ETLA The Research Institute of the Finnish Economy

Tuomo Kässi

The Engineering Industry - Development Paths and Roles of Engineering Companies

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THE ENGINEERING INDUSTRY - DEVELOPMENT PATHS AND ROLES OF ENGINEERING COMPANIES

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ABSTRACT: In this research the Finnish engineering companies are studied in such a manner that both engineering design and engineering project companies are included. The basic premise in the research is that the companies in the engineering industry seem to start following certain development paths. The engineering companies in the alternative paths differ from each other qualitatively in their strategic behaviour and they act in characteristic manners according to the paths. The alternative development paths are non-deterministic by nature.

Theoretically the possibility of the development paths can be argued according to the models of company development, and the development models of industries. Behind the theory of industrial evolution there is an emphasis on the theorising of technological development and change. When the theories of industrial evolution are transferred to the level of individual companies, the development paths of individual companies, i.e. company paths are developed. In addition to forming the company paths the results of strategic studies in management science are used. The developed company paths depict how the companies change within the evolution of the industry.

When the operations of the companies, and their development towards the developed company paths are well known, the characteristic company paths also describe the structural evolution of the industry in the course of time. Thus when emphasising the structure of the industry we can also speak of industry paths. In the research a tentative model of the alternative development paths is built for the engineering companies.

The role of engineering companies is considered in the work as the developers of technology, and the question is set whether the engineering industry in Finland could form its own cluster in the future or whether it could otherwise stimulate the cluster formation in the Finnish economy.

The empirical material in the research is first analysed within the means of a conventional industry study without an exact theoretical framework and then within the developed framework. The company cases illustrate and materialise the developed company paths. The company examples show that the developed model is valid in considering the engineering companies and industry.

The development of the engineering companies, and their movement from one path to another, as well as the preconditions that are necessary for this kind of evolution are the essential focus of the research. The other issue in the work is the consideration of the birth of the new clusters in the industry from the base of the engineering companies.

Besides drawing the research conclusions with regard to the theoretical issues they can be drawn on the company level and the industrial policy level. The management should understand the company path within which the company evolves. The company path is the first estimation of the realistic possibilities for company evolution. The engineering company can divert from its own path but it may require extraordinary efforts or exceptional conditions. The management and the industrial policy makers should consider the technological potential contained within the engineering companies with the notion as to whether they could be more widely utilised for the determined purposes.

Acknowledgements and thanks

I had the opportunity to become acquainted with the engineering industry in the research project organized by the Research Institutute of the Finnish Economy (ETLA) and mainly financed by the National Fund for Research and Development (SITRA) in 1995...96. Then I could familiarize myself with the Finnish engineering industry and write an overview report on it. This in turn gave the opportunity to write a more academic research study on the engineering industry, for which I am indebted to the Research Institute of the Finnish Economy, the National Fund for Research and Development, and my employer IVO Power Engineering Ltd.

The other precondition for this reasearch emanated from the fact that my academic supervisor professor Esa Jutila let Mr Pekka Räsänen, a student of technology to write his Master Thesis on the engineering industry. In preparing his Master Thesis Mr Pekka Räsänen collected the data and material on which this research is based on. The co-operation with both of them continued to be rewarding and fruitful for the writer in the course of the research. I remember particularly the supportive and optimistic attitude of professor Esa Jutila in spite of his health problems.

I could spend essential time during the work in the Research Institute of the Finnish Economy. The atmosphere and facilities of the Reasearch Institute offered excellent surroundings for my research work. The physical facilities are important but I consider even more important the opportunity to discuss with the experienced researchers who have personally gone into similar type of work. I am particularly grateful to Mr Kari Sihtola, assistant director who managed the practical aspects of my staying in the Research Institute of the Finnish Economy, and to Mr. Pekka Ylä-Anttila, managing director of ETLATIETO Oy who expressed aloud at a crucial point of time: "You know quite enough about this matter, stop reading theoretical books and start writing". I can only be grateful and consider that was - good advice. The information managers of the Research Institute and Imatran Voima Oy were of very great help. I extend much gratitude to Ms Kaija Hyvönen-Rajecki and Ms Heli Jyrkönen.

The academic inspectors of my research, professor Erkki Uusi-Rauva and Dr Raimo Lovio have advised me and influenced the final presentation form of the book. The influence of Dr Lovio on my research has been significant. After having read his dissertation carefully I knew that I wanted to use in my own study a relatively similar kind of approach. I walked into Dr Lovio´s working room in Chydenia and asked his help and advice in this study. Thanks to Lovio´s flexibility he did not refuse. His positive and productive influence already began from the time when the official inspectors were not yet determined.

