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On Strategy and Manufacturing Flexibility

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1995

[Link to publication](#)

Citation for published version (APA):

Nilsson, C.-H. (1995). *On Strategy and Manufacturing Flexibility*. [Doctoral Thesis (compilation), Faculty of Engineering, LTH]. Department of Industrial Engineering, Lund University.

Total number of authors:

1

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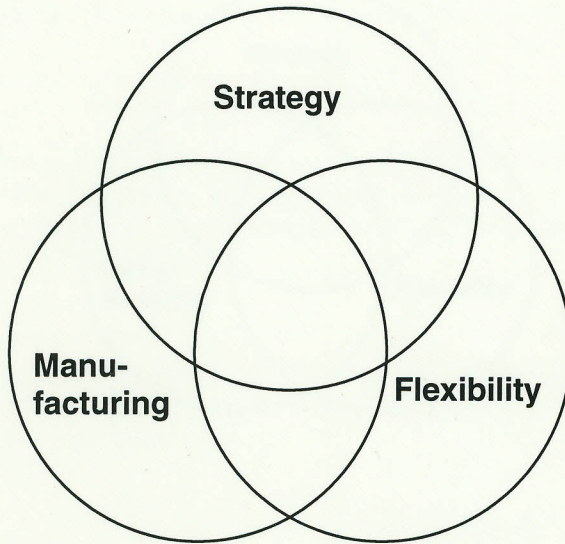
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Carl-Henric Nilsson

ON STRATEGY AND MANUFACTURING FLEXIBILITY



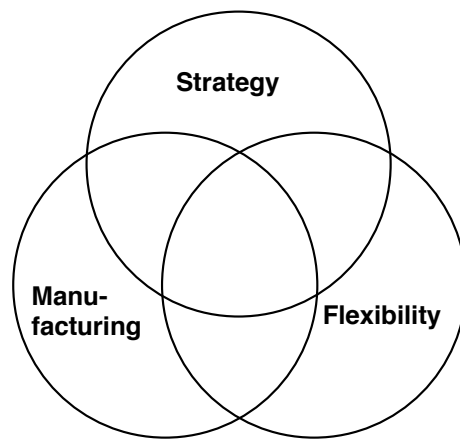
DEPARTMENT OF INDUSTRIAL ENGINEERING
LUND INSTITUTE OF TECHNOLOGY

LUND, SWEDEN

1995

Carl-Henric Nilsson

ON STRATEGY AND MANUFACTURING FLEXIBILITY



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LUND INSTITUTE OF TECHNOLOGY
LUND, SWEDEN
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**ON
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FLEXIBILITY**

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Published by:

Department of Industrial Engineering
Lund Institute of Technology
Box 118
S-221 00 LUND, Sweden

ISSN 0280-722X
ISRN LUTMDN/TMIO--1004--SE

ISBN 91-628-1500-8

2nd printing, April 1995.
Printed in Sweden,
KF-Sigma,
Lund, 1995.

THESIS

This thesis includes a frame of reference, and eight papers appended in full.

Paper I

Nilsson, C-H. and Nordahl, H. (1995) Making Manufacturing Flexibility Operational Part 1 - A Framework, Forthcoming in *Integrated Manufacturing Systems*, Vol. 6, No. 1, pp. 5-11.

Paper II

Nilsson, C-H. and Nordahl, H. (1995) Making Manufacturing Flexibility Operational Part 2 - Distinctions and an Example, Forthcoming in *Integrated Manufacturing Systems*, Vol. 6, No. 2.

Paper III

Nordahl, H. and Nilsson, C-H. (1992) Managers' Perception of Flexibility in Manufacturing - A Study in the Swedish Engineering Industry, in Nilsson, C-H. and Nordahl, H., *Evaluation and Management of Manufacturing Flexibility*, Licentiate Thesis, Department of Industrial Management, Lund Institute of Technology.

Paper IV

Nilsson, C-H., Nordahl, H. and Persson, I. (1992) Analysis and Evaluation of Flexible Capital Investments, in Parsaei, H. R. and Mital, A. (eds.), *Economics of Advanced Manufacturing Systems*, Chapman and Hall, London, pp. 239-254.

Paper V

Nilsson, C-H. (1994) Capital-back - A Continuous Time Interpretation, Department of Industrial Engineering, Lund Institute of Technology.

Paper VI

Nilsson, C-H. and Dernroth, J. (1995) The Strategic Grounding of Competitive Advantage - The Case of Scania, revised and resubmitted for second review in *International Journal of Production Economics*.

Paper VII

Nilsson, C-H. (1995) Strategic Alliances - Optimistic Fiction or Negative Fact, Forthcoming in *Journal of European Business Education*, Vol. 4, No. 2.

Paper VIII

Nilsson, C-H. (1995) Strategic Alliances - Trick or Treat? - The Case of Scania, Forthcoming in *Post Conference Book of the VIII World Productivity Conference*. Stockholm, May, 1993.

ACKNOWLEDGEMENTS

This work has been conducted at the Department of Industrial Engineering, Lund Institute of Technology. Although I have felt that I have walked alone several times during the course of this thesis (especially in the small hours of the morning at the Department), my friends at the Department have not been many hours away. To all of you, thank you for your encouragement and good spirits during these years, I will bear this with me in the future.

Much of the research has been carried out in different constellations. Although I take responsibility for what is written in this thesis, I can not possibly take all the credit for it.

First of all, I would like to direct my thanks to my tutor Ingvar Persson, who has put up with me for such an extended period of time. Truly a remarkable task. He has furthermore guided me with a firm hand towards asking the right questions and viewing problems from several different perspectives. He also managed to bring home to me the significance of methodology for scientists. Ingvar provided the base from which I have probed my areas of research.

Next, my thoughts go to Håkan Nordahl. We worked together throughout the Master's programme, and later on to our Licentiate degree. I have done most of my work on flexibility with Håkan, whom I admire for his stringency as a scientist and dependability as a good friend. Who else would come to the Department at 2 am, on December 30, to give his comments, valuable as always, on the frame of reference for this thesis?

After my Licentiate degree, I continued with team-work, a form that I find rewarding from several aspects. I believe the results of the research to be improved and it is, not least, much more fun than going it alone. Jörgen Dernroth, a true artist, and myself joined efforts in the study of the competitive advantage of Scania heavy trucks. I consider myself privileged to have been working together with such skilful people during my doctoral studies.

Towards the end of my studies, my second tutor, Rikard Larsson, joined the team agreeing to bring the boat into port. A better helmsman for that duty could not have been found, of that I am sure. With unprecedented decisiveness he has pushed me beyond previously conceived mental limits, and I hardly dare to speculate what would have happened (or not) with this thesis, had Rikard not been engaged. I would certainly have missed a very accomplished scientist and a sincere friend.

Now, my thoughts go to my family; to my parents, June and Allan and my sister Anneli, for their continuous support and for inculcating upon me the importance of eating and sleeping as a complement to working, to Calle and Katla, who rightly asked me why I did not get myself another job, so that I did not have to work all the time, and finally, and most importantly, my thoughts go to, and stay with, my wife and research colleague, Guggy. You have had to put up with my mental and physical absence, around the clock, for much too long. The most remarkable thing to me is that you still miss me when I am not at home. My absence and your unintentional loneliness is now, at last, over.

Lund, January 1, 1995

Carl-Henric Nilsson

ABSTRACT

The era when customers bought what companies produced is long gone. The situation is now reversed and companies must produce what customers want; while the customers' preferences are, furthermore, becoming increasingly diverse. This has forced companies to adopt a new mode of thinking in order to survive. The strategy, by necessity, has become to manufacture flexibly.

This thesis focuses on strategy and manufacturing flexibility. It includes a frame of reference and eight papers appended in full, reporting findings in four broad areas:

- Manufacturing flexibility,
- Manufacturing strategy,
- Strategic flexibility,
- Strategic manufacturing flexibility.

The overall purpose of this study is to conceptualise the strategic role of manufacturing flexibility in the continuous realignment between the organisation and its environment. The guiding principle of the methodology applied in this thesis is to use the most appropriate paradigm and methodology given the individual problem at hand.

The results of the studies in *manufacturing flexibility* are used firstly to provide elucidation of the understanding of managers' perceptions of manufacturing flexibility. Secondly, a framework for manufacturing flexibility is deduced which illustrates how to obtain consistency from manufacturing strategy to the resource characteristics in the production system. Thirdly, a method for the evaluation of flexibility in manufacturing, the capital-back method, is developed and analysed.

The results of the study in *manufacturing strategy* are presented as a case, indicating how flexibility of the manufacturing function can be utilised in order to gain competitive advantage in an uncertain and dynamic market. A combination methodology, using both a top-down, grand strategy approach and a bottom-up, grounded methodology is developed and used in the study, and is shown to provide a sound basis for understanding external as well as internal factors impinging upon the company. Furthermore, Porter's (1980) taxonomy of generic strategies is scrutinised and the difficulties of classifying the strategy of a real company into one, and only one, of the deduced taxa are illustrated.

Strategic flexibility is a broad area of research. Consequently, the study of this area embraces only a minor part of the field, namely a meta-analysis of the literature on strategic alliances. The analysis confirms, among other things, that the literature is overoptimistic towards strategic alliances.

Finally, regarding *strategic manufacturing flexibility*, a suggestion for research is presented which involves the synchronisation of three continuous processes within the company, concerning manufacturing flexibility, manufacturing strategy and strategic flexibility. Three major suggestions concerning research in the field of strategic manufacturing flexibility are presented. Firstly, an integrative perspective on the competitive priorities - cost, quality,

flexibility and dependability - is advocated due to synergistic effects. Secondly, since the concept appears to transcend disciplinary boundaries, a multi-disciplinary perspective is also advocated. Thirdly, due to the multi-dimensionality of the concept of strategy as well as flexibility, a multi-methodological approach appears to be advantageous in the pursuit of research within this field.

Keywords: Strategy, Manufacturing flexibility, Manufacturing strategy, Strategic flexibility, Uncertainty, Capital-back, Strategic alliance, Multi-methodology.

Behold, my friend and thou shalt see
that strategies are meant to be
cutting cross taxonomies
as if they were anomalies.

Boxes may be but a hoax,
so use an integrative approach.
For strategic manoeuvrability,
trust manufacturing flexibility!

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PROLOGUE

The era when customers bought what companies produced is long gone.¹ The situation is now reversed and companies must produce what customers want. As if this doesn't put enough strain on manufacturing in companies, customers' preferences are becoming increasingly diverse. This variety in demand has forced companies to adopt a new mode of thinking in order to survive. The strategy, by necessity, has become to manufacture flexibly.

This affects the machinery used to produce the goods. Previously, products were changed as the worn-out machinery was replaced. Today, the shelf life of, for instance, VCR's is approaching six months and decreasing. From this perspective, the machinery has to cope with several generations of the product, many of which are not known at the time of investment in the machinery. However, not only the machinery is affected by this reversed industrial logic, it will of course also have its own impact on manufacturing philosophies, production processes and work organisation. In many respects, manufacturing has become a completely new ball-game. The impetus for change has reoriented manufacturing processes to create more flexible and innovative operations. There are signs that many companies have begun to realise that management and not technology alone will be critical in responding to the challenge. "Soft-side" factors, such as the way business is organised, how it is run, what is viewed as important and how people are treated, are regarded to be of prime importance. Just ten years ago the "hard-side" elements were regarded as more important than the "soft-side" ones. Management of flexible production is cross-functional and predominantly problem-driven. It bridges the existing gap between the field of management and the field of engineering and science. It encompasses many disciplines and is based on an integrative style of management. In this thesis an integrative perspective on the concepts of strategy, manufacturing and flexibility is adopted, studying the concepts from several different perspectives.

Content

This thesis relates to several different research areas. Strategy is a broad, formal² (conceptual) area of research. Flexibility is also a formal research area, although the research is not as abundant as in the area of strategy. Manufacturing is not a formal area of research, but can be regarded as a substantive (empirical) demarcation of an area of research. Simple combinatorial analysis provides four areas of research beyond the three original ones: manufacturing strategy, manufacturing flexibility, strategic flexibility and finally strategic manufacturing flexibility.

¹ This first part of the prologue is, in part, based on Noori's (1990) prologue.

² Glaser and Strauss (1967, p. 32 ff.) make the distinction between a formal and a substantive area of research. A formal, or conceptually defined, research area is not limited to a specific empirical area. A substantive research area is a demarcated, specific empirical area. Formal theories are generally applicable to several substantive areas. "Substantive and formal theories exist on distinguishable levels of generality, which differ only in terms of degree" (ibid. p. 33). Therefore, the one type can overlap into the other in a specific study.

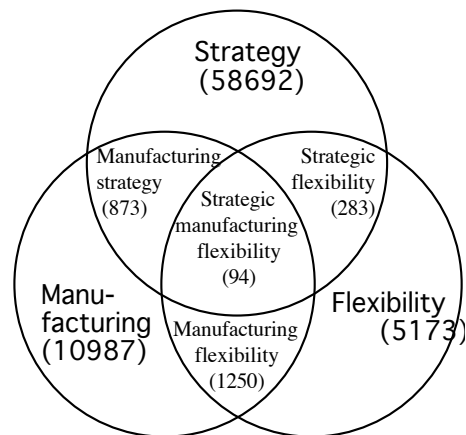


Figure 1. The accumulated number of articles in the database ABI-Inform in research areas related to the thesis.

There is no absolute agreement as to the definition of any of the seven areas of Figure 1. However, it is possible to gain an intuitive idea of the meaning of each area. More stringent definitions are presented later in this thesis, but for the purpose of this introduction, the more intuitive and simplistic approach is used. For instance: What is a strategy? A simplistic interpretation is that *strategy* is a long-term plan of what to do in order to achieve competitive advantage. Scholars of strategy focus on two aspects on strategy; planning and action. Taken to the extreme, some scholars focus solely on planning and others solely on action, while several consider a both aspects. Strategies are generally divided in three levels: corporate, business and functional strategies. *Manufacturing strategy* is thus a functional strategy for the manufacturing function. *Flexibility* refers, in principle, to handling changes efficiently, and *manufacturing flexibility* is about efficient handling of changes involving the manufacturing function. These are mostly well defined research areas. However, *Strategic flexibility*, is not a distinct area of research in the same respect. It has to do with uncertainty and handling changes in the long term to create competitive advantage. Strategic alliance is an example of a concept involving strategic flexibility, where several companies are involved in long-term affairs, aimed at mutually strengthening their competitive position on the market. Admittedly, this reasoning is simplistic, but serves the purpose of an intuitive introduction of the topics of this thesis. Finally, the area of *strategic manufacturing flexibility* is still less developed. I therefore turned to the literature for a definition.

In Figure 1, the accumulated numbers of articles on each topic from the database ABI-Inform between 1971 and 1994 are presented.³ The data in the diagram may give a somewhat

³ The search words were: Strateg*, Manufacturing, Flexib*, thus embracing both strategy and strategic, and flexible and flexibility. In the search these words had to appear in the title and/or in the key words of the articles.

optimistic picture of the number of articles, since the search words do not have to be the focal point of the article. On the other hand, some articles on a topic are not coded with these search words and are thus missed. Still, a relative comparison is possible to make. A special inquiry was made of the ninety-four articles in the centre. About five were closely related to strategic manufacturing flexibility. However, none had an adequate definition of the area.

By extracting the essence from the previously discussed areas, adjacent to the central area, and relating them to each other, a broad understanding of strategic manufacturing flexibility can be achieved. Strategic manufacturing flexibility thus embraces long-term plans and actions, involving manufacturing, with the purpose of achieving a competitive advantage by efficient handling of changes in an uncertain market. The orderly and analytical way forward would be to define a research agenda and firstly make inquiries into each of the three primary fields of research, then the three adjacent areas and, finally most of the effort should be devoted to the central area of research. Today, it is easy to say what I should have done. Unfortunately, I knew little of this when I started my doctoral journey in 1988. The reading of this thesis may thus be facilitated by a short process description, partly explaining why a straight line from start to finish was not used.

