr>
<td>14</td>
<td>Project Continuance/Discontinuance</td>
<td>7,190</td>
<td>1.537</td>
</tr>
<tr>
<td>15</td>
<td>Establishing a “Technology Vision”</td>
<td>7,143</td>
<td>1.769</td>
</tr>
<tr>
<td>16</td>
<td>Organizational Learning About Technology</td>
<td>6,952</td>
<td>1.627</td>
</tr>
<tr>
<td>17</td>
<td>Rewarding and Educating Technical Personnel</td>
<td>6,850</td>
<td>1.843</td>
</tr>
<tr>
<td>18</td>
<td>Alliances/Partnerships Between Technology Companies</td>
<td>6,789</td>
<td>1.960</td>
</tr>
<tr>
<td>19</td>
<td>Cycle Time Reduction</td>
<td>6,810</td>
<td>2.015</td>
</tr>
<tr>
<td>20</td>
<td>Resource Allocations to High-Tech Activities</td>
<td>6,762</td>
<td>2.071</td>
</tr>
<tr>
<td>21</td>
<td>Oversight of High-Tech Activities</td>
<td>6,762</td>
<td>2.119</td>
</tr>
<tr>
<td>22</td>
<td>Using High-Tech for Competitive Advantage</td>
<td>6,700</td>
<td>2.296</td>
</tr>
<tr>
<td>23</td>
<td>Technology Trends and Paradigm Shifts</td>
<td>6,684</td>
<td>2.262</td>
</tr>
<tr>
<td>24</td>
<td>Globalization of Product Development Processes</td>
<td>4,882</td>
<td>1.733</td>
</tr>
</tbody>
</table>

Some suggestions for future research

The avenues for further research have been clearly stated by the participants of this study. Here we will briefly discuss the top five MOT issues as ranked by process industry R&D managers and experts.

1. **Involvement of Manufacturing in New Product Development**

Product and process development are interdependent in process industry because the existing production system must be able to produce a new product without disrupting the continuous production process. Despite that, new products must typically be taken from the R&D laboratory straight to full-scale production, as production ramp-up is more or less impossible. R&D therefore needs extensive information about the limitations of the existing production process. Hence, extensive involvement of manufacturing personnel is needed in the early phases of the product development process. Still, limited context-specific research on the process industry has been conducted on how to involve manufacturing personnel in the product development process.

2. **Technology Core Competence**

Issues involving the identification and development of technology core competence will always be a significant research area of innovation research. Process industry is no different, even though the core product or process technologies used have often been around for a long time and are commonly considered low-tech [8]. Furthermore, strict process control and other issues pertaining to a continuous high-tech and highly
automated production process also require that the firm focus on these production competencies and link them to innovation activities. There are many different avenues to follow within this field of research, including ranking of core competences within a firm or an industry in order of perceived importance [30], how to combine different competences for commercial ends [31], and the importance of aligning strategies with competencies [32].

3. Soft Skills for Technical Personnel
Issues concerning “soft skills” (e.g. negotiating, listening, communicating, coaching, motivating) among project leaders and other technical managers and experts rose in the ranking compared to the Scott studies. It has been concluded that, in general, process-related factors are seldom discussed at post-project reviews in R&D [33]. Instead, R&D organisations focus too much on technical output and other bureaucratic measures when attempting to learn from previous projects. As R&D managers in the process industry believe that the soft skills are important, these issues may lay the foundation for future work in learning from complicated product and process development projects in process industry.

4. Creating a Conducive Culture
Given the increasing strategic importance of knowledge, the importance of internal knowledge sharing is also increasing. As process industry production plants typically have their own R&D unit, and often a geographical distance to other production plants, inter-plant sharing is inhibited. This implies that scientific and technical personnel are somewhat isolated from employees with similar expertise located at other production plants. Therefore, many process industry corporations report difficulties in inter-plant networking (on both formal and informal levels). Hence, process industry is in need of research on how to establish an internal sharing and informal networking culture despite the geographical distance between production plants. Further research could study the numerous knowledge-sharing mechanisms recently identified by Berends et al. [34] to explore knowledge sharing in process industry – between plants as well as between R&D and production units.