My superior Mr Pekka Riala, director of Environment and Refurbishment deserves my gratitude for his attitude and patience.

I gratefully acknowledge the financial support for my work received from the Academy of Finland and the Foundation of Economic and Technical Sciences.

The use of empirical material always includes the dilemma of becoming old very fast over the course of time. The data used and information are from the years 1993...94. The information has been used in the form as it was collected, even though in some companies certain changes have been noted since 1994. Research work can never be a simultaneous activity with the actual life.

The book has been checked by most of the afore mentioned experts, and some others of whom I particularly want to mention Dr Olavi Uusitalo and Mr Matti Ojanperä. I thank all of them for their effort. However, the responsibility for the substance and form of the text remains with the writer.

I have to admit that the finalization of the book would not have succeeded without the help in polishing the English language by Ms Marit Harjula, in finalizing the text by Ms Tuula Ratapalo, and in grafical drawings by Mr Kimmo Aaltonen.

Espoo, June 1997

Tuomo Kässi

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INTRODUCTION

Background

The origins of this research come from two sources. In the context of the wide national research project "The Competitive Advantage of Finland" coordinated by The Research Institute of the Finnish Economy, a partial study "Engineering Industry in Finland - From an Industry to a Cluster?" was prepared by the undersigned during 1995 and 1996. The cluster study in an engineering consisted of the first arrangement and analysis of the data, and a descriptive analysis of the evolution of the engineering industry. The cluster study gave a good base upon which to deepen and expand the work, as well as giving a possibility to continue the analysis towards a more academic direction. The studies made during 1993 and 1994 by Mr. Pekka Räsänen, and my own cluster study clearly form one origin of the current research.

My personal work experience with engineering companies which has lasted more than twenty years, has to be mentioned as a source of understanding and interest in the engineering industry. My most important work experiences relate to Tamglass Engineering Oy, a medium sized international company and IVO International Oy representing a larger scale international operation. The tasks and the missions of these companies are the same, although the issues of development differ greatly. The experiences of the Finnish engineering companies have aroused an interest in the future potential and opportunities of the industry. The engineering industry is, in general, a fairly unknown industrial activity in Finland. However, it is a service industry which sells most of its products and services abroad. It is potentially a knowledge-based activity that exploits the growing level of education in the country in a very positive manner. The engineering industry also enhances export of projects from other Finnish industries. In addition to this, the manufacturing industries may include in their product packages different kinds of engineering services to improve their competitiveness in the market.

There are two more sources of influence behind this research which could be mentioned. The works of Michael Porter have exerted an influence on the writer since the beginning of the 1980s. The national research project "The Competitive Advantage of Finland" happened to become more connected with Porter´s thinking than perhaps was intended. My partial involvement in it did not decrease the influence of Porter on this work. If I have to mention another person who has influenced my thinking on the studies of industries I should mention Raimo Lovio. Besides covering the opportunities of the electronics industry, Lovio in 1989 also dealt with the general question of studing industries, Lovio (89). I had personally experienced the lack of spirit in the traditional industry studies, and the distance of the industry studies from the operative business activities at company level. The new approach of Lovio´s book, the evolutionary dynamics, seemed to bring life and validity to the partly dead field of research involving industrial economics. In his dissertation, Lovio (93), gives an example, how to write a qualitative industry study and still make it intellectually vivid and practically oriented. In the 1990s, interest in the tradition of evolutionary economics has increased in Finland. This tradition has produced collections of seminar papers which have studied the issues in Finnish economy following the evolution of technical change in the Finnish industries, see e.g. Vuori and Ylä-Anttila ed. (92), Vuori and Vuorinen ed. (94) and Kuusi ed. (96). I subsequently learned that Lovio and other scholars have received their ideas and orientation from a school of economics, an evolutionary economics, established by Christopher Freeman in England. The works of the school of Christopher Freeman form a cornerstone of this study.

The purpose of the study

The purpose of this research is to examine the start-ups of engineering companies, and the development conditions of these companies. After having started, the companies seem to find certain distinctive development paths along which they evolve. The purpose of this study is to clarify the development paths of the Finnish engineering companies based on both theoretical development and empirical material. The varying roles of engineering companies come into the focus of the study, starting from the conventional roles of a technical designer and a turn-key supplier of investment project to a developer of investment projects, and an agent of a new technology.