Process

Doctoral studies can differ greatly from each other. They can be straightforward, starting with a research question, followed by a decision about how to answer the question; the relevant studies are then carried out and finally, the results are presented in papers or as a monograph. I have so far only heard rumours of the existence of such research processes. The research that I have experienced myself has been quite different. It progresses along winding roads at best, and along no visible roads whatsoever, at worst. Furthermore, it more often than not is breaking new mental ground. The journey through the doctoral studies under these circumstances, by necessity, becomes uncertain. A move forward may well be followed by a jump to the side and quite often nothing appears to be happening at all. It would be unnecessary cruel to force the reader of this thesis through all these strange events. Instead some sort of post-constructed logic can be superimposed on the process, partly to facilitate reading, but also in order to create a synergistic whole of the separate parts. This is the explanation of why things in this thesis might appear to introduce themselves neatly according to a smooth and logical process, which, however, was not what really happened.

This random walk description is clearly part of the truth, however I have had a desire to walk in the general direction towards strategy and flexibility from early on. This has guided my decisions regarding what to do and what not to do during the process and may thereby implicitly have provided a mental structure of this thesis that may actually have resembled the final result all along. Furthermore, the credibility of each individual paper is not affected negatively by the windingness of the overall process. Each paper is defined by a specific problem and a purpose which is stringently pursued to the result of the paper.

From the very start of my doctoral studies the concept of "strategy" excited my curiosity. Strategic decisions can have a substantial impact on long-term decisions concerning future events. The future in itself is also fascinating due to its inherent uncertainties. Uncertainties can be a double-edged sword, introducing threats as well as opportunities. A strategy can be aimed at reducing the perceived uncertainty of the future by attaining an understanding of the future and thus, in some respect, gaining control of what is to come. A strategy can assist in overcoming the threats and reaping the opportunities. Another way of dealing with uncertainties is to prepare for the contingencies ahead. Flexibility is a way of preparing for uncertainties. Both strategy and flexibility are broad concepts which can be applied to a multitude of different situations in life. Being a mechanical engineer, it seemed reasonable to apply the concepts to the manufacturing industry.

My first research steps were taken in the direction of flexibility. My Master's (Nilsson and Nordahl, 1988), which I wrote together with my research colleague Håkan Nordahl, was initiated by a visit to an Asea plant in Västerås, where an industrial robot (one of Asea's own) was proudly presented as an efficient and flexible production unit. After a minor dispute with the tour guide concerning the economic rationale of the robot unit, Håkan and myself were sent off to one of the managers in charge of automation. After a fruitful discussion, he asked us to define a Master's project to shed some light on the issue, which we agreed to do. From the outset, it was fairly obvious that the main difference between a robot unit and a traditional solution was related to the flexibility of the robot. So flexibility became the focus of our efforts, from a manufacturing perspective. Flexibility proved to be a far more complex issue than we originally imagined, and my Master's as well as my Licentiate thesis⁴ (Nilsson and Nordahl, 1992), addressed the issue of flexibility. It is commonly held that research often provides more new questions than it answers, and sure enough, flexibility is still a major issue in this Doctoral thesis, however addressed from several different perspectives.

In the final stages of my Licentiate thesis, I had the opportunity of carrying out research for the Swedish Advisory Panel on Productivity, financed by the Royal Swedish Academy of Engineering Sciences. Together with my research colleague, Jörgen Dernroth, I was appointed to analyse the heavy truck industry and to find out how the Swedish producer Scania, had managed to perform so well. At first we thought that the major issue was productivity, but after careful examination, the research boiled down to strategic issues. The study of Scania (Nilsson and Dernroth, 1992) brought forth some anomalies to contemporary beliefs, which created directions for further research. One such opening concerned strategic alliances which, as a phenomenon, is often presented in the literature as the panacea of industrial organisation, although the empirical evidence of high failure rates is abundant. Another anomaly concerned generic strategies. Leading scholars in the field (cf. Porter, 1980) maintain that it is not possible to pursue a low-cost and a differentiation strategy simultaneously. Still, it is not possible to fit Scania into a single generic strategy. Both these issues have substantial strategic implications, and are also related to flexibility. So the wheel has come full circle. I am back at flexibility, the point of departure, however at a strategic level, and perhaps somewhat wiser.

⁴ The Licentiate degree is an academic degree in Sweden between the Master's and doctoral degree.

Structure

This thesis consists of a frame of reference and eight appended papers reporting findings in four broad, related areas of research. Each one of the nine parts can be read independently but the intention of the frame of reference is to provide a synergistic whole. The order in which the parts are organised is thus intentional.

The frame of reference is a comprehensive primer of the research areas. In "Problems" the overall problem and the problem of each of the four research areas are discussed and related to current research. "Purposes" presents the overall purpose and the purpose in each area of research. "Papers" presents each of the eight papers, arranged in the same order as the papers are appended. The problem, purpose, method and results of each paper are summarised. In the chapter "Methodological reflections" the methodology is elaborated on, and has been granted more space than is perhaps commonly justifiable in an engineering thesis. This is because methodological as well as paradigmatic stances are presented, which can be regarded as part of the results of this thesis, wherefore the contents of this chapter precede "Conclusions". In "Conclusions" the results of the thesis are summarised, and suggestions for future research presented. Thereafter, the papers are appended: first, five papers concerned with manufacturing flexibility, then one paper from each of the areas manufacturing strategy, strategic flexibility and finally strategic manufacturing flexibility, which concludes this thesis.

PROBLEMS

In the presentation of the problems of this thesis a top-down approach is used to close in on the area of strategic manufacturing flexibility. I will thus take strategy as the starting point in the presentation of the problem, continuing with an initial succinct rotation through the combination areas in order to establish the overall problem of the thesis (Figure 2). Thereafter, the combination areas are discussed in more depth leading to the problem that I have chosen to address within each area.

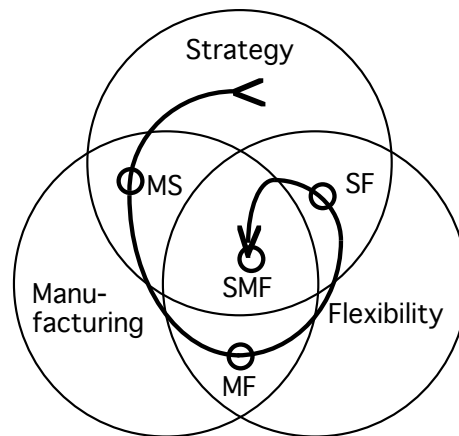


Figure 2. The order of discussion in "Problems".

Strategy

Defining strategy is not an easy task. This is due to the inherent complexity of the concept and the fact that the definition of strategy has not been constant over time. One way of going about defining strategy is to view it from one perspective only. Several authors have done this, for instance, Chandler (1962, p. 13): "Strategy is the determination of the basic long-term goals of an enterprise and the adoption of courses of action and the allocation of resources necessary to carry out these goals." This is a perspective on strategy as a means of establishing the organisational purpose. One way of achieving a more comprehensive definition of strategy, would be to review the literature for several such delimited definitions, and chose articles which view strategy from different perspectives. This has been done, for instance by Hax and Majluf (1988) who compiled the literature on strategy and found six prime dimensions of the concept, and one distinction concerning levels in the organisation, resulting in a comprehensive definition of strategy (ibid. p. 102).

"Strategy

- Is a coherent, unifying, and integrative pattern of decisions;
- Determines and reveals the organizational purpose in terms of long-term objectives, action programs and resource allocation priorities;
- Selects the businesses the organization is in or is to be in;

- Defines the kind of economic and human organization the company is or intends to be;
- Attempts to achieve a long-term sustainable advantage in each of its businesses by responding properly to the opportunities and threats in the firm's environment and the strengths and weaknesses of the organization;
- Engages all the hierarchical levels of the firm (corporate, business, functional); and
- Defines the nature of the economic and noneconomic contributions it intends to make to its stakeholders."

It may appear superfluous to present this comprehensive definition but considering that rather simplistic perspectives of strategy are presented in much of the literature, the definition can serve the purpose of balancing the also rather simplistic discussion in the introduction. Other integrative perspectives on strategy have been presented by, for instance, Chaffee (1985) and Johnson (1987). Mintzberg and Quinn (1991) have analysed the concept of strategy and found five dimensions of strategy: a plan, a position among competitors, a pattern in a stream of actions, a perspective and finally also as a ploy intended to outwit competitors. Bengtsson (1993) presents a useful synopsis of the current status of research on strategy by incorporating Johnson's (1987) continuum of strategy research perspectives into a model with Chaffee's (1985) three strategy models: linear, adaptive and interpretive, as one dimension and Mintzberg and Quinn's (1991): plan, position, pattern and perspective as the other dimension.

Although the concept of strategy can be sliced in many different dimensions, two major streams of strategy research can be identified in the literature. The *content* stream of research focuses on the specifics of what was decided (cf. Fahey and Christensen, 1986), whereas the *process* stream addresses how such decisions are reached in an organisational setting (cf. Huff and Reger, 1987; Pettigrew, 1992). The discussion on the distinction between strategy content and process is not of recent vintage, but can be traced back to Chandler (1962), Ansoff (1965) and Andrews (1971).

Fahey and Christensen (1986) define the domain of strategy *content* research as embracing decisions about the goals, scope and/or competitive strategies of a corporation or one of its business units. An increased interest in strategic issues has led to the emergence of a rapidly growing body of research on strategic decisions made by organisations. These decisions have been studied from the perspective of "strategic management, as well as from the perspective of organizational behaviour/theory, economics, finance, and marketing" (ibid., p. 167).

The central research question on strategy content, then, is: What performance results arise from following specific strategies under different conditions? The research typically emphasises the position of the firm with respect to its environment, "...with considerably less attention (and, in many cases, none at all) devoted to conditions internal to the firm" (ibid., p. 170). The model of strategy research in Figure 3 is rather simplistic, but identifies the prime components and the causality of the model.

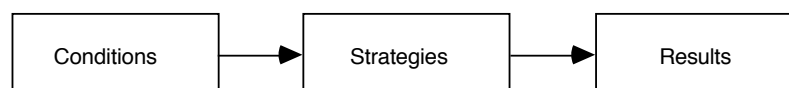


Figure 3. A model of strategy research assumptions
(Fahey and Christensen, 1986).

Schendel and Hofer (1979) present a *process* oriented definition of strategic management as "a process that deals with the entrepreneurial work of the organization, with organizational renewal and growth, and more particularly, with developing and utilizing the strategy which is to guide the organization's operations" (ibid., p. 11). Bower and Doz (1979, p. 159), more explicitly identify three processes which contribute to strategy formation:

- the *cognitive processes* of individuals on which the understanding of the environment of strategy is based;
- the *social and organisational processes* by which perceptions are channelled and commitments created; and
- *political processes* by which the power to influence purpose and resources is changed.

A majority of the process scholars' contributions have been in the study of choice and change processes (Pettigrew, 1992, p. 6). Mintzberg (1990) identifies ten distinct schools of thought on strategy formation. However, a dichotomisation can also be made between two main "schools" on strategy. They go by different names in the literature, but a dividing line can be drawn between an analytical top-down and a synthetic bottom-up approach.

The first approach, *grand strategy*, the analytical top-down approach, is about defining the sources of competitive advantage and hence strategy either inside or outside the company. The strategy process is formal and disciplined, leading to well-defined strategies at different levels by "disaggregating" the strategy in an analytical manner down in the organisation. "An important theoretical issue is where in the chain of causality to best cut into the problem" (Porter, 1991, p. 115). The goal of research is to develop theories until "we can highlight the relatively few variables which can be measured and rigorously examined statistically" (Porter, 1991, p. 116).

The other approach, *grounded strategy*, which is about synthesis and is a bottom-up approach, is aimed at finding the pattern that stands out in the stream of activities in the company. "Three decades of experience with strategic planning have taught us about the need to loosen up the process of strategy making rather than trying to seal it off by arbitrary formalization" (Mintzberg, 1994, p. 114). Instead of viewing strategy as primarily logically deduced, strategy is viewed as emergent from contingencies. Deliberate strategies, as advocated by the grand strategy branch are not excluded, they are rather the other endpoint on the scale from purely deliberate strategies to purely emergent strategies, none of which exists in reality in its pure form. In order to discover strategies, the empirical data unfold as a pattern in the stream of activities in the company, it is argued. Strategy can hence not be totally planned in an analytical way. Instead, strategic thinking is the solution, implying synthesis, involving intuition and creativity. Strategy making is an "immensely complex process, which involves the most sophisticated, subtle and, at times, subconscious elements of human thinking" (Mintzberg, 1994, p. 111). It is argued that the most successful strategies are visions, not plans.

The point here is not to resolve the debate on strategy, merely to outline the major issues that have affected the research presented in this thesis. Furthermore the debate between the

analytical and the synthetic approach does not seem to be resolvable at all, at least not at present. The debate can however be used to sharpen both approaches. Although the separation of the *what* and the *how* of strategy has its merits, the issue of strategy content and strategy process are probably best regarded as inseparable (e.g., Hax and Majluf, 1988; Pettigrew, 1992).

The field of strategic management is currently at a transition point in its development, calling for a greater pluralism, encouragement for methodological diversity and interdisciplinary interest in strategic management from other fields of research such as sociology, social policy and organisational theory (ibid.). Research related to manufacturing can be regarded as a core concept of strategy. For instance, Hill (1985, p. 19) maintains that "considering the fact that manufacturing accounts for some 70-80 per cent of assets, expenditure and people, then it is imperative that senior executives fully appreciate the arguments and counter-arguments in manufacturing...". The manufacturing function possesses numerous desirable characteristics which can enhance companies' strategies as well as strategy research. Recently, concepts such as just in time, flexible manufacturing systems, computer-integrated manufacturing and lean production have become an integral part of the competitive arsenal in the manufacturing industry. The potential of the manufacturing function has thus become recognised to a greater extent; not just as a function in the company, which is supposed to be minimised with respect to cost, but as a potential source of competitive advantage, if wisely utilised.

Towards Strategic Manufacturing Flexibility

The area of *manufacturing strategy* was launched some 25 years ago by Skinner, in his classic 1969 article "Manufacturing - Missing Link in Corporate Strategy". Skinner pointed out that the strategy of manufacturing can have a major impact on the performance of the company and that the manufacturing strategy should support the business strategy in reaching the company objectives and achieving competitive advantages. The infusion of the manufacturing perspective into strategy can both consolidate old themes and create new themes for the research area and, through conceptual transfer, deepen the analytical and ontological basis for strategy research.

Manufacturing flexibility is perhaps the most obvious response to external uncertainty, because of its accommodating nature. However, the literature on manufacturing flexibility is, to a great extent, concerned with operational details and much of the literature uses analytical methods for optimising, for instance, the degree of flexibility of resources in the production system. Within a limited operational perspective, the manufacturing function is more effectively run as a closed system, by analytical rules, without interference from the environment. However, manufacturing is still forced to comply with the uncertain and dynamic demands of the market. What is needed is an elevation of the perspective of manufacturing, acknowledging that manufacturing flexibility has more to offer than just flexible machinery for production. System level flexibility is achieved not only with flexible machinery but also from an integrated infrastructure in parity with the strategic goals of the company. From the 1986 Manufacturing Futures Survey, De Meyer et al. (1989) conclude that the Japanese, after successfully

overcoming quality problems, are turning their attention to flexibility. Based on the results of the Manufacturing Futures Survey, Gerwin (1993, p. 395) concludes that "Decision makers therefore have a growing need for research on the strategic aspects of manufacturing flexibility".

Strategic flexibility raises the issue from an operational, mainly intra-company perspective, to a strategic level, where the interrelation between the company and its environment comes into focus. This interplay is viewed as a means of adaptable and accomodational manoeuvres in response to externally induced changes. These manoeuvres can take several forms, from vertical relations involving suppliers and customers, to horizontal relations for the sake of shaping the competition within an industry and finally to association with organisations from unrelated fields, for the sake of risk reduction through diversification. Judging from the diversity of topics that are addressed in the literature under the label strategic flexibility, this is not a narrowly delimited area of research, on the contrary, it is open to a multitude of different definitions and thus several possible interpretations of the area.