5. Involvement of Marketing Groups
Many process industry firms lack a centralised R&D unit, as process and product development is conducted at each production plant. A process industry firm often consists of numerous production plants scattered over large geographical areas in order gain access to a natural resource (such as mills, remote forestry areas). However, each process industry firm normally has a corporate headquarters in a large city, where the marketing & sales function is also usually located. Therefore, process engineers and R&D employees based at local production plants often have difficulty in keeping abreast of market needs. Hence, process industry is in need of research on how to bridge the gap between the more or less autonomous R&D functions located at each production plant and the centralised marketing and sales function. The vast research on integrated product development (recently reviewed by Boyle et al. [35]) does not seem to have made an impact on the process industry. Therefore, we suggest that more industry-context-focused research on involvement of marketing groups in new product development is needed.
Ranking discrepancies in light of industry context

Discussion of the rankings from an industry perspective

This study was conducted to establish critical MOT issues as determined by R&D managers and specialists in the process industry. Understanding what issues are important, and why, is necessary if researchers really wish to contribute to business practice. A second objective, related to the first, is to gain a better understanding of the differences between process industry and other manufacturing industries. Using the Scott’s findings as a starting point for the survey in this study makes it possible to discuss the relevant issues in process industry compared to issues associated with high-tech product industry. Table 5 compares the ranking of management of innovation and technology issues established in this study to the ranking presented by Scott (as presented in Scott, 2000).

Table 5: Comparing rankings of management of innovation and technology issues

<table>
<thead>
<tr>
<th>Management of technology and innovation issue</th>
<th>Ranking in process industry</th>
<th>Ranking by Scott</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involvement of Manufacturing in New Product Development.</td>
<td>17</td>
<td>1</td>
<td>+16</td>
</tr>
<tr>
<td>Technology Core Competence.</td>
<td>4</td>
<td>2</td>
<td>+2</td>
</tr>
<tr>
<td>Soft Skills for Technical Personnel.</td>
<td>12</td>
<td>3</td>
<td>+9</td>
</tr>
<tr>
<td>Creating a Conducive Culture.</td>
<td>6</td>
<td>4</td>
<td>+2</td>
</tr>
<tr>
<td>Involvement of Marketing Groups.</td>
<td>9</td>
<td>5</td>
<td>+4</td>
</tr>
<tr>
<td>New Product Project Selection.</td>
<td>2</td>
<td>6</td>
<td>-4</td>
</tr>
<tr>
<td>Senior Managers’ Involvement in Technology.</td>
<td>11</td>
<td>6</td>
<td>+5</td>
</tr>
<tr>
<td>Customer/Supplier involvement.</td>
<td>10</td>
<td>8</td>
<td>-2</td>
</tr>
<tr>
<td>Coordination and Management of New Product Development Teams.</td>
<td>7</td>
<td>8</td>
<td>-1</td>
</tr>
<tr>
<td>Productivity of Product Development Activities.</td>
<td>21</td>
<td>10</td>
<td>+11</td>
</tr>
<tr>
<td>Within-Company Technology Diffusion and Transfer.</td>
<td>15</td>
<td>11</td>
<td>+4</td>
</tr>
<tr>
<td>Organization Structure for R&amp;D.</td>
<td>13</td>
<td>12</td>
<td>+1</td>
</tr>
<tr>
<td>Strategic Planning for Technology Products.</td>
<td>1</td>
<td>12</td>
<td>-11</td>
</tr>
<tr>
<td>Project Continuance/Discontinuance.</td>
<td>23</td>
<td>14</td>
<td>+9</td>
</tr>
<tr>
<td>Establishing a “Technology Vision”.</td>
<td>20</td>
<td>15</td>
<td>+5</td>
</tr>
<tr>
<td>Organizational Learning About Technology.</td>
<td>3</td>
<td>16</td>
<td>-13</td>
</tr>
<tr>
<td>Rewarding and Educating Technical Personnel.</td>
<td>22</td>
<td>17</td>
<td>+5</td>
</tr>
<tr>
<td>Alliances/Partnerships Between Technology Companies.</td>
<td>14</td>
<td>18</td>
<td>-4</td>
</tr>
<tr>
<td>Cycle Time Reduction.</td>
<td>5</td>
<td>19</td>
<td>-14</td>
</tr>
<tr>
<td>Resource Allocations to High-Tech Activities.</td>
<td>19</td>
<td>20</td>
<td>-1</td>
</tr>
<tr>
<td>Oversight of High-Tech Activities.</td>
<td>24</td>
<td>20</td>
<td>+4</td>
</tr>
<tr>
<td>Using High-Tech for Competitive Advantage.</td>
<td>16</td>
<td>22</td>
<td>-6</td>
</tr>
<tr>
<td>Technology Trends and Paradigm Shifts.</td>
<td>8</td>
<td>23</td>
<td>-15</td>
</tr>
<tr>
<td>Globalization of Product Development Processes.</td>
<td>18</td>
<td>24</td>
<td>-6</td>
</tr>
</tbody>
</table>