In addition, as a complementary purpose of this study is to clarify the significance of technology, or more closely the role of technology in the development of engineering companies. This is a natural question as the engineering companies are working all the time with different technologies at different levels. On the other hand, at least the engineering design companies are continuously serving the investing companies of the industrial base clusters, and their technological evolution. A relevant question is whether there is any space for an independent approach to a technological development within engineering companies. Assuming a positive answer, there is reason to ask what kind of engineering companies could have their own technology strategies, and with what expectations.

The total value of the turnover of the Finnish engineering industry was in 1993 about 6500 million Finnish Marks. Over three quarters of this total were exported. The significance of the engineering industry can, however, be really seen in the follow-up sales that its services and products in foreign market may enhance. The emerging roles of agents relating to technologies and development may be the becoming role of significance for the evolution of the whole industrial structure of the country.

The series of studies in the engineering industry, Räsänen (94), Räsänen et al (94), Kässi (96), and the present one are interlinked with each other so that they fill the gaps in the basic knowledge in the industry of engineering and in its significance. As the engineering industry is quite invisible in the economy of Finland, insufficient research work has been made for its use on long term basis. A good exception is the dissertation study of Erkki Uusi-Rauva from the 1970s. Its main focus is in the engineering design companies and it succeeds to gather fairly good empirical material regarding the industry, see Uusi-Rauva (79). He also refers to the earlier studies. Since the 1970s the engineering industry has been poorly studied.

The significance of the study also has to be seen in the light of the growing roles of the knowledge-based engineering industries in the structures of the Finnish industry as a whole. This basic understanding is needed if the agent role of the engineering industry is to be emphasized by the industrial policies in the evolution of the other Finnish industrial branches.

As based on the cluster studies of Finnish industries, the natural additional purpose of this research is to clarify the opportunities of engineering companies to form an overall engineering cluster in the future. As well the purpose is to study the emergence of new clusters, and the potential roles of engineering companies in the emergence and development of industrial clusters.

The objectives of the study.

The first objectives in the work are the following:

- to clarify the alternative mechanisms in which engineering companies may emerge
- to understand and describe the development of individual engineering companies within the industry and
- to describe the roles of engineering companies in different stages of their company development, and in respect to the development of their customer industries.

This research is a study of the engineering companies in their industrial context. Their current position and the future opportunities are clarified. When the development of the individual companies is known well enough, some conclusions can also be made regarding the engineering industry as a whole. In this way the study functions both at a company as well as an industry level. The technological context and the one involving the cluster structure form the background of the work.

In the industry studies the question always is how complete the data of the industry concerned has to be in order to make any conclusions on the subject. In this study the target industry includes a limited number of companies, and only a few are those companies which are international and large. In this study a selected group of companies is biased towards the international and large end of the scale. In this qualitative study the stand is taken that it is more important to make conclusions on relevant issues than to show exact figures as results. In fact, this is the only possible way to make the study on the engineering industry at this stage since the official statistics are lacking in the heterogeneous engineering industry.

Specification of the research questions.

The research questions can be determined to the main questions and additional questions or considerations.

Main questions:

1. How the engineering companies are started, and for what kinds of purposes? What are the preconditions for the companies to develop further as companies?

2. As the engineering companies have different kinds of start-ups, the question is what the development paths of the companies are as they have got started. Are the development paths of the companies distinctive from each other, and are the differences to be explained by the different kinds of start-ups of the companies?

3. What were the traditional roles of engineering companies in the investment projects? How the roles and the importance of the engineering companies may be developing in the future as the demand changes in the evolution of the industries.

Additional questions or considerations:

4. What is the role of technology in the development of an engineering company? What roles can the engineering companies take in the development of technologies for the benefit of their customer industries?

5. Is it expected that the engineering companies are forming an overall engineering cluster into the Finnish industry in the near future? What could be the role of engineering companies for enhancing the emergence of the new industrial clusters?

Structure of the study

This study starts with a general view on the industry. Chapter 1 explains why the engineering is needed and for which purpose. Those who already know the subject may leave the chapter, but to them who are not familiarized with the engineering industry chapter 1 gives an understanding in which context the questions made shall be discussed. The very basic information of the products, services, and the types of engineering companies is presented.

Chapter 2 relates to methodology of the study. The generation of data and information is disclosed. The research strategy, as well as the connections with other research in the field are revealed.