Strategic manufacturing flexibility is one possible answer to the demand for a more strategic perspective on manufacturing flexibility, beyond the narrow limited quantification attempts presented in the majority of the current literature on manufacturing flexibility. The area of research has not yet been rigorously defined in the literature, although some steps in this direction have been taken. For instance, Goldhar, Jelinek and Schlie (1991, p. 255) suggest that investment in "CAD, CAM, FMS and the rest of the alphabet soup of advanced technology will provide acceptable returns *only if flexibility exists throughout the organisation embracing engineering, distribution, and marketing as well*".⁵ Managers must recognise the fundamentally different prerequisites for competition using advanced and flexible manufacturing technologies. The benefits of manufacturing flexibility lie in doing a broad range of things, not in doing the same things better and faster. As a consequence, new and unexpected windows of strategic opportunity may open (ibid.). This leads to the *overall practical problem* of this thesis:

How can a flexible manufacturing function be strategically utilised to create and maintain competitive advantage for the company?

From a theoretical perspective, research on the manufacturing function must be opened up to the dynamics of the market. This means that isolating the manufacturing function from outside disturbances and then analytically deducing rules for a closed system no longer has any validity in relation to the present situation for companies. Instead, the dynamic interaction between the manufacturing function and a changing environment becomes the moving target for research (e.g., Newman, Hanna and Maffei, 1992). Thus dynamic concepts and models must be developed and tested against the current, and evolving competitive realities. The *overall theoretical problem* of this thesis is thus:

⁵ The alphabet soup refers to a substantial amount of three-letter acronyms, such as CAD Computer Aided Design, CAM Computer Aided Manufacturing, FMS Flexible Manufacturing Systems, and CIM Computer Integrated Manufacturing.

How can the strategic role of flexible manufacturing be conceptualised in the dynamic alignment between the organisation and a changing environment?

Also, from a methodological point of view, the radical changes in the practical and theoretical problem induce a need for novel methodological approaches. For example Swamidass and Newel's (1987) adoption of path analysis from social science to test a model relating environment, manufacturing strategy based on flexibility and performance, proved very successful. Another methodological approach can be to adopt and develop constructs originating from related disciplines. Leong et al. note that researchers in business strategy have used this approach with success. For instance, Miller (1987) has adopted the well-tested organisational structure construct, developed by Pugh et al. (1968), while Porter (1980, 1985), with well-known success, has adopted concepts from industrial organisation and applied them to business strategy. Leong, Snyder and Ward's (1990) call for novel approaches in the field of manufacturing strategy may also apply to adjacent areas of research: "...researchers must be willing to invest in finding and learning new methods of analysis" (Ibid. p. 120). Since both flexibility and strategy are multi-dimensional concepts, using a single method to study the concepts will inevitably cause aspects that can be of major importance for the conceptualisation to be overlooked. For instance, manufacturing flexibility can be studied on the operational as well as the strategic level, implying the use of a bottom-up as well as top-down approach. Adding the relation to the uncertain and dynamic environment, applying a range of different methodological approaches can be fruitful. A multi-methodological research approach on strategy and manufacturing flexibility thus seems to have substantial potential. This implies the *overall methodological problem* of this thesis:

How can the interaction between the flexible manufacturing function and the uncertain and dynamic competitive realities on the market be studied?

In order to further the discussion on the problem, each of the four research areas is focused, one after the other. Furthermore, a problem of each area, which will be addressed in this thesis, is identified. The four research areas are: manufacturing strategy, manufacturing flexibility, strategic flexibility and finally strategic manufacturing flexibility.

Manufacturing Strategy

"A manufacturing strategy is determined by the pattern of decisions actually made (that is, by what managers do), not by what the business says its manufacturing strategy is ... The more consistent these decisions are, ... the more effective the manufacturing strategy is likely to be ... the primary function of a manufacturing strategy is to guide the business in putting together the set of manufacturing capabilities that will enable it to pursue its chosen competitive strategy over the long term" (Hayes and Wheelwright, 1984, p. 33). This involves not only the machinery but, more importantly, how production is organised, and the principles that guide the evolution of manufacturing, depending on external changes. "The key to successful operations in the 1990's is recognition of the world as a global market and the imperative for systems integration. Many of the changes in the marketplace ... will continue to have great

impact on company operations. The manufacturing strategy will be based on an evolution of organizational needs (structure and process), continuous measuring of company strengths (in design, manufacturing, marketing, finance, and human resources), and a persisting reinforcement of participative management style" (Noori, 1990, p. 364).

A divide has existed in manufacturing companies, between, on the one hand, the demand on the manufacturing function, imposed by the corporate strategy, of satisfying the customers needs, and, on the other hand, the capabilities of the manufacturing function depending on its intrinsic desire to excel within predetermined conditions, and thus resist change. A mutual disrespect appears to have been built up between strategic management and the manufacturing function. Skinner (1983) proposes, as an explanation of the grudging treatment of manufacturing, that many executives regard manufacturing as a necessary nuisance. It "soaks up capital in facilities and inventories, it resists changes in production and schedules, its quality is never as good as it should be and its people are unsophisticated, tedious, detail-oriented and unexciting" (ibid., p. 83). This view may contribute to an inefficient utilisation of the manufacturing function.

An essential goal of manufacturing strategy has been to bridge this gap in order to improve the competitiveness of companies. In earlier days, buffers and inventory were a practicable way of disconnecting manufacturing from outside "disturbances" (cf. Thompson, 1967). But this is no longer feasible for products other than standard components. Other means must thus be established in order to align the manufacturing function with the company's uncertain and dynamic external environment.

The research on manufacturing strategy can, in analogy to research on business strategy, be divided into a process and content stream of research. Manufacturing strategy, being a young and emerging field of research, may perhaps still gain from this division of the research area, while the more mature area of business strategy has passed this phase in the "research area life-cycle" and is now aimed at an integrative perspective. Evidence in this direction is found in Pettigrew (1992, p. 7) who, concerning *business strategy*, notes that "the sharp distinction between process and content appears [to be] more of an analytical hindrance than a help", while Leong, Snyder and Ward (1990, p. 109) maintain that "The fact that process and content issues are tightly intertwined in published research in *manufacturing strategy* suggests problems in this literature which need to be addressed".

The manufacturing strategy *content* stream of research has become more stable, agreement being reached upon a few important dimensions: cost, quality, flexibility and dependability (Buffa, 1984; Wheelwright, 1984; Fine and Hax, 1985; Swamidass and Newell, 1987; Leong, Snyder and Ward, 1990; Lindberg, 1990; Tunälrv, 1991; Garvin, 1993). Corbet and Wassenhove (1993) add innovativeness to the list, which is also advocated by, for instance, Bolwijn and Kumpe (1990). Garvin (1993) argues that these strategic priorities are generic categories with a multitude of possible interpretations and that they are too highly aggregated to guide decision making. Corbet and Wassenhove (1993) make the distinction between an outward-looking and an inward-looking perspective on the same concepts and compare price,

product and place from the 4Ps of marketing⁶ to cost, quality and time, where time includes dependability, flexibility and rate of innovation. De Meyer and Ferdows (1987) used principal component analysis to identify eight dimensions of manufacturing strategy, and flexibility was shown to be the most important to the respondents. Flexibility can prove advantageous, also from a process perspective.

In contrast to the taxonomy⁷ approach of the content stream of research, the *process* stream of research, for instance, Skinner (1969) and Hayes and Wheelwright (1984), characterises manufacturing strategy as consisting of a pattern of many individual decisions which affect the organisation's ability to meet its long-term objectives. Itami and Numagami (1992) make inquiries into the link between technology and strategy over time and distinguish three effects: strategy capitalises on technology; strategy cultivates technology and technology drives cognition of strategy. Past research has been dominated by the exploration of the first link, while a major potential can be expected to be realised by the pursuit of the third link, how technology accumulation can alter the cognitive and idea system of the organisation in a way that can have a substantial impact on future business strategy.

Skinner's work (1969, 1978), together with that of Fine and Hax (1985), Hill (1989) and Hayes and Wheelwright (1984), suggests a hierarchical model in which corporate strategy drives business strategy. This in turn drives the strategies of manufacturing and other functional areas. The principles behind the top-down approach can be traced back to Chandler's (1962) idea that strategy dictates organisational structure. The dominant view of the strategy process is still top-down, although Hayes (1985) maintains that functional capabilities should, in an uncertain and unstable world, drive corporate strategy.

A major problem of manufacturing strategy is that manufacturing is dependent on the contingencies in the environment. Thompson (1967) takes his starting point in the duality of uncertainty - certainty and technical core - boundary spanners of an organisation. He proposes that organisations seek to isolate their technical cores from environmental influences by establishing boundary-spanning units to buffer or level out environmental fluctuations. The traditional way of dealing with external uncertainties has thus been to disconnect manufacturing from the environment by installing buffers before the production process, within it and after it. However, as the environment becomes increasingly uncertain and the rate of change is furthermore increasing, buffering may no longer be an effective way of dealing with the uncertainties (e.g., Celley, et al., 1986; Banerjee and Goldhar, 1993; Fiedler, Galletly and Bicheno, 1993). From this perspective, buffers and inventories are more of a hindrance

⁶ The fourth P, promotion, deals with influencing customers' awareness and perception of the first 3 Ps and is hence not considered here.

⁷ "Taxonomy is the theory and practice of delimiting and classifying different kinds of entities" (Chrisman, Hofer and Boulton, 1988, p. 415). Taxa are "sets of entities sufficiently similar to each other and sufficiently different from the entities in other such sets that they are separately delimited and named" (ibid.). A category is a level in a hierarchical classification and is composed of taxa. For example Porter's (1980) scheme of generic strategies is a category which consists of three (or four) taxa: cost leadership, differentiation, and focus (cost focus or differentiation focus).

than a help in efficient and effective production, since inventories, among other negative effects, will "blur" the view of the production system.⁸

Several new principles of manufacturing have emerged during the last decade or two, aimed at handling uncertainties, internal as well as external. They are aimed at improving the company's competitive position, often in one of the primary competitive dimensions: cost, quality, flexibility and dependability. Concurrent engineering, group technology and modular production are examples of such principles. More exhaustive production philosophies such as JIT (Just in Time) and TQM (Total Quality Management) have also been employed. The common goal of these philosophies and principles is to streamline the flow of goods through production, thus improving the technical core's flexibility and adaptability. As if echoing Thompson's (1967, p. 80) suggestion: "Yet as the pace of technological change increases and as host environments become more complicated and more dynamic ... Another device seem gradually to be evolving, another form of organization designed especially for flexibility and adaptability..."

The traditional view on strategy in the literature is that strategy is formed in a top-down formal mode, beginning in the corporate strategy then being disaggregated in an analytical manner down through the organisation, for instance to the manufacturing strategy. Among other things, this perspective has created theoretically deduced taxonomies for strategy and manufacturing strategy. It is potentially dangerous if managers perceive these deduced boxes as the only allowed modes of competition. As a reaction to this perspective, a more grounded⁹ approach has been advocated (Hayes, 1985; Lindberg, 1990). However, the majority of the studies on manufacturing strategy are still performed from a top-down analytical perspective. "Descriptive research is badly needed to develop a better understanding of the process of manufacturing strategy" (Leong, Snyder and Ward, 1990, p. 110). Research on manufacturing strategy may therefore gain by using descriptive methods, in order to capture the many vague nuances and contingencies of strategy making within organisations. A problem of manufacturing strategy is thus:

How can the flexibility of the manufacturing function be utilised in order to gain competitive advantage on an increasingly uncertain and dynamic market?

From the discussion it can be concluded that manufacturing strategy is a multi-dimensional problem visible at several levels of the organisation, from the implementation of machinery on the shop floor, to the connection with the market via the business strategy of the company. For instance, Bennett and Forrester's (1991) DRAMAII (decision rules for analysing manufacturing activities), is an empirical collection of guiding principles which allows managers to analyse the company's competitive position and design an appropriate production

⁸ As discussed in the Japanese River analogy (cf. Suzaki, 1987). The depth of the water symbolise the inventories that hide the shoal at the bottom, indicating problems in the productions system, that will become visible, and can thus be improved, once the inventory level is lowered.

⁹ The term grounded is borrowed from Glaser and Strauss' (1967) terminology and implies studies that are empirically based as opposed to purely theoretically deduced studies.

system. This theory, as with most manufacturing strategy theories, advocates a top-down, market-driven approach to strategy formation and its translation to the level of operational design. However, the possibility of a bottom-up approach and the importance of lateral forces are also acknowledged.

The problem of manufacturing strategy is broad, but one common factor stands out, the need for research methodologies which study manufacturing from a grounded perspective. It is evident that the manufacturing function, and hence manufacturing strategy, is an important determinant for the business strategy of manufacturing companies. It is also clear that uncertainties play a major part in strategy and manufacturing strategy. Especially latent uncertainties (Lindberg, 1990) demand flexibility in aligning manufacturing with the external uncertainties. The greater the uncertainties in the environment, the more important manufacturing flexibility becomes for the manufacturing strategy. "Flexibility is the very essence of the future to satisfy the customers' continued preference for choice, therefore the manufacturing system must be designed to service that market requirement" (Sweeney, 1991, p. 19).

Manufacturing Flexibility

Manufacturing flexibility is perhaps the most obvious response to external uncertainty. Manufacturing flexibility can be defined as "the ability of a manufacturing system to adapt successfully to changing environmental conditions and process requirements" (Swamidass, 1988). Buffers, inventory control and capacity are alternative ways of dealing with the uncertainties of manufacturing (Newman, Hanna and Maffei, 1992). The literature on manufacturing flexibility is, to a great extent, concerned with operational details and much of the literature uses analytical methods for optimising, for instance, the degree of flexibility of resources in the production system. The connection between manufacturing strategy and manufacturing flexibility is thus not as strong in the literature as the conceptual relation implies. Within the area of manufacturing flexibility, factors at the resource level, such as set-up times, multi-product machines and multiply skilled labour are analysed, instead of strategic aspects, and furthermore often without their interrelationships. Quantification of flexibility is frequently discussed (e.g., Hutchinson and Sinha, 1989) often from an analytic perspective (e.g., Abdel-Malek and Wolf, 1991).

Within a limited operational perspective, the manufacturing function is more effectively run by analytical rules, as a closed system, without interference from the environment. Traditionally, most organisations have therefore tried to insulate their technical core from the effects of uncertainty (Daft 1986; Schoderbek, Schoderbek and Kefalas, 1985). However, this voluntary isolation may be truly sub-optimal in the sense that manufacturing may still be forced to comply with the demands of the market but has deprived itself of the possibility of providing input to the strategies at the business level.

This analytical resource perspective on the factors of internal competence, is applied in the majority of the literature on manufacturing flexibility. Manufacturing is a complex system, which primarily the technical personnel and managers comprehend since they are comfortable

with and fluent in technical topics (Frohman, 1982). Manufacturing flexibility has, consequently, often been regarded as an operational issue. However, since manufacturing is the major function, dwarfing for instance marketing, R&D and accounting in terms of assets, expenditure and people, it is evident that strategic issues of manufacturing flexibility can be of paramount importance for the performance of a company.

Another problem of manufacturing flexibility (cf. Upton, 1994) is the fact that flexibility is a polymorphous concept, which can be made operational in several different ways. In order for a company to pursue a strategy involving manufacturing flexibility, it is important that the employees, especially the managers, have a common understanding of the concept of flexibility related to their specific context. The problem of conceptualisation is thus twofold; firstly the concept is difficult to grasp even for a single individual, secondly, employees within a company can have substantially disparate perceptions of flexibility, which may cause problems. In order for a company to pursue a strategy involving manufacturing flexibility, it is vital to have a common understanding among managers of different departments of what manufacturing flexibility is, how it is achieved and to what use it can be put.