Table 5 reveals that there are many shifts in the ranking between Scott’s original study and this study. However, this discussion will predominantly focus on those six issues that have either risen or dropped by more than ten positions (marked in bold). These are; Involvement of Manufacturing in New Product Development, Productivity of Product Development Activities, Strategic Planning for Technology Products, Organisational Learning About Technology, Cycle Time Reduction, and Technology Trends and Paradigm Shifts.

Involvement of Manufacturing in New Product Development

Issues related to the involvement of manufacturing groups in new product development, e.g. inflexibility of advanced manufacturing systems (such as CIM); manufacturing as a bottleneck in new product development and introduction; preoccupation of manufacturing managers with their own operations, which reduces the extent and effectiveness of their involvement in new product...
Issues related to the involvement of manufacturing in new product development have advanced 16 steps in the ranking from Scott’s study in high-tech industries to being the top issue in this study of process industry. Involvement of manufacturing in new product development is more important in process industry partly because product development, process development, and manufacturing are so closely linked. In the high-tech firms studied by Scott, separating product development from these activities is less problematic. However, in process industry the integration between process and product development is necessary, as process technologies directly influence a product’s characteristics, and changing the product inevitably leads to changes in the production process. For example, at the completion of biopharmaceutical development work, both products and processes may look completely different from what the firm had conceived from the onset [28]. Another reason for involving manufacturing in new product development is because of the heavy capital investments that are required for process industry production. Together with a high degree of automation and high-tech production, it is difficult to make any major changes once the production process has been started. For these reasons introducing new products or making ramp-ups in a continuous production process is difficult, so it is important to get everything right at production start-up. A further reason for involving manufacturing early on is far-reaching environmental legislation that stipulates how raw materials and residual products are to be handled. Hence, it has to be ensured that the new product is possible to produce without violating environmental laws and legislation.

Productivity of Product Development Activities

Issues involving productivity and productivity measurement of high-tech new product development activities, e.g., success rates of new product introduction; measurement system shortcoming; and methods for improving productivity of pure and applied research activities.

Issues involving productivity of product development activities have advanced 11 steps compared to the Scott studies. This may seem strange, as firms in the process industries often develop relatively few new products (with the minerals and metals industry at the low end of the spectrum and food and beverage industry at the higher end [32]). On the other hand, extensive projects coupled with few product introductions imply that the success rate of introduced products must be high. Product development in process industry often implies extensive and expensive projects. This is because of the capital-intensive and complex continuous production processes, and the intertwining of product and process development.Traditionally, process industry firms are producers of commodity products. However, in many process industry sectors firms are trying to move away from being commodity producers and instead add value to the products. This may explain why product development is regarded as being more important. The issue of productivity of product development activities is also linked to the issue of product continuance and discontinuance, which also advanced in the ranking (product continuance/discontinuance rose by nine steps compared to the Scott study).
Strategic Planning for Technology Products

Issues associated with strategic and long range planning for technology-product development, such as aligning high-tech strategies with business strategies (or vice-versa if the technology strategy should be dominant); new product introduction strategies; strategic decision-making processes; lack of understanding of technology and its roles among corporate strategic planners; lack of coherent corporate level planning for high-tech management; failure to identify the critical success factors of a company’s technology activities; and establishing the corporation’s technology climate.