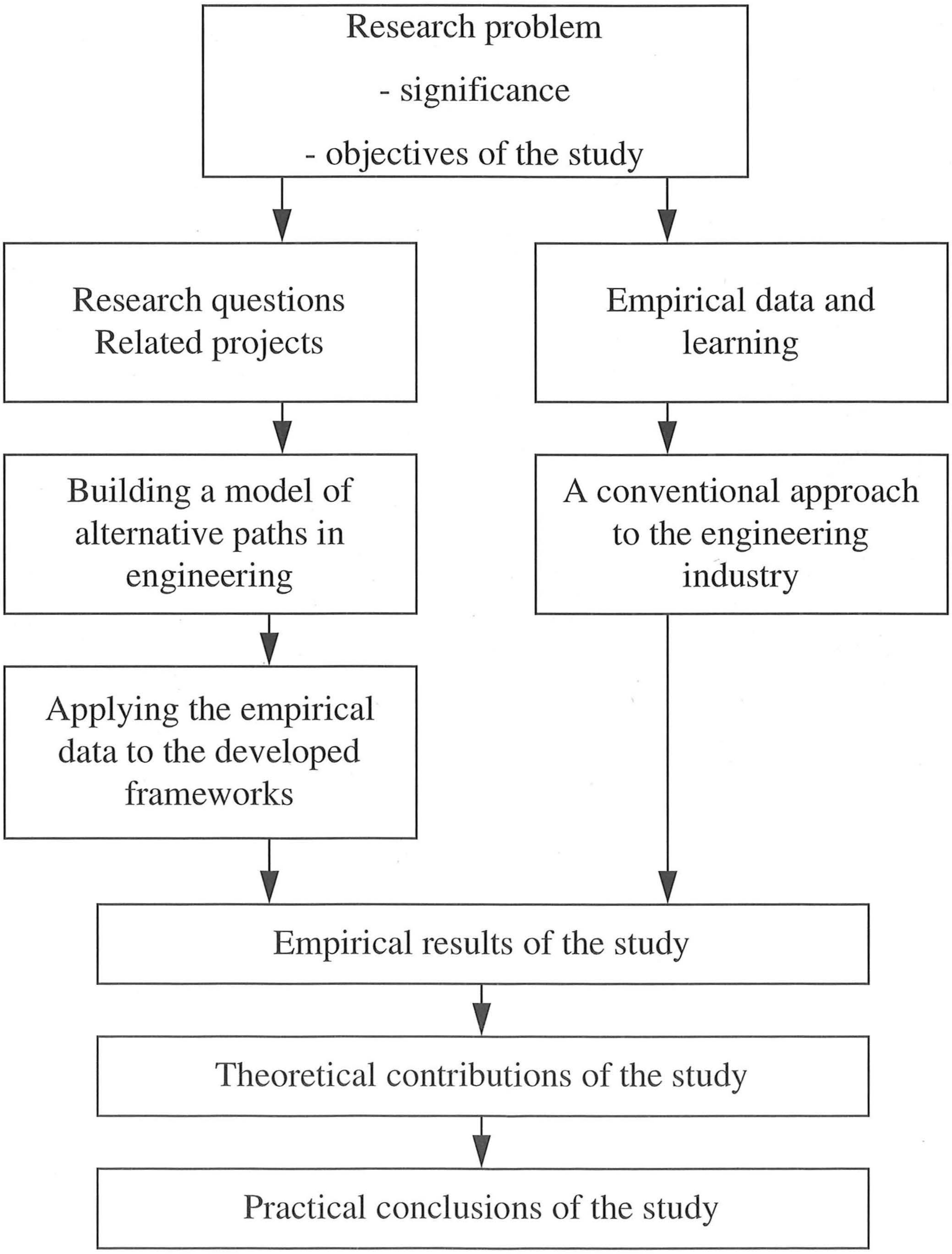
The core of the theoretical part of the work is included in chapters 3 - 8, the development of a model of alternative paths in the engineering. The creation of a model for the development paths is started from the theories of an individual company in chapter 3. The theories of a company do not take us very far in the development of a framework. Therefore the theories of an industry are used, in addition to the learnings of chapter 3. The evolutionary theory of an industry, chapter 4, gives us an understanding about the occurrences of the internal evolution of an industry. The internal interrelationships are described by the evolutionary theory. The competitive forces are described in chapter 6 both in a day-to-day operations in the market and in the internal cost adaptation to the competitive forces. The impact of the environment, including the market and infrastructures, are described by the model of the small diamond, or the one of the eight factors on the development of the company in chapter 7. The model of chapter 7 gives the preconditions for the knowledge-based engineering company development from the initial stages to a mature state in its strategic group.