What is needed is an elevation (cf. Gerwin, 1993) of the perspective of manufacturing acknowledging that manufacturing flexibility has more to offer than just flexible machinery for production. Viewed at a system level, the individual production resources can be utilised to add competitive advantage at the business level. Manufacturing flexibility at the production resource level is the potentially necessary, but not sufficient, operational characteristics of manufacturing flexibility at a system level. System level flexibility is, however, achieved not only with flexible machinery but also from an integrated infrastructure involving people, procedures and policies that are appropriate for the existing technologies and in parity with the strategic manufacturing goals of the company. The point of manufacturing flexibility, from an open system perspective, is that it enables the organisation to dynamically coordinate its throughput process with adjoining organisations in its environment. Thus a problem of manufacturing flexibility is:

How can manufacturing flexibility be utilised in the strategic realignment between the organisation and its environment?

A misconception of manufacturing flexibility (cf. Leong, Snyder and Ward, 1990) is the narrow operational perspective adopted by personnel both within the manufacturing function and from other departments, as well as by several scholars. This restricts the natural utilisation of manufacturing flexibility as a means of achieving strategic competitive advantages. Flexibility, however, can also be viewed from the perspective of the entire firm, not just the manufacturing function. Although manufacturing flexibility can be of paramount importance *per se*, it also has to be put into a company strategic perspective (cf. Gerwin, 1993).

Strategic Flexibility

Strategic flexibility is a novel term for a classical (Hart, 1937) principle of strategy: to enable a course of action to be modified in accordance with an encountered situation which may capriciously deviate from prior anticipation. Authors in the field have tried to make distinct definitions of strategic flexibility, but strategic flexibility has yet to crystallise into a well-defined area of research which, for instance, manufacturing strategy and manufacturing flexibility have.

Eppink (1978) argues that strategic flexibility seeks to reduce the impact of a detrimental, unforeseen event, to minimise response time and to minimise the cost of the response. Eppink further scrutinises the concept "strategic flexibility" by discussing some important dimensions of the concept. Reversible and irreversible changes are introduced, inspired by Rhenman (1973). Flexibility is dichotomised into passive or active, while strategy is defined at three levels, operational, competitive and corporate, together making up an array of interpretations of strategic flexibility. Ansoff (1984), further dichotomises strategic flexibility as external or internal in relation to the company. Ansoff adopts a corporate perspective and argues for diversification as the way to achieve strategic flexibility. These definitions are primarily based on flexibility of assets, but to a large extent omit the connection to organisational aspects.

Aaker and Mascarenhas (1984) fill this gap, by adopting an all-embracing approach of organisational flexibility. On the other hand, by embracing productivity and cost aspects of most functions of the company in their definition, they simultaneously dilute the meaning of strategic flexibility. When the word flexibility in a text can be replaced by, for instance, productivity or quality the definition is too wide. It appears that this problem of conceptual dilution is frequent among authors who are consultants, writing for a practical audience. The logic behind this may be that it does not matter what you call it as long as it helps the client. This problem is not so frequent in the academic literature, in which the opposite may be a problem. Authors (myself included) tend to only address their topic, may it be flexibility, quality or productivity, and omit the relation to the other concepts.

Flexibility, can be used both in *proactive* and *reactive* modes depending on the degree of uncertainty (Lindberg, 1990). Evans (1991) added the dimension *ex ante* - *ex post*, providing a two-by-two matrix of possible aspects of flexibility. This is then further developed into a taxonomy for four archetypal manoeuvres for obtaining strategic flexibility: pre-emptive, protective, exploitive and corrective. Evans (ibid.) further makes an instrumental positioning of the research on strategic flexibility as well as an analysis of the concept of flexibility. Recent publications acknowledge that the concept of flexibility is polymorphous also at the strategic level, but contrary to prior belief, argue that the multi-dimensionality can be more of an opportunity than a threat (Upton, 1994; Kogut and Kulatilaka, 1994). These scholars discuss primarily intra-organisational strategic flexibility.

Another interpretation of strategic flexibility is that it involves inter-organisational collaboration. For instance Harrigan's book (1985) with the title "Strategic Flexibility" proposes that strategic flexibility examines a company's ability to reposition itself in a market, change its game plans or even dismantle its current strategies, for instance when its customers are no longer as attractive as they once were. The barriers to flexibility can be asset specific but

they are more likely to suffer mental blocking by the company's managers. Intermediate options (such as strategic alliances, between acquisitions and internal development) represent "a special, highly flexible means of facilitating innovation or achieving other strategic goals that managers should not overlook as their industries become global" (ibid., p. 58).

Strategic flexibility, thus embraces several different meanings, depending on each author's perspective. It is therefore hard to present a definition that is valid for all interpretations of strategic flexibility, but which still makes an operational demarcation. All definitions of flexibility have one thing in common, and that is the relation to uncertainty and handling of changes in the long term. Although difficult to define in an indisputable way, strategic flexibility is becoming increasingly important, especially in high technology industries, since products, manufacturing processes, markets, distribution channels and competitive boundaries are in a constant state of flux (Evans, 1991). The eloquence of the literature on the necessity of strategic flexibility to cope with dramatic environmental jolts is quite understandable. The perceived environmental uncertainty appears to be constantly increasing and creating major changes in the prerequisites for competition. However, also minor incidents, on their own merits assessed as insignificant, may build momentum to trigger the need for strategic flexibility.

For companies within the manufacturing industry, several of the aspects of strategic flexibility are related to the manufacturing function. Research on strategy has been influenced by manufacturing to the extent that manufacturing strategy is now a well acknowledged research area. This also holds true for flexibility, where manufacturing flexibility is a major independent research area. Both these research areas are defined by the interconnection between a formal (conceptual) and a substantive (empirical) area of research. Strategic flexibility consists of two formal areas of research. Adding a substantive area may imply a stricter and more operational definition of an area of research, and hence reduce some of the confusion concerning strategic flexibility. The intersection between a formal and a substantive area of research may be a more fruitful approach than connecting two conceptual areas (cf. Larsson, 1990). Strategic flexibility omits the operational constraints and opportunities of a flexible throughput in manufacturing, obstructing an empirical grounding of the research area. Furthermore, the contingencies limiting the organisation in the pursuit of strategic flexibility are probably internal more often than external, since the external alternative actions appear to be vast, if not unlimited. A problem of strategic flexibility is thus:

How can the internal prerequisites of the manufacturing function be utilised in order to enhance the strategic flexibility of the organisation?

It seems reasonable to add the empirical area of manufacturing as a demarcation of strategic flexibility since, according to Figure 1, one third of the articles on strategic flexibility already concern manufacturing.¹⁰ This implies the research area of strategic manufacturing flexibility.

¹⁰ The 94 articles of the central area are counted in all of the other areas as well since they also fulfil these criteria. Thus, about one third of the 283 articles on strategy and flexibility are also related to manufacturing.

Strategic Manufacturing Flexibility

Strategic manufacturing flexibility, to my knowledge, yet remains to be defined in the literature. For instance, in the full text search of ABI-Inform, consisting of over 950 000 articles, none contained the expression "strategic manufacturing flexibility" anywhere in the title, keywords, abstract or text of the article. This does not however necessarily mean that similar ideas have not been pursued. It does not either imply that a strict definition is to be desired. What may be interesting is to present some ideas of what strategic manufacturing flexibility can be, in order to advance the discussion.

One approach to gain an understanding of strategic manufacturing flexibility is to look at it from a content and process perspective in analogy to the research areas strategy and manufacturing strategy. In the manufacturing strategy literature four (or five depending on author) competitive priorities are defined, one of which is flexibility. The extension of this would lead the area of strategic manufacturing flexibility to focus on the dimensions of flexibility that provide competitive priorities. This implicitly suggests the construction of a taxonomy of different flexibilities of manufacturing that can have a strategic, long-term, effect on the companies' competitive abilities. The process area of research would then centre on the pattern of implementation of the flexibility taxa of the taxonomy.

However, several warning signs arise for this analytic perspective. Firstly, when reviewing the literature it is apparent that practitioners find it much more difficult to relate to a flexibility taxonomy than academics. The majority of the taxonomies in the literature are theoretically deduced (e.g., Buzacott, 1982; Browne et al., 1984; Gerwin, 1987; Slack, 1988; Chen, Calantone, and Chung, 1992; Hyun and Ahn, 1992). In the relatively few empirically grounded studies (e.g., Slack, 1990; Hum and Leow, 1992), a certain pattern emerges. Managers are most comfortable with resource level aspects as opposed to system level aspects. The definitions of different flexibilities, do not come naturally to the respondents, but must firstly be defined (e.g., Slack, 1990). This is also evident from my own empirical studies. The first conclusion that comes to mind, and which is also the predominant explanation in the literature, is that the majority of managers need to be educated on the concept of flexibility. The logic behind this seems to be that academics, in general, are so much more fluent in the terminology, that academics' conceptualisations of flexibility are more elaborate, thus more correct than those of practitioners. Although this may bear some truth, it does not have to be the only explanation as to why practitioners appear to have a harder time relating to a flexibility taxonomy than academics. What if managers actually do know what they are doing? What if flexibility is not actually perceived as a major issue in the competitive environment of practitioners, simply because it is not a major issue *per se*?

Answering these question in the affirmative would pull the carpet from under the feet of flexibility researchers, including my own. Therefore, a closer inspection of this proposition is called for. Although the majority of the flexibility taxonomies are purely theoretically deduced, some of these taxonomies are then verified against the empirical data, by letting practitioners

relate to flexibility taxa such as; product flexibility, volume flexibility, delivery flexibility etc. These taxa may look relevant, in printing, especially when accompanied by a definition. Few managers would probably disagree with their importance, and, thus, the taxonomy is verified. But why then are the managers' conceptualisation of flexibility found to be partial rather than comprehensive? (e.g., Slack, 1990; Hyun and Ahn, 1992). Why are managers reluctant to discuss flexibility, except on the resource level?

One suggestion is that managers see little intrinsic merit in flexibility *per se*, but view flexibility as a means to other ends (e.g., Slack, 1990). The ends to flexibility are typically one or several of the following: better product availability, reliable deliveries, higher productivity, higher perceived product quality etc. This leaves us with managers who assess several means of achieving flexibility at the operational level, and who see several possible advantages on the market, but who do not regard flexibility *per se* as a major competitive factor.

One possible and far-reaching, but not far-fetched, explanation is that the connections between the business strategy, via the competitive priorities and further down to the means at the system and resource level may be much more complicated than is commonly acknowledged. The analytical top-down disaggregation of business strategies pays no regard to the synergistic interrelations between factors at the lower levels. And if the synergistic relations are substantial, as is suggested, the analytical top-down deduced taxonomies are of limited interest to practitioners and may further *not* provide a sound basis for academic research.

Possible cause-effect chains from resource characteristics to business strategy may thus be obscured by the intermediary level of competitive priorities - cost, quality, flexibility and dependability. This intermediary level figuratively speaking cuts across the characteristics at the lower level as well as the higher level in a way that is more of a hindrance than a help. Forcing resource characteristics into boxes labelled, for instance, with different types of flexibility, might give the false impression that a resource characteristic is not related to any of the other factors at the intermediary level. The characteristics leading to flexibility might simultaneously lead to higher quality and be related to productivity as well. If so, researchers (myself included) have been collectively barking up the wrong tree. What is needed then is a view of the competitive priorities as being simultaneously enhanced by the same characteristic. Short set-up times, for instance, may lead to higher product flexibility, as a manager would probably agree, if asked explicitly. However, short set-up times can give a lot more: dependable deliveries and more consistent quality due to the automation needed to reduce the set-up times in the first place. Shorter series, can reduce inventories and may decrease, or increase, the productivity as well as be a means of sustaining or increasing the market share at a certain cost. Viewed from this perspective, it is understandable that managers will agree that product flexibility is important, but only if asked about the term directly. What is really important to the manager is the short set-up time along with other aspects at the resource level, and how they can enhance the manufacturing and business strategy, irrespective of the labels of competitive priorities of the intermediary level - cost, quality, flexibility and dependability.

The tree-like structure, implicitly assumed by scholars of a business strategy as the stem and competitive priorities as branches and the resources as leaves, might thus not convey the correct picture, since the resource "leaves" are actually connected to the business strategy

"stem" via several "branches" of competitive priorities. A more correct picture may be several intertwined and interconnected chains of effects in some organic structure. It is hard to find a valid metaphor for this type of structure, which may actually be one explanation of why the tree structure is implicitly assumed.

It is also understandable that academics pursue the intermediary level since they are often engaged in research on one topic; flexibility, quality or productivity etc. However, an integrative perspective is needed to pursue the research on strategy, manufacturing strategy and on strategic manufacturing flexibility. This also means that researchers will either have to expand their area of research or engage in joint research projects over the present research boundaries. The phenomenon of strategy does not acknowledge traditional borders between either concepts or research areas or, for that matter, research disciplines (cf. Leong, Snyder and Ward, 1990; Pettigrew, 1992). From a theoretical perspective, this conception of strategic manufacturing flexibility has several implications for scholars. Firstly, since the concept transcends disciplinary boundaries, it appears advantageous to tackle strategic manufacturing flexibility from several disciplinary perspectives. The strategy constituent requires primarily a management perspective, while manufacturing and flexibility require an engineering science perspective. Adding the polymorphous nature of flexibility as a concept (cf. Evans, 1991), a cognitive perspective might prove an additional advantage which, however, is not pursued in this thesis. Secondly, due to the multi-dimensionality of the concept of strategy as well as flexibility, a multi-methodological approach appears to have merits that are difficult to obtain in any other way. This discussion finally leads to the problem of strategic manufacturing flexibility:

How can manufacturing flexibility via manufacturing strategy influence the organisation's strategic flexibility in order to facilitate the continuous realignment between the organisation, its manufacturing function, and its environment?

Strategic manufacturing flexibility can assist companies in developing and maintaining production systems that function in the long run. The sequential relationship of strategy research assumptions between conditions - strategies - results, as depicted in Figure 3, can thus be modified for research on strategic manufacturing flexibility in accordance with the processes outlined in the dynamic model in Figure 4. The objective is to synchronise these processes and invigorate the inherent reciprocity of the processes.

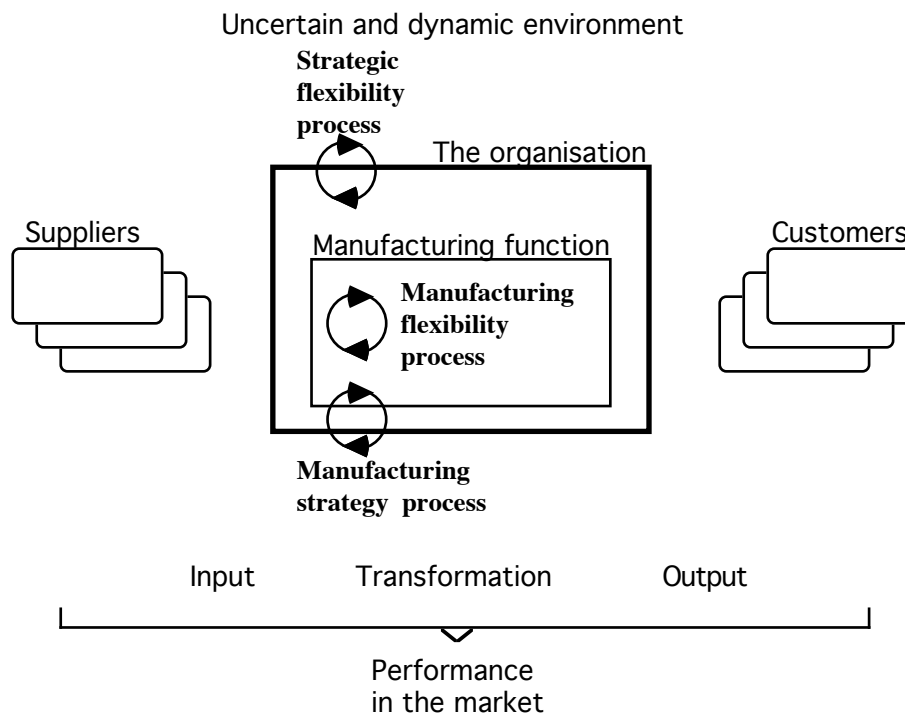


Figure 4. A model of strategic manufacturing flexibility research assumptions.