Rank: 12 Change: -11

Strategic planning for technology products, the top-ranked issue in the Scott studies, fell 11 steps in this study. Compared to the high-tech industry studied by Scott, most process industries face few technological discontinuities. For example, the copper industry uses basic technologies developed over a period of almost 150 years, with few paradigm shifts [29]. There are of course exceptions to this general rule, such as biopharmaceuticals [28]. The lack of discontinuous technological change implies that there is less need for research on strategic long-range planning for technology products or aligning high-tech technology with business strategies. It is not that process industry firms do not plan strategically for technology products – because they do. However, technology is simpler to plan when future technological trajectories are clear. For example, technology plans reaching 10 years or more are not uncommon in the mining and minerals industry.

Organizational Learning About Technology

Issues related to organizational learning and institutional memory about new technology and new product development, including how to conduct training; how to provide updating educational opportunities for technical personnel; how to accelerate organizational learning; how to accumulate and preserve organizational learning; how to systemize and maximize core competence and core technology learning that is based on experience rather than education and training; how to measure the level of core technology knowledge and increases/decreases of this level; and how to develop education and training programs for special needs such as for design for manufacture.

Rank: 16 Change: -13

Issues related to organisational learning about technology have fallen 13 steps in the ranking compared to the Scott studies – from third place to place 17. A possible reason for this is that in the process industries a firm’s technology in itself is not a competitive factor as is the case in the high-tech industries described by Scott. As process industry firms often use technology developed over a long period of time and have made heavy investments in their existing production capabilities, there is less need to be on the constant lookout for new technologies. For example, the food industry has been characterised as an industry which does not do its own innovation but brings through to the marketplace the benefits of research conducted further upstream, be it in information technology, biotechnology, or process engineering [36]. In that setting, the ability to exploit new technological developments, as described by Cohen and Levinthal [37], is not a considered a critical capability by managers. Also, as the productions processes are usually highly automated, many employees working as process operators have little or no involvement in technology selection or product development. Hence, their primary task is to monitor the production process. Therefore, at each production plant there are typically only a few process engineers and R&D employees who conduct product development and optimize the production process.
Cycle Time Reduction

Issues related to accelerating new product development cycles (cycle time reduction), e.g. limitations of cycle speed benchmarks; making concurrent engineering work; and the virtue of using cycle speed to permit a later start on product development (in order to capture the most current technologies and customer needs) rather than introducing new products sooner.

Rank: 19  Change: -14

Issues concerning cycle time reduction of product development fell 14 steps compared to the ranking by Scott. Product development in process industry is often slow and incremental. The industry is generally characterised by longer product life-cycles (e.g. milk, butter, copper) where major product changes involve costly changes in production processes and production technology. Products with shorter life cycles, such as consumer electronics produced by the high-tech industry described by Scott, need to be updated more often than commodity products such as base chemicals or pulp and paper. Also, the first-mover advantages of introducing a product quickly and gaining market shares are minor in the process industry. Accelerating product development cycles is therefore not considered a critical issue in many process industry sectors.

Technology Trends and Paradigm Shifts

Issues pertaining to detection and evaluation of technology trends and paradigm shifts and convincing the company that these shifts require dramatic repositioning of the company’s technology posture, as well as to the acceptance in the marketplace of particular technologies and the future need for new kinds of products that customers do not yet say they need, e.g. the nature and structure of technology scanning and intelligence systems for early warnings; technology forecasting; and analysis methodologies to demonstrate eventual impact on the company of a paradigm shift.