The external development of the alternative paths means the location of the paths in a space determined by economic and technological factors over time. The concept of the technology, adopted from the theories of an evolutionary economics is presented in chapter 4 where it serves also as a base of the evolutionary theory of an industry. The basic technological trajectories, equivalent to technological patterns, are based on the statistics of innovations and presented in chapter 4. The industrial sectors are categorized into four separate basic technological trajectories, the structure of which gave the idea of building alternative company paths for the engineering industry. The technology based thinking is strengthened by the view of business management studies using the concept of strategic groups of chapter 5. This gives us a model of external development of alternative paths which forms mainly a set of exogenous factors for an individual company.

A tentative model of alternative paths in the Finnish engineering industry is presented in chapter 8. The logic of the study design of the model building of the alternative paths for the engineering is described more closely in chapter 2, the methodology.

The empirical material is presented in two ways. Chapter 9 presents the empirical material in a conventional way of an industry study. In chapter 10, the collected data material is applied to the developed framework of the study. The empirical conclusions are made from the traditional analysis, and from the analysis made with the framework based on the approach of the evolutionary economics. The empirical conclusions have been collected to chapter 11 as the answers to the research questions.

Figure 1. The structure of the study.



The theoretical contributions have been collected to chapter 12, and the practical conclusions are summarized separately for management and industrial policies in chapter 13. The review of the structure of the study is presented in Figure 1.

1. ENGINEERING ACTIVITIES

1.1 Engineering companies and investments phases

The definition of an engineering industry can easily be made by help of products and services which the companies in the engineering industry produce. Technical engineering companies produce technical, design and project implementation services. This study includes:

- the engineering design companies which produce conventional engineering services and other technical expert services, and
- the engineering project companies which implement investment projects taking care of different sizes and scopes of responsibilities in the supply and assembly of the investment projects.

By the engineering companies is meant here the engineering design and engineering project companies. The difference between them is that engineering design companies sell only engineering and expert services for a time based charges, whereas engineering project companies also sell turn-key projects. The similar turn-key projects can also be offered by different component suppliers and multi divisional concerns as an additional service combined to their other products.

We have included in the considerations, particularly on the part of the empirical material, the technical investment projects, plant construction, and the investments based on the process technology, machinery and equipment building. Excluded are, however,

- engineering services produced by public organizations like research institutions and universities of technology,
- component and machinery producers, the engineering services of which are integrated with the sale and production of a component or a part of a whole, and
- engineering services of construction companies.

In some Anglo-Saxon countries the term engineering is used in a very wide meaning. Sometimes it refers to the entire metal and machinery industry, including design, and production, procurement and project implementation.

In the analysis of the engineering activities, the conventional services relating to the different phases of an investment project form a good starting point. In this context it is easy to understand what the basic role of engineering companies is. Simultaneously a clear connection is built with the basic activity for which purpose the engineering companies originally were established. Engineering activities have always been needed for helping to fulfil the required actions by the investor.

The ideas of the investments are found in the market through different kinds of signs or through searching them purposefully. The investment idea often includes already a thought of the type of an investment. The proceeding of the investment, however, requires a clarification and securing of several details. The project is first clarified on a general level of the concept design phase and, later on, the technical content of the project is designed in the technical design phase. Other possible studies may relate to market developments, investments in infrastructures needed, possible permissions by the authorities, and environmental studies.

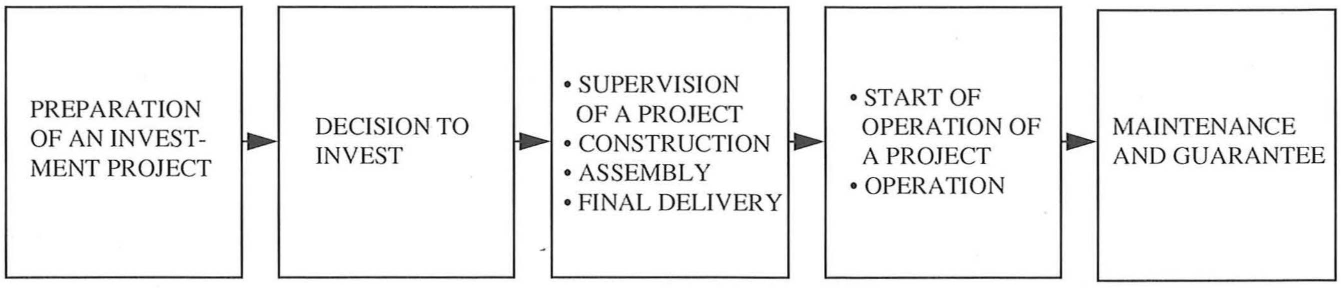
When all the studies have been made and when they still support the investment decision, it is possible to make the investment decision. Simultaneously the detailed design continues, as well as the possibly emerging additional studies.