An example of an industry where strategic manufacturing flexibility is assessed as the direction of the future is the semiconductor industry.¹¹ A new generation of processors is introduced every 18 to 24 months. The speed to market and the importance of efficient manufacturing units is imperative. Considering Intel's 1993 sales of processors of \$ 8.8 billion, a one-day delay to the market will imply a loss of sales of approximately \$ 30 million. The cost of developing Intel's Pentium processor's successor (unnamed, but called P6) is in the region of \$ 10 - 15 billion.

According to the marketing research company VLSI Research, the future for the industry lies in mini-plants. The objective of these plants is to make manufacturing into a process industry. The semiconductor industry resembles the steel industry in several respects. The major steel companies once tried to achieve economies of scale in huge manufacturing plants, however, today mini-factories dominate. Economies of scale are superseded by economies of scope. A mini-factory for semiconductors can, at best, produce 20% of the number of chips produced by the huge manufacturing units used today. However, what the mini-factories lack in size they gain in speed. Today, it takes about two years to trim a new traditional manufacturing unit, which can be reduced to one year for a mini-factory implying a 60% increase in sales the first two years for a mini-factory. A mini-factory is further expected to substantially reduce the *cost*

¹¹ The facts concerning the semiconductor industry are from Teknisk Tidsskrift (1995), p. 24-25.

of production as well as the batch-sizes allowing for *flexible* production and cost-efficient *dependable delivery* of small orders. The automated process further will increase the *quality* in production, by automation. The production process is simplified from 200 process steps to approximately 70. Furthermore the chips are transported in air-tight boxes and all operations carried out without any contact with the surrounding air. This alone will save \$ 2 million per factory, according to VLSI Research, since the employees do not need to use traditional "space suits" in the production.

This example illustrates how manufacturing flexibility, via manufacturing strategy, can enhance the company's strategic flexibility in the continuous realignment between the organisation and its environment. Furthermore, the synergistic effects between the competitive priorities- cost, quality, flexibility and dependability are illustrated.

PURPOSES

The problems discussed in the previous chapter form the basis for the purposes of this thesis. Rather than proceeding in the same order as in the previous chapter, the sequence of the purposes and the appended papers starts in manufacturing flexibility where I initially built the foundation for the whole research project. Manufacturing flexibility is then strategically elevated to manufacturing strategy and strategic flexibility before concluding in strategic manufacturing flexibility as the final part of the thesis. The discussion of the purpose and the papers of the thesis thus follows the order depicted in Figure 5.

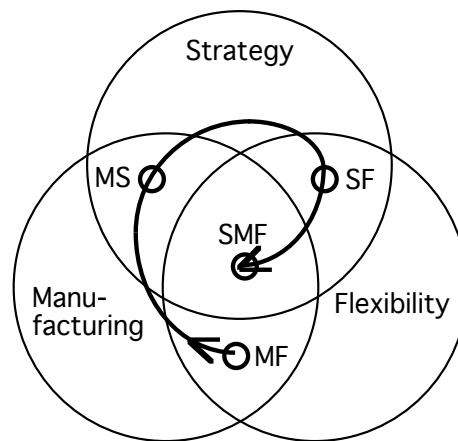


Figure 5. The order of presentation in "Purposes" and "Papers".

Today, manufacturing has several options available to reduce uncertainties. Increased integration and simplification of both technologies and infrastructure can reduce internal uncertainties (Hayes, Wheelwright and Clark, 1988; Imai, 1986). Better integration of supplier and customer relationships has been shown to reduce the external uncertainties (Ansari and Modarress, 1986; Dumond and Newman, 1990). Flexible manufacturing equipment, such as FMS and CIM, has provided cost-effective means of accommodating manufacturing uncertainties through manufacturing flexibility (Goldhar and Jelinek, 1985). Newman, Hanna and Maffei (1992) proceed further and present a "dynamic equilibrium model" based on the relationship between modern process technology options, the level of integration in the process and the ability to compete in a cost-effective manner based on speed, flexibility and quality.

The overall purpose of this study is to conceptualise the strategic role of manufacturing flexibility in the continuous realignment between the organisation and its environment.

Although manufacturing flexibility is one of the most obvious responses to external uncertainties, the majority of the literature on manufacturing flexibility is still preoccupied with quantification of flexibility on the operational level. The authors seem more interested in excelling

in numerical analysis than in solving problems encountered by real managers (cf. Kochikar and Narendran, 1992; Benjaafar, 1994). There is a lack of models and methods for assessing the merits of manufacturing flexibility that are applicable in managers' empirical reality.

The purpose of the manufacturing flexibility section of this thesis is to chart the understanding of flexibility in manufacturing and develop models and methods for strategic realignment between the manufacturing function and the organisations' environment that can be used by managers.

This can be split into three sub-purposes:

- * *To chart the understanding of manufacturing flexibility,*
- * *To develop models for analysing manufacturing flexibility in a corporate decision-making context, and*
- * *To develop methods for a priori evaluation of flexibility in manufacturing.*

Manufacturing flexibility can be viewed as emanating from the operational characteristics of the manufacturing resources. Thus flexible machinery, for instance, is in most cases advantageous for making a production unit flexible. However, flexibility in response to market demands is achieved not only with flexible machinery, but also from an integrated infrastructure involving people, procedures and policies. Furthermore, existing technologies, work organisation and other infrastructural components have to be in parity with the strategic manufacturing goals of the company. Thus, an integrative approach involving not only machinery, but also the other aspects of manufacturing, is necessary to evaluate the strategic aspects of flexible manufacturing.

The purpose of the manufacturing strategy section of this thesis is to illustrate how flexibility in the manufacturing function can be utilised in order to gain competitive advantage on an uncertain and dynamic market.

One aspect of Harrigan's (1985) interpretation of strategic flexibility is that it can be viewed as a tool for company growth. The two extreme variants of growth are acquisition, which is fast but costly, and internal expansion, which utilises internal resources and is therefore inexpensive but slow. However, a golden means exists which is both inexpensive and fast; the forming of a strategic alliance. The aim of a strategic alliance is to share resources between companies and thus gain a broader base without financial outlays. The literature on different growth strategies is abundant. The set of strategies includes, for instance, mergers and acquisitions, strategic alliances and joint ventures, all of which are major areas for research. One question in these research areas concerns motives for company growth. However, often no distinction is made between advantages of growth *per se* and advantages connected with one specific growth strategy when compared with others. This is clearly conceptually confusing. There is another major source of confusion concerning the flexible growth strategy of forming strategic alliances. The majority of the contributions in the field of strategic alliances are pro-alliance, although the broad surveys which have been presented indicate a mediocre success rate for strategic alliances.

The purpose of the strategic flexibility section of this thesis is to analyse strategic alliances, as one method for flexible combinations of the operations of several organisations.

Although Gerwin (1993) promotes a strategic perspective on manufacturing flexibility, the majority of the manufacturing flexibility literature appears to be caught in the deadlock of detached analytical quantification of different aspects of flexibility. The merits of interrelating research on strategy with this branch of manufacturing flexibility research appear to be of little or no practical value. However, based on the argument in "Problems", an integrative approach between these areas may be fruitful and is consequently advocated in this thesis.

The purpose of the strategic manufacturing flexibility section of this thesis is to provide an illustration of the strategic role of manufacturing flexibility in the continuous realignment between the organisation and its environment.

PAPERS

The papers included in this thesis are arranged according to the structure depicted in Figure 6 and are summarised individually in this order in this chapter.

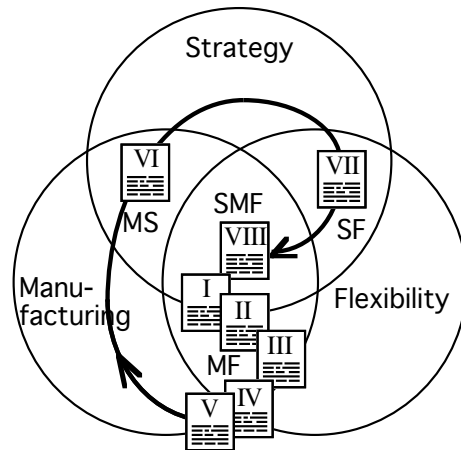


Figure 6. The papers arranged according to research area and order of presentation.

Authors' Contributions

Five of the articles are the result of joint efforts. Making clear distinctions of who has written what is, in many cases, irrelevant. The research has been a process, driven forward by each individual, but primarily by the interaction with and confrontation of each other's ideas. However, some distinctions can be made concerning the main responsibilities of some parts of these articles.

Paper I:

Carl-Henric Nilsson was mainly responsible for compiling and writing the paper, the remainder was a joint effort.

Paper II:

Carl-Henric Nilsson was mainly responsible for compiling and writing the paper, the remainder was a joint effort.

Paper III:

Håkan Nordahl was mainly responsible for compiling and writing the paper, the remainder was a joint effort.

Paper IV:

Carl-Henric Nilsson was mainly responsible for the analyses of the use of capital-back and pay-back in relation to standard methods such as IRR and NPV. Håkan Nordahl was mainly responsible for the system for dividing the components of an installation into sub-systems. He was also responsible for the discussion and definition of component flexibility. The remainder of the paper was a joint effort by the three authors.

Paper VI:

Carl-Henric Nilsson was mainly responsible for the theoretical frame of reference, the methodological discussion and writing the paper. The collection of the empirical material for the paper was a joint effort by the authors.

Abstracts

The problem, purpose, method and results of each of the appended papers are summarised according to the order of the papers in this thesis.

Paper I

Nilsson, C-H. and Nordahl, H. (1995) Making Manufacturing Flexibility Operational Part 1 - A Framework, Forthcoming in *Integrated Manufacturing Systems*, Vol. 6, No. 1, pp. 5-11.

The strategic importance of the manufacturing function has experienced a renaissance, becoming the focus of many of the latest trends in global competition. FMS, CIM, JIT and lean production are examples of tools and principles which enhance flexibility. The issue of flexibility is complex, closely related to the overall strategic plan of the enterprise and, at the same time, to single production factors at the operational level. A need for wider product scopes and the trend towards shorter product life cycles are some of the factors which make flexibility a top priority issue in manufacturing strategy. It is thus evident that flexibility in manufacturing is an important issue and is expected to be even more important in the future (Noori, 1990).

The purpose of this paper was to develop a framework for manufacturing flexibility which shows how to obtain consistency from manufacturing strategy to the resource characteristics in the production system. The framework provides guidance on how to analyse and develop manufacturing flexibility in a corporate decision-making context.

A primarily deductive methodology is applied. The model used as a starting point for the framework is the Input-Transformation-Output (I-T-O) Model. The frameworks of Porter (1980) on the strategic level, Hill (1985) on the manufacturing strategy level and Chamber's (1990) link between manufacturing strategy and flexibility, are supplemented by our framework.

The results of the study is the framework that goes into detail on how to make flexibility operational in manufacturing. The framework is conceptual in the sense that it will guide the manager's method of thinking. It is tangible in the sense that it will make operational the flexibility aspects of manufacturing. It allows the managers to make the connection between decisions at the strategy level right down to those decisions on single production resources. Furthermore, the process of analysing the I-T-O system can begin anywhere in the framework.

Paper II

Nilsson, C-H. and Nordahl, H. (1995) Making Manufacturing Flexibility Operational Part 2 - Distinctions and an Example, Forthcoming in *Integrated Manufacturing Systems*, Vol. 6, No. 2.

The variety of definitions of flexibility has caused the term to lose some of its usefulness. In order to analyse flexibility, the phenomena behind the concept must be brought forth. The flexibility concept has different meanings for different people, therefore, a large variety of aspects are discussed in the literature (e.g., Kumar and Kumar, 1987; Gerwin, 1987; Gerwin and Tarondeau, 1989; Slack, 1990). Mandelbaum (1978) defines flexibility as "the ability to respond effectively to changing circumstances". It is this definition that we use as a starting point for the structuring of the concept of flexibility.

The purpose of this paper was to further develop the theories behind the framework for manufacturing flexibility initially presented in Paper I. More specifically:

- to provide a conceptual structure of flexibility, and to
- describe the use of the framework for manufacturing flexibility by working through a concrete example.

The study is based on a deductive methodology, and the usability of the framework is indicated by working through an example.

The results of the study are the distinctions of the concept of flexibility in the three generic dimensions: utilised flexibility versus potential flexibility, external flexibility versus internal flexibility, and requested flexibility versus replied flexibility. As a secondary result, the example that is worked through illustrates how the framework can be used in a top-down mode, to align the transformation process with the market strategy resulting from changes in customer preferences in the market. However, the framework can also be used in a bottom-up mode to enhance the market strategy based on competitive characteristics in manufacturing.

Paper III

Nordahl, H. and Nilsson, C-H. (1992) Managers' Perception of Flexibility in Manufacturing - A Study in the Swedish Engineering Industry, in Nilsson, C-H. and Nordahl, H., *Evaluation and Management of Manufacturing Flexibility*, Licentiate Thesis, Department of Industrial Management, Lund Institute of Technology.

Swamidass and Newell (1987) have shown that there is a positive correlation between flexibility and the performance of a company. However, the flexibility concept has different meanings for different people, and a large variety of flexibility aspects are discussed in the literature. In summary, flexibility is a multi-dimensional concept for which no one has been able to provide a set of valid measures, or define it in an indisputable way.

The purpose of this paper was to investigate:

- How managers in the Swedish engineering industry perceive flexibility in manufacturing depending upon departmental affiliation and company.
- Which aspects of flexibility managers perceive as the most important for manufacturing, now and in the future.

Twenty-four managers from the finance, marketing, production and product development departments of six companies were interviewed. The six companies in the study were a convenience sample generated from industry contacts. The methodology of the study can be regarded as a "mini-case study" or a "mini-survey". The analysis of the raw interview data consisted of five major steps. The first two constitute a within-company analysis, the last three, a cross-company analysis. The different steps were not performed in sequence. Instead, an iterative process was used where we turned back and supplemented the analysis as further insight into the cases and the flexibility concept was gained.

The results of the study can be summarised as follows:

The most-mentioned resource characteristics and their main goals were:

- Set-up times - to increase delivery range flexibility.
- Multi-product machines - to provide high product flexibility.
- Multiply skilled labour - to provide volume flexibility.

The position-related findings were:

- Finance - set-up times and labour.
- Marketing - set-up times and multi-product machines.
- Production - labour, multi-product machines and set-up times.
- Product development - product flexibility.

Company-related findings were:

- The larger the company, the more complex the view of flexibility.
- The more complex the products, the more important the infrastructure.
- The higher the level of technology in production, the higher the perceived need for flexibility in the company.

Paper IV

Nilsson, C-H., Nordahl, H. and Persson, I. (1992) Analysis and Evaluation of Flexible Capital Investments, in Parsaei, H. R. and Mital, A. (eds.), *Economics of Advanced Manufacturing Systems*, Chapman and Hall, London, pp 239-254.

Flexibility is a broad concept and is dependent upon the circumstances under which it is used. Many authors have discussed and defined flexibility in the manufacturing process. It is mainly concerned with two dimensions, the product dimension and the material flow dimension. The analyses do not consider the possibilities of reusing the equipment in different manufacturing processes. In this paper, flexibility related to the product scope and flexibility related to the components of an investment, is discussed.

The purpose of this paper was to analyse capital-back (cb) as a method for evaluating flexible capital investments. cb is compared with pay-back (pb) and the use of cb together with pb is compared with the standard capital budgeting techniques - net present value (NPV) and internal rate of return (IRR).

The cb method is theoretically deduced, but empirically supported by a retrospective longitudinal study (Nilsson and Nordahl, 1988) of five robot installations' ability to handle minor and major environmental changes.