Rank: 23  Change: -15

Issues pertaining to detection and evaluation of technology trends and paradigm shifts dropped 15 steps in the ranking compared to the studies by Scott in high-tech industries. This is not so surprising, considering the lower rate of technology change in the process industry compared to high-tech product industry. A firm in the process industry is very seldom faced with the necessity of dramatically repositioning its technology posture. Therefore, technology scanning and intelligence systems for early warnings are not activities to which the firm will commit resources. While paradigm shifts have the potential to severely disrupt an industry (as exemplified by the float glass process), these shifts are infrequent in most process industry sectors [11]. Also, in most sectors of the process industry the industry boundaries, even today, are extremely well defined; perceived quality is stable over time, while competition is played out in the dimension of price (e.g. commodity products). Hence, industry boundaries are seldom questioned, and new industry entrants seldom occur as the sectors are often based on access to natural resources.
Conclusions
This study identifies MOT issues that technology professionals believe are top concerns in process industry corporations and need to be addressed in the academic literature. The five most important issues derived in this study on the process industry are as follows;
1. Involvement of Manufacturing in New Product Development.
2. Technology Core Competence.
4. Creating a Conducive Culture.
5. Involvement of Marketing Groups.
Many of these areas are currently being researched, but seem to lack a process industry perspective.

Another object of this study was to establish whether the ranking of research topics differs between high-tech manufacturing industry and process industry, which has often come to be regarded as low-tech. Several significant differences are apparent between the Scott studies and this study. On the one hand, process industry participants rank Involvement of Manufacturing in New Product Development (up by 16 steps) and Productivity of Product Development Activities (up 11 steps) much higher in importance than do the high-tech participants in Scott’s study. On the other hand, Strategic Planning for Technology Products (down 11 steps), Organizational Learning About Technology (down 13 steps), Cycle Time Reduction (down 14 steps), and Technology Trends and Paradigm Shifts (down 15 steps) are ranked much lower by process industry participants than by the high-tech participants in the Scott studies. Much of this discrepancy seems to be explained by industry context factors, such as the level of intertwinement of product and process development, the rate of technology development, and differing product life-cycles.

This study has indicated that the process industry is in need of somewhat different research than other sectors of the manufacturing industry. Hence, industry context matters when it comes to establishing fruitful directions for further research.
Critical management of technology issues in process industry

References


Critical management of technology issues in process industry

APPENDIX 1

24 MOT Issues

1. Involvement of Manufacturing in New Product Development.
Issues related to the involvement of manufacturing groups in new product development, e.g. inflexibility of advanced manufacturing systems (such as CIM); manufacturing as a bottleneck in new product development and introduction; preoccupation of manufacturing managers with their own operations, which reduces the extent and effectiveness of their involvement in new product development; how to integrate these groups with the product development team; and how to foster innovative manufacturing processes.

Average: 8.700  Ranking in Scott’s JPIM study: 17  Up/down: +16

2. Technology Core Competence.
Issues involving identification and development of technology core competencies.

Average: 8.238  Ranking in Scott’s JPIM study: 4  Up/down: +2

Issues related to the need for improved “soft skills” among project leaders, technical managers and other technically trained new product development personnel, including such soft skills as negotiating, listening, communicating, mentoring, and understanding peoples’ motivations for work and creativity.

Average: 8.143  Ranking in Scott’s JPIM study: 12  Up/down: +9

4. Creating a Conducive Culture.
Issues having to do with creating a corporate culture conducive to high-tech new product development, e.g. establishing an internal sharing and informal networking culture; reducing within-company rivalries; gaining full cooperation of all groups in the company; giving recognition to the importance to the company of new product development; and elevating the importance of scientific and technical personnel.

Average: 8.000  Ranking in Scott’s JPIM study: 6  Up/down: +2

5. Involvement of Marketing Groups.
Issues related to the involvement of marketing, market research and customer service personnel in new product development, such as their participation in selecting research and product development projects; identifying customer needs; defining the market timing in the introduction of new higher-tech products that will make the company’s existing products obsolete; establishing the high-tech product family mix; and accelerating feedback from the marketplace about customer satisfaction with the newest high-tech products.