When the content of the project has been defined, the documents are produced to request the component manufacturers and the turn key deliverers to send the offers for the implementation of the investment. When the offers have been received the comparisons are made to select the best ones.

After the purchase decisions, the supervision of the implementation of an investment project has to be arranged to guarantee that the construction and the installation of the equipment follow the expected standards and procedures. The implementation of the project in practice consists of the construction of the project, the assembly and finally the delivery and the acceptance of the project.

When the investment has been delivered and accepted, it will be taken to the normal use, i.e. production. The last phase before the final acceptance is to arrange the normal guarantees and the maintenance.

Figure 1.1 Phases of an investment project in an investing company.



The phases of investment, presented in Figure 1.1, each include some engineering activities of which the investor has to take care. Many companies have their own personnel to manage these matters, but when the investment projects become larger the companies have to bring an outside technical expertise to help in various tasks. The way and the phases of an investment, how the outside experts are brought into the company, determine the roles the internal and outside engineering may take in the investments of the company.

Examples of other possible engineering services can be technical and economical planning, evaluation and management of offers, preparation of an investment for the investor, different services in the acceptance and delivery phase.

Another often presented way of presentation is to consider the proceeding of an investment project from the viewpoint of a financier. The international banks have had to develop a careful procedure to screen the projects for their finance decisions. The banks use the so called project cycle proceeding to consider the investment proposals. The idea in the cycle is that each project has to proceed through certain steps, and only then the banks are ready to make the credit decisions.

1.2 Alternative tasks and roles of engineering companies

The tasks of engineering companies can be considered from the point of view whether the companies work for the suppliers or the investors. The tasks may vary depending on the wideness of responsibilities that the engineering companies are willing or able to take for the project implementation. In Figure 1.2 the two typical extremes are identified in a construction project depending on the type of implementation the investor decides to select.

Figure 1.2 Roles of an engineering company in the implementation of a project.

TOTAL RESPONSIBILITY OF A SUPPLIER FOR THE WHOLE	**RESPONSIBILITY OF AN INVESTOR FOR THE WHOLE**
TURN KEY DELIVERIES	IMPLEMENTATION THROUGH PARTIAL SUPPLIES
SELLER RESPONSIBLE FOR THE DELIVERY AND FOR THE COMPLIANCE OF THE PARTIAL COMPONENTS AND THEIR INTEGRATION	BUYER TAKES THE RESPONSIBILITY FOR THE COMPLIANCE THROUGH PARTIAL SUPPLIES. SUBSUPPLIERS RESPONSIBLE EACH FOR THEIR OWN PART
TURN KEY SUPPLIER	ENGINEERING COMPANY POSSIBLY AS A TRUSTEE OF THE BUYER

The responsibility for the entire project during the implementation may lie either on the seller's (supplier's) or buyer's (investor's) side. The side being responsible takes care of the project management. If the responsibility for the entire project is on the side of the supplier, the question is often about the turn-key delivery. Then the main supplier or one of the subsuppliers takes the responsibility for the whole delivery, and takes care of the project management. In principle, the main supplier can also use an engineering company to perform the project management which then takes responsibility for the project management, although the responsibility for the economy of the project lies on the main supplier. Or vice versa, the engineering company may take the responsibility for the project, for the economy and for the project management. In the latter case, the engineering company is the active party on the side of the seller, it makes the deal with the investor, integrates with its expertise the whole of the project, and uses component manufacturers as subsuppliers.

The responsibility for the whole may also lie on the side of the investor even during the implementation. Naturally the ultimate responsibility and risk always lie on the investor. The investor may take the responsibility because it considers to know best the knowledge of the industry needed, and in this way estimates to decrease the total investment cost to the lowest level. In this case, the investor procures from different sources the subdeliveries of the project, and takes the responsibility for the compatibility of the parts together, and for the integration of the parts into a whole. In this case, the investor may take an engineering company to a role of the consult. The project management can be carried out by the engineering consult, but the responsibility for costs and technological parts is left to the investor.

Figure 1.2 presents two typical implementation models of the projects which easily come up when the responsibility is either on the seller´s or the buyer´s side. The responsibility of the seller often leads to the turn-key delivery, whereas the responsibility of the buyer takes place in the implementation with the subdeliveries from different component manufacturers.

In this study the roles, tasks, responsibilities, and risks of the engineering companies will be further explored. They have had several interactive connections with the other companies. The role of the engineering company between the sellers and the buyer in the investment process has obliged them to the middle of information flows. The intermediating role has forced an engineering company to collect and coordinate information and materials between the parties.