As a result of the study it is concluded that the pb method emphasises the short-term planning, uncertainty and the initial strength of the investment. However, for flexible investments, this method can lead to erroneous investment decisions. The advantage of the cb method is that it takes into consideration the uncertainty in the risky part of the investment and the requirement for profitability for the flexible part. The annuity method is used to describe the residual value of the flexible part of the investment over time, a is the annual net receipt for the investment, n is the life-span and i is the discount rate. When $NPV > 0$ and $IRR > i$, it can be shown that $\partial cb / \partial f < 0$. This means that the investment is acceptable and thus the cb period \leq pb period for all values of f . When $NPV = 0$ then $\partial cb / \partial f = 0$ and $cb = pb$. The formula for the capital-back period is:

$$cb = \frac{(1-f)G}{a - f \cdot G \cdot \text{annuity}(n \text{ years}, i \%)}$$

Paper V

Nilsson, C-H. (1994) Capital-back - A Continuous Time Interpretation, Department of Industrial Engineering, Lund Institute of Technology.

The capital-back method (cb method) is a capital budgeting method for measuring the inherent flexibility of an investment. Capital-back has been developed to provide a method for considering the flexibility of production equipment in the manufacturing industry. Existing models of capital-back are based on discrete time. From a theoretical point of view a continuous time interpretation may prove advantageous, for instance in analysing the effects of the discrete time simplification.

The purpose of this article was to introduce a continuous time interpretation of the existing cb method and to develop a more general version, based on continuous time. The basic version of cb in Paper IV is converted into continuous time in order to evaluate the effect of the simplifications of a discrete and annual cb cash flow. Three limitations of the basic cb method can be identified:

- discrete cb cash flows,
- constant cb cash flows, and
- a is not discounted.

A positivistic deductive research approach is applied.

Concerning the first limitation, the discrete cb cash flow, the analysis indicates that the difference between the discrete and continuous interpretation of the basic cb formula is negligible for practical purposes. It is only for investments with very low profitability and very high flexibility that the methods can yield considerably different cb periods. For profitable investments the continuous interpretation will always yield cb periods equally short or shorter (better) than the discrete interpretation. To resolve the three limitations of the basic cb method, a continuous time generalisation of cb is developed. The general model allows continuous, variable receipts $\alpha(t)$, miscellaneous depreciation methods of the flexible investment $\xi(t)$, as well as dual interest rates ρ_α, ρ_χ . In the formula the fundamental idea behind cb is distinguishable. The left-hand side is the risky part (1-f) of the total investment G, and the right-hand side is the cb cash flow, consisting of the discounted accumulation, under the cb period, of the net receipts minus the cost of the flexible part of the investment.

$$(1-f)G = \int_0^{cb} \left[\alpha(t) e^{-\rho_\alpha t} - \left(fG\rho_\chi + \xi(t) - \rho_\chi \int_{z=0}^t \xi(z) dz \right) e^{-\rho_\chi t} \right] dt$$

Paper VI

Nilsson, C-H. and Dernroth, J. (1995) The Strategic Grounding of Competitive Advantage - The Case of Scania, revised and resubmitted for second review in *International Journal of Production Economics*.

What are the sources of competitive advantage? This was one of the main questions posed by The Swedish Advisory Panel on Productivity. An objective of the Expert Report No. 6 (Hörnell, 1992), one of nine studies prepared for the Panel, was to identify companies that performed very well within their industry and to explain the external contingencies as well as company factors leading to this above-average performance. In order to explain the success of each company, its strategy as well as the sources of competitive advantage had to be analysed.

The purpose of this paper was to describe the sources of competitive advantage for Scania, the Swedish heavy truck producer, and how these sources may have been used to build up Scania's strategy. The two perspectives on strategy and competitive advantage, grand strategy versus grounded strategy, are both used as tools in analysing the case.

A descriptive mode of research can be advantageous in discovering new theories or fallacies of extant theories and a case study was hence used. The research started with a literature study on the formal theory of competitive advantage and the empirical area of the truck industry. Parallel with the literature study, personal interviews with leading employees within and around Scania were performed. Some twenty managers within Scania were interviewed with semi-structured interviews during a one-year period. In order to ensure the validity of the material, additional interviews of respondents outside the company were performed. High-ranking employees who had left the company were interviewed as were competitors, subcontractors, retail dealers and hauliers.

The results of the study were threefold: Firstly, Scania's sources of competitive advantage support each other mutually in achieving economies of scale at the item level which is where scale is important and achieving high-quality products, thereby justifying a price premium on the market. Important sources of competitive advantage for Scania, that were identified are: item standardisation and modular production, in-housing of strategic parts and out-sourcing of others, avoiding horizontal collaboration and keeping full control of the product development and production processes. Secondly, Porter's (1980) generic strategy theorem does not appear to be a true reflection of the competitive realities. This conclusion is supported by several other studies. We go one step further and suggest that by constructing a set of pre-defined options, the degree of conceptual freedom for managers and scholars is severely restricted, which may prohibit the pursuit of an even more successful strategy. Thirdly, the study presents some normative suggestions for future research concerning research on strategy and the sources of competitive advantage. A grounded strategy approach is advocated as a complement to the grand strategy approach in order to explain the sources of competitive advantage and their interrelationships within the company.

Paper VII

Nilsson, C-H. (1995) Strategic Alliances - Optimistic Fiction or Negative Fact, Forthcoming in *Journal of European Business Education*, Vol. 4, No. 2.

There seems to exist a great divide between, on the one hand, the optimistic feeling and rosy picture concerning strategic alliances conveyed in the literature and, on the other hand, the empirical facts concerning alliances. The fact that failed relationships "isn't the kind of thing you like to write up in a press release" (DeYong and Davis, 1990, p. 36) is of course one explanation for the lack of empirical evidence of failures, but this is not sufficient to explain the divide and the exceedingly positive attitudes toward strategic alliances.

The main purpose of this paper was to analyse, in a systematic way, to what extent there actually exists a divide between the optimistic fiction on strategic alliances presented in the majority of the literature and the empirically grounded facts of high failure rates presented in other articles. A secondary purpose was to examine if the divide could be explained in terms of author profession, "scientificness" and empirical grounding of the studies.

A meta-analysis is the most suitable method, considering the purpose of this study. A meta-analytical approach allows for inference between empirical and theoretical research in a time-effective way not feasibly obtainable by performing the empirical work oneself. An integrative review is to "summarize past research by drawing overall conclusions from many separate studies that are believed to address related or identical hypotheses." (Cooper, 1984, p. 11). 121 articles, with strategic alliance in the title, found in ABI-Inform from 1971 up to 1993 were reviewed.

The study empirically confirms three major issues. Firstly, the literature on strategic alliances is, on average, over-optimistic. Secondly, there exist clear relationships between author profession, "scientificness", empirical grounding and attitude toward alliances. Thirdly, the natural divide between different types of empirical grounding is between survey and non-survey studies. This divide may be further explained as a function of the biases intrinsic to each method used. The skewness of the material is taken as a probable indicator of these biases. Surveys are the least skewed thus indicating less bias. The case studies and examples can be skewed due to access bias, response bias and selection bias. The non-empirical studies can be skewed due to prejudice bias. While skewness was found for all methodological approaches it was higher for practical studies than scientific ones, with the exception of non-empirical studies where the scientific and practical studies were approximately equally skewed.

Paper VIII

Nilsson, C-H. (1995) Strategic Alliances - Trick or Treat? - The Case of Scania, Forthcoming in *Post Conference Book of the VIII World Productivity Conference*. Stockholm, May, 1993.

The nature of cooperation, or rather the purpose of cooperating, has shifted towards issues concerning the business concept of the enterprise (Porter and Fuller, 1986, p. 315). These issues are strategic in nature and will intrinsically, through the strategic aspects, have substantial and long-term effects on the enterprise. One cooperative form is called strategic alliance and is directed at utilising the advantages of sharing. The opposite form, based on the idea of non-cooperation, is labelled "go it alone strategy" (Devlin and Bleackley, 1988) and is aimed at being strong on your own and utilising the advantages of not having to collaborate.

The purpose of this paper was to demonstrate that strategic alliances are not always the panacea they are believed to be. The failure rate of alliances and joint ventures, as reported in the literature, varies between 30% and 75% (Grunberg, 1981; Killing, 1983; Reynolds, 1984; Porter, 1987; Devlin and Bleackley, 1988; Schaan, 1988). Many advantages that are accredited as being due to collaboration can also be achieved with a "go it alone strategy". The case of Scania is presented as an illustration. Particular emphasis is placed on factors related to Scania's strategic choice of staying out of alliances and their relationship to the performance of the company.

The empirical data for this study - the case of Scania, in the heavy truck industry, is the same as in Paper VI, but analysed from a different perspective. Porter's frameworks (1980, 1985, 1986, 1990) for analysing competitive factors relating to companies, industries and countries were used as a theoretical foundation for the study supplemented by other frameworks such as those of Lawrence and Dyer (1986) and (Imai, 1986). The literature on strategic alliances is abundant and most authors are pro-alliance. By presenting a case, in which forming a strategic alliance would be disadvantageous to the firm, a complementary view to the much more common pro-alliance picture is provided. The case is presented together with the prerequisites of the industry, and other relevant facts. This provides an opportunity for practitioners to relate their company to the case and achieve a more nuanced picture of the advantages and disadvantages of strategic alliances as well as to draw conclusions concerning their own company. These conclusions can be more valuable than the generalised and thus partly diluted recommendations most often provided in the literature. For scholars, the case of Scania can provide new insight into the research on strategic alliances from a novel perspective.

The primary benefit of this study is an illustration of primarily the possible negative effects of joining an alliance. The question is raised whether forming a horizontal alliance is more or less flexible than going it alone. Three strategically important issues that are related to a company's choice to join a strategic alliance or not are elaborated on - time-based advantages, economies of scale and different aspects of flexibility. The process of forming a strategic alliance can turn out to be irreversible. The decision to join an alliance therefore requires the utmost consideration by senior management.

METHODOLOGICAL REFLECTIONS

This chapter starts with methodology as the focal point and only address issues which, in a conceptual sense, are at most one step removed from methodology. Furthermore, these issues are addressed from the perspective of the research process. "Methodology is a difficult subject. There is no easy way out. This is understood by every conscientious scientist" (Bjerke, 1981, p. 18). The objective of this chapter is twofold. Firstly, one aim is to describe the "mental glasses" through which I have viewed reality and my research. This is important for the reader in order to understand and evaluate what I have been doing, how and why. Secondly, I will present some methodological and paradigmatic suggestions. The methodological reflections are intended to provide a comprehensive contextual frame for the research of this thesis.

A research project concern the creation of a fit between its three nodes (Figure 7):

- the *paradigm*, which concerns ontology and epistemological stance, that is, the basic assumptions of reality and knowledge of the researcher,
- the *methodology*, which concerns how the study is carried out, involving methods and techniques, and
- the *problem*, which is what is studied, or the research question.

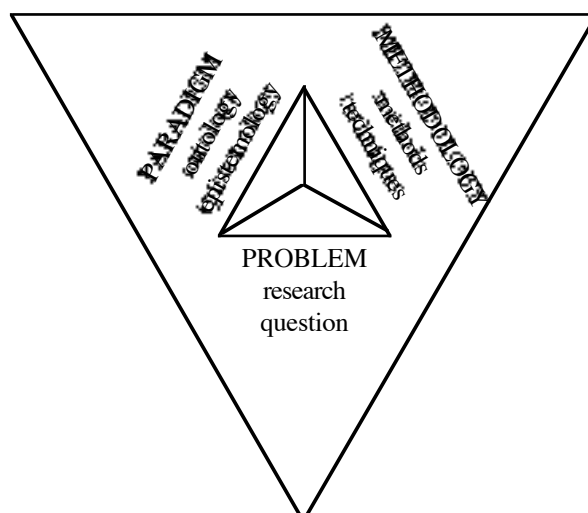


Figure 7. Three nodes of research.

Research is a broad concept, not only embracing the research problem, but also bridging the basic assumptions of reality as well as the methodology, and the relation between the three. The creation of tension, between the three nodes of a research process¹², can be just as important as the creation of a simple fit between the three nodes of a research project. This

¹² A research process can extend over several research projects.

tension can be utilised as a driving force to enrich and balance the results of earlier studies by applying a new perspective in one of the three nodes and exploiting the difference and/or complementarity of the results, thus stretching beyond a tunnel vision approach.¹³

During the research for this thesis I have used different methodological approaches and paradigms. In Figure 8, the research possibilities defined by four basic methodological approaches and three paradigms are illustrated, and some of the traditional methodological distinctions are positioned in relation to these dimensions. The methodological distinctions and the three paradigms are briefly discussed in order to provide the means for full apprehension of Figure 8. The discussion on paradigms is primarily adopted from Arbnor and Bjerke (1994), while the positioning of the paradigms relative to one another relies on Larsson's (1990) Appendices A and B.

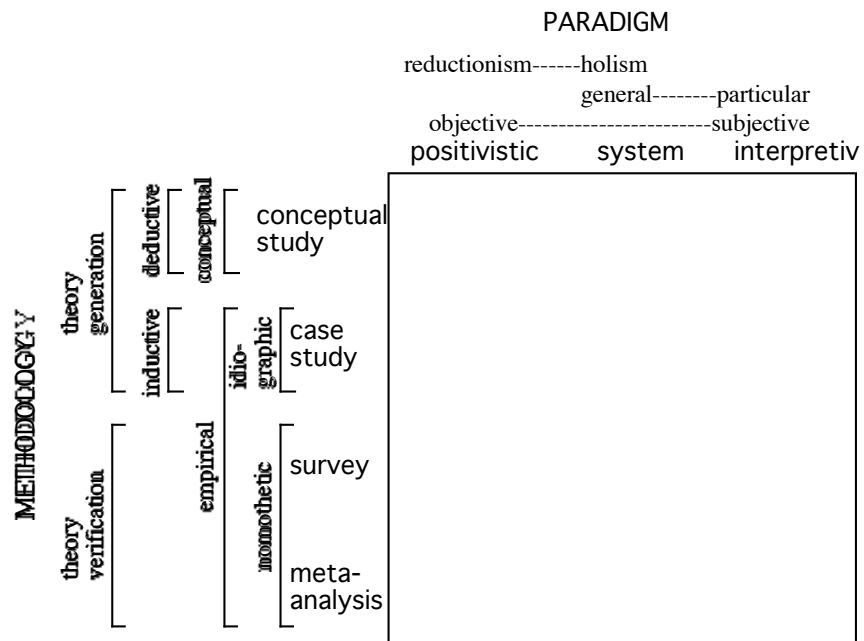


Figure 8.¹⁴ Research possibilities.

¹³ By tunnel vision I refer to research on a narrowly defined problem using one and the same methodology and paradigm at all times.

¹⁴ The model of Figure 8 is intended to illustrate a taxonomy of methodological distinctions of common aims of each method. The taxonomy is, however, not indisputable. For instance, case studies are often theory generative in nature, however, they can arguably also be used for verification. Depending on paradigmatic affiliation, researchers might argue that their own pet method can be used for more purposes than indicated in Figure 8, which is quite possible.

Research can be related to two worlds, the empirical world and the theoretical world (Figure 9). Theories can be *generated* either by induction or deduction. *Induction* is development of theory based on empirical observations. *Deduction* is the development of theory from theory which is advocated by rationalists who argue that logical thinking is the most important source of knowledge. *Verification* is the connection back to the empirical world in which the theory's relevance can be tested. This divides research into two types; on the one hand *empirical*, that is connected to the empirical world either by inducing theory from practice, or by verification of theory, and on the other hand, *conceptual* research which is strictly theoretical in the sense that it starts in theory and ends in theory without being directly affected by empirical data.