Average: 7.952  Ranking in Scott’s JPIM study: 9  Up/down: +4

Issues involved with high-tech new product development project selection, e.g. the criteria (costs/benefits, strategic necessity, etc.); how to establish a systematic approach to selection; inability of conventional financial analysis criteria to evaluate the potential of radical new technology; etc.

Average: 7.857  Ranking in Scott’s JPIM study: 2  Up/down: -4

6b. Senior Managers’ Involvement in Technology.
Issues surrounding corporate senior managers’ interaction with high-tech product development, such as a need for senior management to understand their company’s technology; a need for their long-term commitment; a need for champions and sponsors for technology projects and embryonic products and product lines; and the need for senior managers to take the lead in creating the corporate culture needed.

Average: 7.857  Ranking in Scott’s JPIM study: 11  Up/down: +5

8a. Customer/Supplier Involvement.
Issues of whether and how to involve customers and/or suppliers in product development, e.g. how can collaborating vendors be prevented from passing new technology developments along to their other customers; circumstances in which suppliers should develop prototypes for the company or should be restricted to contractual arrangements based on technical specifications; and a need to help suppliers upgrade their capabilities so they can better assist the company.

Average: 7.476  Ranking in Scott’s JPIM study: 10  Up/down: -2

8b. Coordination and Management of New Product Development Teams.
Issues surrounding new product development team structure, team size, membership composition of teams, team operations, team leader selection, need to train teams in teamwork and conflict resolution, team management, inter- and intra-team coordination, team control and evaluation, team reward structures, team motivation, team member access to project data bases, and types of structures for communications systems needed by teams.

Average: 7.476  Ranking in Scott’s JPIM study: 7  Up/down: -1
Issues involving productivity and productivity measurement of high-tech new product development activities, e.g.
success rates of new product introductions; measurement system shortcomings; and methods for improving
productivity of pure and applied research activities.
Average: 7.429  Ranking in Scott’s JPIM study: 21
Up/down: +11

11. In-Company Technology Diffusion and Transfer.
Issues involving programmes and policies to assist technology diffusion and transfer to both other technology areas
(such as to manufacturing) and non-technology areas within a company.
Average: 7.333  Ranking in Scott’s JPIM study: 15
Up/down: +4

12a Organization Structure for R&D.
Issues involving which organization structures are effective for managing R&D and for coordinating R&D with other
parts of the product development cycle.
Average: 7.289  Ranking in Scott’s JPIM study: 13
Up/down: +1

12b. Strategic Planning for Technology Products.
Issues associated with strategic and long range planning for technology-product development, such as aligning high-
tech strategies with business strategies (or vice-versa if the technology strategy should be dominant); new product
introduction strategies; strategic decision-making processes; lack of understanding of technology and its roles among
porate strategic planners; lack of coherent corporate level planning for high-tech management; failure to identify the
critical success factors of a company’s technology activities; and establishing the corporation’s technology climate.
Average: 7.289  Ranking in Scott’s JPIM study: 1
Up/down: -11

Issues associated with continuance vs. discontinuance of each project, involving such considerations as the uncertainty
of results, management’s commitment, and funding cutbacks which may cause cancellation or cause motivation,
personnel assignment and other problems at the project level.
Average: 7.190  Ranking in Scott’s JPIM study: 23
Up/down: +9

15. Establishing a “Technology Vision”.
Issues concerning the need for senior technology managers and senior corporate managers to create a “technology
vision” and communicate and “sell” this fully to the technology groups as well as to the other parts of the company.
Average: 7.143  Ranking in Scott’s JPIM study: 20
Up/down: +5

16. Organizational Learning About Technology.
Issues related to organizational learning and institutional memory about new technology and new product
development, including how to conduct training; how to provide updating educational opportunities for technical
personnel; how to accelerate organizational learning; how to accumulate and preserve organizational learning; how to
systemize and maximize core competence and core technology learning that is based on experience rather than
education and training; how to measure the level of core technology knowledge and increases/decreases of this level;
and how to develop education and training programs for special needs such as for design for manufacture.
Average: 6.952  Ranking in Scott’s JPIM study: 3
Up/down: -13