When an engineering company functions as an independent service company, on behalf of the investor, it may have connections in addition to the investor also to the component producers, the constructors, the subsuppliers of design services, the authorities, the financial organizations, the research institutes, the customers of the potential investor, the materials suppliers and producers of partial components.

When working for the supplier group of companies almost the same contacts are needed. A careful supplier, often represented by an engineering company, has a concern for the progress of the investment project from the viewpoint of the investor, too. The sales and marketing effort is even lost, if the investment project does not proceed for one reason or another.

An engineering company may end up to many roles both on the sides of the supplier and investor including among others:

- a supplier of expertise
- an intermediator of information
- a collector and coordinator of information and partial components of the project
- a project manager
- an accumulator of technical expertise.

This study explores more about the different roles of engineering companies.

1.3 Alternative types of engineering companies

Different kinds of potential engineering companies can be considered from tasks to be performed by some organization during the investment planning and implementation. In order to carry out an investment the tasks presented in Figure 1.3 have to be performed on the side of the supplier and the investor.

Figure 1.3 Different tasks to be performed by some organizations during the investment planning and implementation.

D	C	A	B
OTHER TASKS: • Construction of buildings • Production of component X • Production of component Y • Research and development • Ownership of product rights of components	SUPPLIER´S TASKS: • Concept design • Planning of investment • Making the offer • Implementation of investment • Process design • Project management	INVESTOR´S TASKS: • Secure the feasibility of the investment • Secure the studies and permits being granted • Make the decision on the investment • Take the ultimate responsibility and risk	OTHER TASKS: • Concept design • Detail design • Planning of investment • Preparing tender documents • Evaluating bids • Implementation of investment • Process design • Project management

SUPPLIER (D, C) INVESTOR (A, B)

The roles and the tasks of the engineering companies are related to the industrial and other investments. The main responsibility for the investment lies on the investor. He has to make sure that the feasibilities and the permission of the investment are in order. If the implementation fails he carries the losses. The investor cannot give his main tasks (column A) to any other organization. But the service organizations can perform many tasks for the investor on his behalf. Some of the services needed (column B) can be bought from engineering firms.

In a traditional case the investment consists of some main machinery components and the constructions (column A). In a straightforward case the constructions are built and the machinery components are supplied in order to make the investment. In practise, however, the investments are made up of many components, technical processes, constructions and, not to forget, the technical know how and expertise to integrate the parts to a whole. The borderlines between the different deliveries are especially risky areas for the investor.

The investor does his best to lessen insecurity and to avoid risks in his investment process. Therefore it is his interest to avoid risks by commercial contracts. The active suppliers acting in interactive relationship with the investor offer many services in addition to the hardware of investments. Some of these services are presented in Figure 1.3 (column C). It is often the interest of the supplier to interact with the investor as early as possible when planning the investment, and try to propose to carry out certain tasks of the investor, therefore some of the tasks of column C and column B are similar. The investor has the choice, whether to make the preparations in his own organization, to prepare some of the plans together with the supplier (column C) or to buy the services from his own trustee engineering consultant (column B).

The list of tasks relating to the preparation and implementation of an investment is presented in columns A, B and C. Engineering companies perform these tasks to the extent to be determined together by customers. The core tasks or functions of an engineering company are, however, concept design, detail design, planning of investment, and implementation of an investment as a project manager. Besides these tasks, all the other choices are optional making the profiles of engineering companies very varied. Due to the various potential tasks to be selected by individual companies, the profiles of engineering companies have become very varied making the industry heterogeneous.

1.4 The engineering industry

Still 50 years ago it was globally very common that all the large organizations had their own technical departments to take care of the investments. As the competition became tighter, the companies found out that one and the same engineering organization could serve the investments of two or more local companies, particularly if they did not compete with each others. The barrier to start using outside technical services was naturally lower when the new engineering companies were local and the experts were known. The engineering and construction services became international mainly after World War II, and the international competition appeared since that, Porter (90, pp. 267-270).

By it's nature, the engineering industry is a local business. The rate of concentration in the industry is very low. Wider or global engineering business became possible, in general, only after the geographical distances in travelling have shortened. Even now the large engineering companies are world widely small by market share which reflects the very local nature of the business. For certain tasks, however, the large organizations, have their benefits, and there is a market for large engineering companies, too.