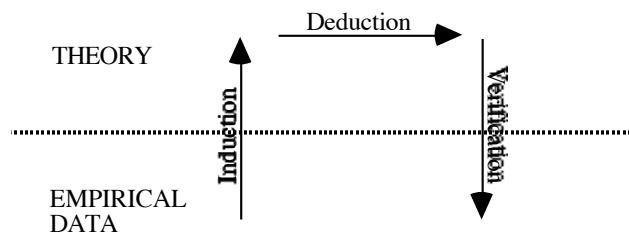


Figure 9. A model of theory generation and verification.
Adopted from Arbnor and Bjerke (1994, p. 107)

The *idiographic* approach supports the idea that one can only understand social phenomena by getting close to the investigated subject by exploring, for instance, its detailed background and life history. The analysis is focused on the subjective understanding and explanations, which are generated by getting inside situations, instead of examining them as an external observer. It is further emphasised that the subject should be allowed to unfold its nature and characteristics during the research process (Burrell and Morgan, 1979). The *nomothetic* approach, on the other hand, focuses on systematic protocol and technique. It is most often preoccupied with testing hypotheses with the "canons of scientific rigour" (ibid., p. 6) and often applies quantitative methods and standardised research instruments. The distinguishing point is whether a study should be performed through intensive, multi-aspect, in-depth studies of a few cases (*idiographic*) for descriptive studies of individuality, or an extensive study of a few aspects across a large sample (*nomothetic*) in the search for laws (e.g., von Wright, 1971).

The *positivistic* or analytical paradigm is the traditionally dominating approach and is used widely in research in the natural sciences. One basic assumption is that there is an *objective* reality that is independent of individual human beings, such as the researcher. The objective of research is to explore this reality. The gaining of scientific knowledge thus follows formal logical procedures. Furthermore scientific knowledge is of an additive character, a *reductionistic* stance, meaning that the whole can be explained by the sum of the parts. The aim of research is to reconstruct reality and establish causal connections between entities, often to explain and guide or forecast.

The second paradigm is the *systems theoretical* paradigm, which emerged in the 1950's as a reaction to the additive picture of reality of the positivistic paradigm. The systems paradigm also believes in an objective reality but in contrast to the positivistic paradigm, takes a *holistic* stance believing in synergistic effects. The relation between entities comes into focus since they can add positive or negative effects to the system. Multifinality and equifinality¹⁵ are acknowledged as well as *generality* of theories.

The third paradigm is the *interpretive* paradigm which applies a phenomenological approach to science and became established as a paradigm in business management in the 1960's. Reality is assumed to be a social construction (cf. Berger and Luckmann, 1967), which is dependent on the actors. Reality consists of several different images, picturing the meaning and content *particular* actors put into their actions and surrounding environment. Knowledge is a *subjective* property and reality does not exist in an objective sense. Systems do not exist as objective entities as in the systems paradigmatic sense but exist only in the mind of the scientist. The reality of several individuals can have common components that constitute an objectified reality¹⁶ for this group of individuals, whether scientists, organisations or the society. This objectivity is not universal, but created by man and can therefore be questioned and changed.

Problem

A core question for research is whether methodology should determine the problem or whether the problem should determine the methodology. When reading the literature, the conformity of methodological approach is noticeable. Most authors appear to be caught within a narrow methodological frame of reference. Few, if any, alternatives to their standard strategies of research are utilised. One line of argument in favour of this methodological focus is that each area of research is suited to one type of method. Thus, between a paradigm and a problem, there is just one suitable methodology. Another standard argument for this procedure is - in analogy to the argument presented by Skinner (1974) for a focused factory - focus on a limited, concise manageable set of types of papers, concepts, methods and journals.¹⁷ This is clearly the most efficient method for producing square boxes, but is the scientific community best served by square articles by square authors? I think not.

Problems of empirical reality can not be expected to respect conventional borders between research areas or research disciplines, nor should they be treated as if they did. This paves the way for inter-disciplinary research programmes. Multi-disciplinarity on behalf of each researcher appears to yield more possibilities than threats, however it is not a necessity. Corroboration within a multi-disciplinary group of researchers may be a more plausible way to proceed. Furthermore, inter-disciplinarity has a broader potential than merely sharing the

¹⁵ Multifinality means that a cause can have several effects, while equifinality means that various causes can have identical effects.

¹⁶ Reality is however not objective in the sense of the other two paradigms.

¹⁷ For Skinner, it was a limited, concise manageable set of products, technologies, volumes and markets.

problem. The possibility of sharing metaphors and drawing on analogies between different fields of research has proved to be a powerful tool in advancing research. For instance, models from biology and physics can, and frequently have been, applied in organisational theory.

Paradigm

The definition of science, the definition of knowledge and the interpretation of what we know can differ substantially, between researchers with different paradigms. Each researcher, implicitly or explicitly, makes certain basic assumptions about the constituents of reality. The decisive point in these assumptions concerning the basic construction of reality is that they can not be empirically or logically tested, but only reflected upon intellectually (Bjerke, 1981). The sets of assumptions, stipulations or normative propositions can collectively be called a research paradigm (Kuhn, 1962/1970). A research paradigm contains philosophical preconceptions which guide the researcher concerning research objects, applicable methodology for the research, and also the interpretation of the results. A paradigm defines the boundaries of research that are sanctioned by members of an area of research. These paradigmatic assumptions in essence concern the basic construction of reality, the view of research and its aim, what constitutes scientific ideals and ethical and aesthetic elements of scientific progress (Bjerke, 1981; Törnebohm, 1975; 1982).

Kuhn's propositions have not been spared criticism by the scientific community (e.g., Suppe, 1974). After his initial publication in 1962, Kuhn has subsequently made several specifications of the concept of paradigm. In this presentation I relate particularly to three conceptions of paradigm. Firstly, the basic meta-theoretical and philosophical proposition concerning the concept of paradigm as an implicit or explicit view of reality that binds together scientific communities. To this view I subscribe. Secondly, that paradigms shift in phases of revolution in which one paradigm supersedes the other. This conception I regard to be too restricted and monistic. Thirdly, the position that one researcher can not comprehend more than one paradigm, which I will discuss more after a brief discussion of the second notion.

Kuhn refers to the natural sciences when discussing paradigm shifts. However, researchers from other fields, such as the theory of science (Törnebohm, 1975, 1982) and business management (Arbnor and Bjerke, 1994) maintain that paradigms may develop evolutionary and may furthermore coexist. I conceive paradigms as coexistent and that they transcend through evolution as well as revolution. It can thus be implicitly assumed that I define the natural sciences not to be my field of research. However, since I do not regard the isolationistic perspective to science to be the most fruitful, I argue that a forced choice of paradigmatic affiliation would not be a true reflection of my research. With educational grounding (borrowing from the useful terminology of Glaser and Strauss, 1967) in both natural and social science traditions, the possibility of shifting perspective and identifying the entities of paradigmatic content *with* and also *as* something¹⁸ (Israel, 1979) can be utilised as

¹⁸ Identifying something *with* something means to identify based on similarities, thus arranging entities into identical taxa, while identifying these entities *as* something, focuses on the differentiating aspects of the entity that make it unlike other entities.

methodological and scientific propellants in the research process. In practical terms: keeping a foot in both camps can be advantageous, since it allows for an inside as well as outside perspective on the content of research as well as the research process.

The assumptions underlying research paradigms can be analysed according to a hierarchical typology. Above any research are the constitutive *ontological* assumptions of reality. Concretisation of these fundamental assumptions in terms of favoured metaphors (Morgan, 1980) or basic schools of thought, through which the assumptions become meaningful, represents a particular epistemological stance, or a particular view of the possibilities of knowledge (Oliva, 1988) and the creation of knowledge. *Epistemology* concerns the understanding of reality, and how we communicate this to other people. There is hence a close relationship between ontological assumption and epistemological stance. I refer to this as a paradigm¹⁹, since the way of achieving knowledge is affected by one's ontological assumptions, an epistemological stance will imply a certain ontology (cf. Björkegren, 1989, p. 117).

Arbnor and Bjerke (1994) propose a trinity of paradigms of social science (more specifically, business management is focused upon), thus in some respect take the opposing stance to Burrell and Morgan's (1979) dichotomising perspective on paradigms. Arbnor and Bjerke argue that three *harmony groups*, exist. A harmony group is a unit with a fit between problem, solution techniques and basic assumptions. Made operational to the researcher this means that the scientist should chose research techniques that are in harmony with the scientist's basic assumptions of reality and with the problem that seems to be at hand (Bjerke, 1981). Three paradigms have shaped my view on science: the *positivistic*, *system theoretical* and *interpretive* paradigms. To these I will relate my research, in the assurance of the existence of other paradigms as well as different opinions on the definition of these three paradigms. (For a thorough discussion on these paradigms see: Arbnor and Bjerke, 1994; Bjerke, 1981; Larsson, 1990).

Contrasting the *dichotomising* view of Burrell and Morgan (1979) in another way than Arbnor and Bjerke's (1994) "*triadisation*" of the dichotomy, Berger and Luckmann (1966) present forceful argumentation for *complementarity* in the subjective - objective dimension. Starting in two of the most famous and influential "marching orders" for sociology: Durkheim's (1938/1966) objective positivism versus Weber's (1922/1976) subjective German idealism, the complementarity of the objective - subjective dimension is advocated. "Durkheim tells us: 'The first and most fundamental rule is: Consider social facts as things.' And Weber observes: 'Both for sociology in the present sense, and for history the objective of cognition is the subjective

¹⁹ My view of the term differs somewhat from that of the scholars referred to. For instance, Arbnor and Bjerke, argue that paradigms exist at two levels: the upper, which connects basic assumptions to methodology, and a working paradigm, which connects the methodology to the research area, both of which I embrace. Morgan (1980, p. 606-607) has a more intuitive definition: "an implicit or explicit view of reality". De Mey (1982, p. 36) suggests that a paradigm is a very elaborate cognitive structure that is supposed to specify the prerequisite knowledge necessary for processing the information in a given area of science. Kuhn (1962/1970) finally, who introduced the concept, used paradigm to embrace at least twenty-two different meanings in the original text (Masterman, 1964).

meaning-complex of action.' These two statements are not contradictory. Society does indeed possess objective facticity. And society is indeed built up by activity that expresses subjective meaning. And, incidentally, Durkheim knew the latter, just as Weber knew the former. It is precisely the dual character of society in terms of objective facticity and subjective meaning that makes its 'reality sui generis'²⁰ (Berger and Luckmann, 1966, p. 30).

Continuing in the spirit of Berger and Luckmann, Larsson (1990) also scrutinises Burrell and Morgan's (1979) four-level dichotomisation of the objective - subjective dimension and focuses his efforts on advocating the traditional dichotomisation between idiographic and nomothetic approaches as a misinterpretation of what is really a practical and economical restriction rather than a scientific contradiction.

From the discussion in the literature, it can be concluded that there are *objects*, upon which the positivistic paradigm is focused, there are *relations*, which the system paradigm focuses on, and there are *subjects* which the interpretive approach focuses on. None of these paradigms denies the existence of these three factors, and most scholars would thus agree that objects, relations and subjects are present in most situations.

I advocate paradigmatic flexibility as a research strategy, thus reaping the potentials of a multi-paradigmatic approach. I furthermore propose that this can be advantageous on the level of the individual researcher. There are scholars who propose advantages from the simultaneous pursuit of different paradigms from a collective scientific community's point of view. "...new alliances between natural sciences and social sciences which will reveal the intricate complementarity between knowledge of external worlds and models of ourselves" (De Mey, 1982, p. 259). According to Morgan (1980) the idea of simultaneous pursuit of paradigms will have revolutionary implications for the research process as well as the results of research.

Methodology

There appears to exist a widely spread methodological prejudice against multi-methodological approaches at the extension of the paradigmatic rigidity. According to methodologists (e.g., Arbnor and Bjerke, 1994; Morgan 1983) several researchers have specialised in using one and the same methodology. This conformity can extend over several levels of research from the individual level, to the research group and even for an entire research area. However, few research areas seem to be best researched by approaching the problem with a collective tunnel vision. By specialising in using one single method the researcher can be expected to master this method. However, if you loose your key in the street at night, looking directly under the streetlight will facilitate the search, but you will probably never find the key... Therefore, the purpose should determine the method, not the other way around. This principle has guided my research.

²⁰ Reality of its kind (as it is).

It has become increasingly clear that research methods can not, a priori, be regarded as neutral or a-theoretical tools (Brewer and Hunter, 1989). This is true for natural sciences, such as physics²¹, as well as for social sciences. The multi-methodological approach rests on the idea that methodology should not be treated as a choice between mutually exclusive methods. Individual methods might be defective through favouring certain results, but the deficiencies of different methods are not identical. The fundamental strategy of a multi-methodological approach is thus to "*attack a research problem with an arsenal of methods that have nonoverlapping weaknesses in addition to their complementary strengths*" (ibid., p. 17). The authors (ibid., pp. 48-54) propose a number of advantages of the multi-methodological approach for theoretically oriented research. Employing different methods helps to guard against, and correct for, inherent methodological biases.

From the literature on methodology we conclude that integration, by applying a multi-methodological approach, can manifest itself at different levels. It can be used at the upper level, the area of research, but also within the research group. "Interaction between colleagues - even colleagues of quite different methodological persuasions - can be a powerful integrative force" (Brewer and Hunter, 1989, p. 24). Finally, at the individual level, integration is possible. This is perhaps the least exploited possibility of integration, while simultaneously providing the greatest opportunities. Some researchers even seem to be afraid of the idea. "We are not advocating that each researcher take on all methods in their research portfolio... What we advocate is that each researcher appreciate and encourage the diversity of various methods dedicated to the growth and understanding of logistics [their research area] as a whole" (Dunn et al., 1993, p. 124). I propose that this is exactly what should be advocated, that each researcher extend his or her research portfolio beyond the tunnel vision approach to integrate multiple research methods at the individual level. This could pave the way for the much coveted understanding of other methodological approaches than each researcher's own pet method. Having tried different approaches on an individual basis could facilitate the understanding within a research group, as well as within the research area as a whole. This does not mean that all researchers have to become methodological generalists. Specialists are clearly needed in certain fields, and some individuals are more apt for specialisation than to become generalists. A balanced blend seems to be a fruitful approach securing the internal reliability and validity of the results of the research within a research area, as well as the external validity.

Thesis

The guiding principle of the methodology applied in this thesis is to use the most appropriate paradigm and methodology given the problem at hand. In concluding this chapter I will discuss some of the methodological problems encountered in this work from an inter-paper perspective. The methodology of each paper is discussed in each appended paper. Each paper is positioned in the most appropriate place in the matrix in Figure 10. It is not possible to identify an paper with a certain paradigm and exclude any connection to the others in an

²¹ Quantum mechanics, to be more specific.

unobjectionable way. It is also an oversimplification to identify each paper solely with one methodology. However the graphic presentation can still be useful as a starting point for the discussion.²²

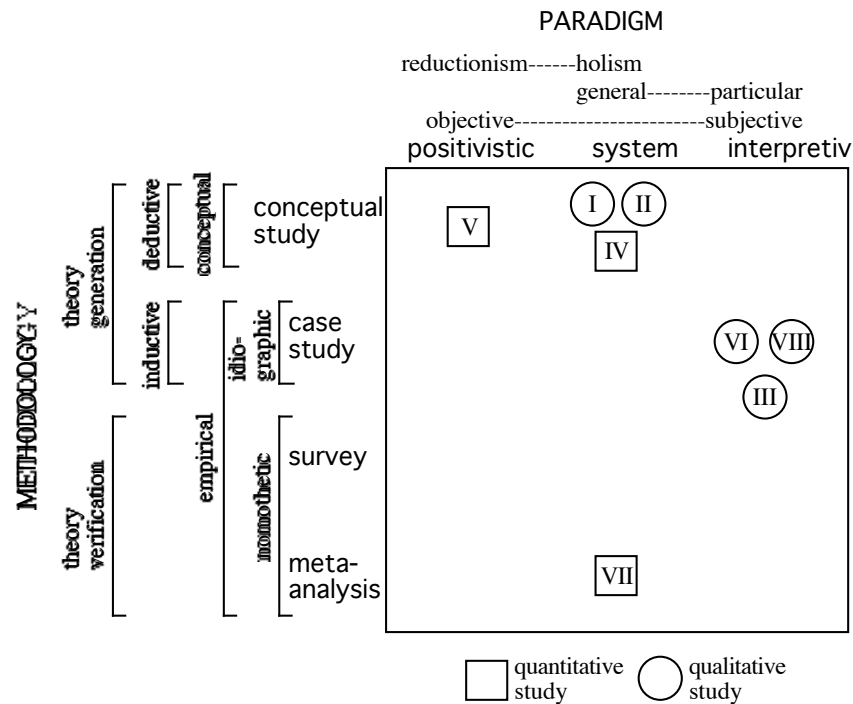


Figure 10. Main paradigmatic affiliation and methodological approach used in the papers making up this thesis.