17. Rewarding and Educating Technical Personnel.
Issues associated with educating, recruiting, rewarding, and retaining technology personnel who are involved in new
product development (such as scientists and engineers), e.g. the need to develop more extensive rewards for good
performance and to encourage more persons to continuously improve their scientific/technical educations, and the need
for some management education and project management education for these personnel.
Average: 6.850  Ranking in Scott’s JPIM study: 22
Up/down: +5

18. Alliances/Partnerships Between Technology Companies.
Issues associated with choosing to participate in and managing the relationships of alliances, consortia sharing or joint
development of technology, or of external partnerships (including trans-national), or issues involving outsourcing
technology development activities
Average: 6.789  Ranking in Scott’s JPIM study: 14
Up/down: -4

Issues related to accelerating new product development cycles (cycle time reduction), e.g. limitations of cycle speed
benchmarks; making concurrent engineering work; and the virtue of using cycle speed to permit a later start on product
development (in order to capture the most current technologies and customer needs) rather than introducing new
products sooner.
Average: 6.810  Ranking in Scott’s JPIM study: 5
Up/down: -14

Issues related to in-company resource allocations to high-tech product development, e.g. the overall process for budget allocations; how different projects are prioritized; “patient capital” concerns; competing with information technology activities for funds; unsophisticated allocation of methodologies; and allocations among new product projects.

**Average:** 6.762  **Ranking in Scott’s JPIM study:** 19  **Up/down:** -1

### 20b. Oversight of High-Tech Activities.
Issues associated with oversight of technology visions, strategies, project selection approaches, and processes and operations, such as via technology management executive committees, technology strategy audits, and corporate boards of directors.

**Average:** 6.762  **Ranking in Scott’s JPIM study:** 24  **Up/down:** +4

### 22. Using High-Tech for Competitive Advantage.
Issues associated with defining the role of using high-tech new product development as a basis for gaining competitive advantage, e.g. establishing an explicit understanding of competitive advantage concepts among new product developers; how companies can focus new product development on competitive advantage; ways to create competitive advantage with high-tech products (such as for entry barriers); and the value of using a high rate of R&D as a strategy to discourage possible new entrants to the industry.

**Average:** 6.700  **Ranking in Scott’s JPIM study:** 16  **Up/down:** -6

### 23. Technology Trends and Paradigm Shifts.
Issues pertaining to detection and evaluation of technology trends and paradigm shifts and convincing the company that these shifts require dramatic repositioning of the company’s technology posture, as well as to the acceptance in the marketplace of particular technologies and the future need for new kinds of products that customers do not yet say they need, e.g. the nature and structure of technology scanning and intelligence systems for early warnings; technology forecasting; and analysis methodologies to demonstrate eventual impact on the company of a paradigm shift.

**Average:** 6.684  **Ranking in Scott’s JPIM study:** 8  **Up/down:** -15

Issues associated with “globalisation” of high-tech product development processes, such as integration of R&D and development team activities across multiple country locations; the impact of different cultures; and dealing with the effects of protectionism and trade barriers on the trans-national transfer of technology.

**Average:** 4.682  **Ranking in Scott’s JPIM study:** 18  **Up/down:** -6
Epilogue
EPILOGUE

For you who have read this and shared my interest in designing R&D organisations in process industry - you have now made it through to the end (I take it that you did so without skipping any parts) - Congratulations!

I can only hope that these pages have given you new insights into the design of R&D organisations. There are valuable lessons and interesting findings within this thesis. If I have been able to represent these findings adequately then I have done a fine job.

Moving on in life after a feat such as writing a doctoral thesis and becoming a man of science is not easy. Almost four years have passed since I received the keys to my office and it is in many ways a different man that walks those halls now. However, it is just now that the real fun begins…

Yours sincerely,
Markus Bergfors

No - process industries are not “boring”!