This thesis reports findings from four different fields of research (Figure 5, p. 26), however, the differences between the areas are not so great that they can also be arranged under one area of research, industrial management. Based on the former footnote, the aim of papers in a thesis can be of dual nature. The aim can be to improve the field of research and/or to improve the researcher's research capabilities. Viewed from this perspective the multi-methodological

²² There appears to be a narrow-minded conception concerning the output of a doctoral programme. The thesis is regarded as the output while the work performed by the doctoral student to produce it is the input. It is, however, quite possible to reverse the logic; the thesis can be regarded as the vehicle for the author's transformation into a certified researcher, though this perspective is usually parsimoniously treated in theses. With this latter view, the thesis may not be the primary result of the doctoral study. Instead, the process which the author has experienced becomes the primary result. The dualistic relation between the researcher and the thesis as being simultaneously input and output of the research process is mirrored in the relation between knowledge and learning. The researcher learns by creating knowledge and creates knowledge by learning. Both knowledge and learning should be acknowledged as important results of a doctoral programme.

approach has been used with the primary aim of improving the field of research in the first five papers, which have manufacturing flexibility as the lowest common denominator. The remaining three papers of this thesis, each addresses a different field of research, related to the main theme: strategy and manufacturing flexibility. These papers further expand the methodological dimension of the thesis. A common denominator for these three papers is the expansion into novel areas of research for the author. An important aim of the multi-methodological approach for these papers can thus be viewed as improving the researcher's capabilities.

How should research be conducted? "In conceptualization, the assumptions upon which the problem definition is based are defined and if these assumptions are incorrect, then the problem that is solved may indeed be the wrong problem" (Lyles, 1981, p. 62). Therefore, great caution is needed in making the assumptions. If the assumptions are too specific, the solution arrived at, might be disconnected from, and thus irrelevant to, the empirical reality. On the other hand, by using too general assumptions, in order to reach general conclusions which will apply to a vast number of situations, the collecting and subsequent analysis of data may demand unreasonably large resources. The assumptions will thus, in part, decide the outcome.

I entered into the area of manufacturing flexibility with some preconceptions and formed other assumptions during the course of my research. It is difficult to decide the exact point in time when different assumptions broke the surface of consciousness. However, from an ex post perspective, it can be concluded that my research on manufacturing flexibility has been guided by the following basic assumptions:

- (a) Flexibility is a polymorphous concept.
- (b) The literature has addressed multi-dimensionality primarily by theoretically deduced taxonomies of flexibility.
- (c) In order to utilise the potentials of flexibility in manufacturing, a common understanding of the concept among managers can be advantageous.
- (d) A common understanding of the means and ends of flexibility is also advantageous.
- (e) Traditional capital budgeting techniques do not assess flexibility of investments to their full potential, thus underrating flexible investments.
- (f) Managers prefer simple methods of investment assessment to theoretically correct ones.
- (g) A theoretically correct model can be advantageous, to provide a means of assessing the effects of the simplifications.

The area of manufacturing strategy has been penetrated from these preconceptions. Based on assumptions (a), (b), (c) and (d), a number of studies have been performed and reported in several papers, of which three are included in this thesis. These papers were all founded on several of the first four assumptions. Papers I and II are aimed at providing a structural framework with which to relate flexibility to the manufacturing strategy of a company. The framework is built on an organisational hierarchy and a generic system of flexibility dimensions. The results of these two papers are primarily theoretically deduced, however, the possibility of an empirical connection is proposed in Paper II, in which a, hypothetical but realistic, example of the use of the framework is demonstrated.

A number of mini-case studies were performed prior to the development of the flexibility structure, thus implicitly providing at least a mental empirical grounding of the findings. Some of the mini-case studies or mini-surveys, depending on perspective²³, are reported in Paper III and account for the inductive theory development on managers' perception of flexibility in manufacturing.

Based on assumptions (e) and (f) a method for evaluating the flexibility of the machinery in an investment was developed in Paper IV. The method is more aimed at usability than theoretical correctness. Based on assumption (g), a more stringent analysis and a theoretically more correct version based on continuous time is developed in Paper V. This version of the method is compared to the "user-friendly" version of Paper IV, and for all practical purposes the differences are negligible. However, the continuous time version can be advantageous for further theoretical deductive research by analytical modelling.

Each of the last three papers, VI, VII and VIII opens up a new field of research to the author. Not withholding the independent merits of each paper, one major benefit of these three papers, from a thesis perspective, is to expose me, the author to untried methodologies, which have not been utilised in previous studies. Case study and meta-analysis, have improved my research capabilities by expanding my methodological portfolio.

One case study has been performed, the case of Scania in the heavy truck industry, which is used two ways, with different theoretical backing. In Paper VI, in the field of manufacturing strategy, the case of Scania is used to illustrate the difficulties involved in classifying an empirical example in Porter's (1980) taxonomy of generic strategies. Furthermore, some methodological propositions for studying strategy from a grounded approach are presented. Paper VII is used to probe the node strategic flexibility, which is not directly connected to manufacturing, it is flexibility at a higher organisational level. For instance, strategic alliances, constitute one form of strategic flexibility. This literature is scrutinised in Paper VII based on the overoptimistic picture of strategic alliances conveyed by the majority of the literature, contrasting the more modest success rates of strategic alliances reported in broad surveys. Paper VIII, finally, utilises the case of Scania as an empirical propellant for making investigations into the field of strategic manufacturing flexibility.

²³ This is an excellent example of the difficulties of taxonomies. Paper III is based on semi-structured interviews with twenty-four managers from the Swedish engineering industry. The study can thus be argued to be a small survey, or "mini-survey". On the other hand, the respondents were chosen because they worked in companies that the authors had prior knowledge of, in order to provide a contextual framing for the study. This, in some respect, opens up the argument for a ground, "mini-case" study of six companies. Paper III therefore balances between the "survey box" and the "case study box" in Figure 9, partly, but not completely fulfilling the criteria of both of the two labels.

CONCLUSIONS

In the closing chapter of this thesis I will firstly point at some of the results then address some of the issues that I assess as interesting for future research. The results are discussed in the same order as the purposes, thereafter the results from the methodological discussion in the previous chapter are added. The discussion is not limited to the results of each individual paper, but also address the broader integrative results from this whole thesis.

Results

The overall result of this thesis is a conceptualisation of the strategic role of manufacturing flexibility in the continuous realignment between the organisation and its environment. *Strategic manufacturing flexibility* is one possible answer to the demand for a more strategic perspective on manufacturing flexibility, beyond the narrow limited quantification attempts presented in much of the current literature on manufacturing flexibility. From one perspective, strategic manufacturing flexibility can be viewed as the synchronisation of the three interrelated processes manufacturing flexibility, manufacturing strategy and strategic flexibility as illustrated in Figure 4 (p. 21). Strategic manufacturing flexibility can assist companies in developing and maintaining production systems that function in the long run. It is also concluded that flexibility *per se* is of minor relevance, but it is in the relation to other competitive priorities such as cost, quality and dependability that flexibility becomes a meaningful and important concept, in manufacturing as well as in connection with the manufacturing strategy and business strategy of a company. The research areas of each of these three processes (Figure 4, p. 21) have been investigated during the course of this work.

The results of the studies in *manufacturing flexibility*, provide elucidation of the understanding of managers' perceptions of manufacturing flexibility, and the development of models and methods that can be used by these managers in the strategic realignment between the manufacturing of the company and its environment. More specifically, in **Paper I**, a framework for manufacturing flexibility is deduced which illustrates how to obtain consistency from manufacturing strategy to the resource characteristics in the production system. The framework provides guidance on how to analyse and develop manufacturing flexibility in a corporate decision-making context. In **Paper II**, flexibility is defined in three generic dimensions and an example of the use of the frame-work is illustrated using a top-down approach, however, the framework can also handle a bottom-up approach. Furthermore, in **Paper III**, the perception of flexibility in manufacturing of managers from four departments: product development, production, marketing and finance, were charted. The aspects of flexibility that the managers focused on were primarily those related to their departmental affiliation. Different perceptions of flexibility were found within companies as well as between managers of the same department in different companies. However, similarities were also found in both these dimensions. The most often mentioned resources were, in order of declining frequency, short set-up times in order to increase delivery range flexibility, multi-product machines to provide high product flexibility, and multi-skilled labour to provide volume flexibility. Finally, in **Paper IV** and **Paper V**, a method for the evaluation of flexibility

in manufacturing is developed. The method, capital-back, assesses the residual value of the flexible part of an investment, and thus implicitly promotes flexible investments.

The results of the study in *manufacturing strategy* are presented in **Paper VI** as a case, indicating how flexibility of the manufacturing function can be utilised in order to gain competitive advantage in an uncertain and dynamic market. Furthermore, Porter's (1980) taxonomy of generic strategies is scrutinised and the difficulties of classifying the strategy of a real company into one, and only one, of the deduced taxa are illustrated. A combination methodology, using both a top-down, grand strategy approach and a bottom-up, grounded methodology is used in the study, and is shown to provide a sound basis for understanding external as well as internal factors impinging upon the company.

Strategic flexibility is a broad area of research. Consequently, the study of this area embraces only a minor part of the field, namely a meta-analysis of the literature on strategic alliances, in **Paper VII**. The analysis confirms a number of issues. The literature is, on average, over-optimistic towards strategic alliances. Furthermore, the natural divide of the articles as a function of positiveness towards alliances goes between survey-based articles which, on average, are neutral, and studies based on case studies, examples or non-empirical, purely theoretical studies, which on average are overoptimistic. Finally, practitioners are on average more optimistic than academics, and practical articles are on average more optimistic than theoretical ones, except for non-empirical studies, which are relatively optimistic regardless of "scientificness".

The area of *strategic manufacturing flexibility* is then discussed. Only one paper, **Paper VIII** directly addresses the triple intersection. However, by combining the three double intersections a broader result can be obtained. A suggestion for research is presented which involves the synchronisation of three continuous processes within the company, concerning manufacturing flexibility, manufacturing strategy and strategic flexibility. Three major suggestions concerning research in the field of strategic manufacturing flexibility are presented. Firstly an integrative perspective on the competitive priorities - cost, quality, flexibility and dependability - is advocated due to synergistic effects. Secondly, since the concept appears to transcend disciplinary boundaries, a multi-disciplinary perspective is also advocated. Thirdly, due to the multi-dimensionality of the concept of strategy as well as flexibility, a multi-methodological approach appears to be advantageous in the pursuit of research within this field. Following this, a case study illustrating the strategic role of manufacturing flexibility in the continuous realignment between the organisation and its environment is presented.

Some *methodological reflections* are discussed in the **Frame of Reference**. The overall finding concerning the three nodes of a research process problems, paradigms, and methodology is that changes of perspectives appear to be advantageous in all three nodes, for the research area, the research group and also for the individual researcher. This should however not be interpreted as suggesting that every researcher should continuously change perspective in all three research dimension. The proposition is the expansion of the three-dimensional space of research possibilities, and the suggestion that a change in any dimension will intrinsically

create a new perspective and the possibility of comparative analysis (cf. Glaser and Strauss, 1967), irrespective of the dimension of change.

Future Research

The number of settled research issues is clearly outnumbered by the number of questions raised during the research process. I will restrict the discussion to some topics that I, based on this thesis, regard to be of value for future research.

Manufacturing flexibility

The field of manufacturing flexibility requires major redirection. The goal of pursuing more and more elaborated flexibility taxonomies needs to be replaced. One way to advance this field of research which appears advantageous is to probe beyond the taxonomies in order to understand the means and ends to flexibility, irrespective of flexibility label. One way to approach this problem is to chart managers' conceptualisation of flexibility in manufacturing, by verification of the theoretically induced findings presented in Paper III, for instance by a broad survey.

The capital-back method needs to be further developed, including more of the traditional capital budgeting parameters, in discrete as well as continuous time.

Manufacturing strategy

The grounded strategy approach needs to be further developed, and evaluated as a complement to the grand strategy approach, as a means of studying internal as well as external relations to a company's competitiveness.

Furthermore, the competitive priorities - cost, quality, flexibility and dependability - need to be analysed in relation to each other, since the synergistic effects from the resources of the production system are often too important to be ignored. Research problems do not respect borders between research areas. This may be an important concept, since it assumes the researcher should apply an integrative approach, which so far has been rare in the literature. One way to perform a nomothetic study the competitive priorities is the statistical method LISREL, which contrary to traditional statistical methods, can assess synergistic effects, in this case between competitive priorities.

Strategic flexibility

One source of confusion in the field of strategic flexibility concerns the rationale for company growth. There are different strategies for growth, for instance merger and acquisition, strategic alliance and internal growth. These different growth strategies are often treated separately in articles, and motives for growth are presented. However, since these motives are not related to other possible strategies for growth, it is difficult to distinguish advantages of growth *per se* and advantages which are dependent on the choice of strategy for growth. This is an issue which needs to be further investigated.

Another interesting issue raised by the meta-analysis of strategic alliances is the study of the "positiveness" of streams of literature on other research object, such as mergers and acquisitions, joint ventures, etc. The literature on these other topics may not be more neutral toward its topic, than the literature on strategic alliances is toward strategic alliances.

Strategic manufacturing flexibility

The limits of this topic are more vague than those of the previous three topics. This provides several opportunities for the pursuit of novel research directions. The primary task ought to be to establish a research agenda for the area. A major point in this agenda should be that the research on strategic manufacturing flexibility needs to use both a theoretical and an applied approach. Figure 4 (p. 21) can be used as a starting point in the development of a research agenda. Also, Gerwin (1993) can provide substantial input towards strategic manufacturing flexibility, for instance, concerning the utilisation of flexibility concepts in industry. However, in agreement with the suggestions above on manufacturing flexibility, flexibility taxonomies may be more of a hindrance than help in propelling the area towards problems relevant to the empirical situation for managers.

Methodology

A nomothetic, retrospective longitudinal study of scholars' methodological conservatism could provide empirical backing for the suspicion on methodological conservatism and tunnel vision approaches, and, furthermore, fuel to the methodological debate. The methodological taxonomy in Figure 8 (p. 37) can be used for classification of the publications.

The taxonomy can also be used in mapping entire research areas based on a meta-analysis of the research contributions. This mapping of research areas could be performed in several areas of research to find complementarity between conceptually close, but methodologically separated, areas of research. The methodological maps of research areas can be used as means of motivating inter-area cooperation to reduce the potential methodological bias of the results of the research in each area. Maps of entire tunnel vision research areas may also initiate methodological diversity within the area.

Epilogue

"There is a line among the fragments of a Greek poet Archilochus which says: 'The fox knows many things, but the hedgehog knows one big thing'. Scholars have differed about the correct interpretation of these dark words, which may mean no more than that the fox, for all his cunning, is defeated by the hedgehog's one defence. But taken figuratively, the words can be made to yield a sense in which they mark one of the deepest differences which divide writers and thinkers, and, it may be, human beings in general. For there exists a great chasm between those, on one side, who relate everything to a single central vision, one system less or more coherent or articulate, in terms of which they understand, think or feel - a single, universal organising principle in terms of which alone all that they are and say has significance - and, on the other side, those who pursue many ends, often unrelated and even contradictory, connected, if at all, only in some de facto way, for some psychological or physiological cause, related by no moral or aesthetic principle; these last lead lives, perform acts, and entertain ideas that are centrifugal rather than centripetal, their thought is scattered or diffused, moving on many levels, seizing upon the essence of a vast variety of experiences and objects for what they in themselves, without, consciously or unconsciously, seeking to fit them into, or exclude

them from, any one unchanging, all-embracing, sometimes self-contradictory and incomplete, at times fanatical, unitary inner vision. The first kind belongs to the hedgehogs, the second to the foxes" (Berlin, 1978).

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APPENDED PAPERS