Porter (90) has discussed thoroughly the role of supportive and related businesses for the fully developed clusters. The type of services the engineering companies are offering to the industrial clusters are dependent on development stage of the industrial structures. In the last tens of years the supportive functions needed have been the engineering services for the companies making their major investments due to the high investment rate in the Finnish industry. In the future, however, it is expected that variety of supportive companies and their services will be much wider as the industry moves towards the period of growth driven by innovations, Kässi (96, chapter 3.1). In Finland the engineering industry is about 30 to 40 years old. Only since the 1950s and 1960s, the big technical departments of the Finnish companies have been reduced to the minimum, and outside engineering services have been utilized. The only exception of the rule is the predecessor of Ekono which was established at the beginning of the century for the technical services of pressure vessels.

2. METHODOLOGY

2.1 Preceding studies

In the year 1994 an effort was started to collect basic information about the Finnish engineering industry. The experts in the field had an understanding about the engineering industry in Finland, but the industry analysis was old. The data on the engineering industry was collected for the Master Thesis and reported, Räsänen (94). In addition, the empirical facts and conclusions were reported and published in another context by Räsänen et al (94).

The analysis of the engineering industry in Finland was deepened from the points of view of economic history and case descriptions by the writer, Kässi (96). In that report the emphasis was laid in the practical conclusions.

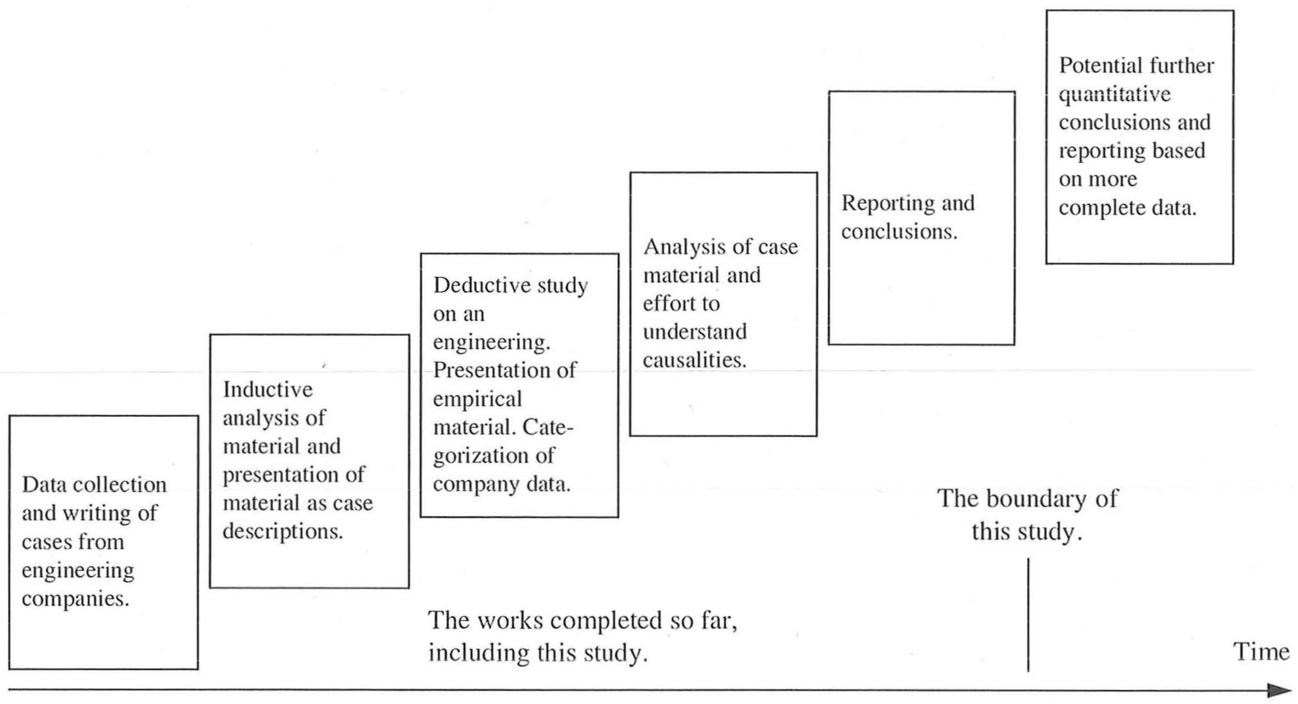
All these works are conventional industry studies with minor theoretical connections. The only framework presented and used was the cluster idea of Porter (90). The Finnish engineering companies were shown to have emerged from the strong and semistrong clusters of industries in the course of industrial evolution in the country. The studies were inductive in their approaches, i.e. efforts were made to draw general conclusions from the disaggregated level. These works have their value as they familiarize the researchers with the data. The analysis of the company cases, as well as the inductive conclusions were started. The issues in the engineering industry already became familiar in this phase. The writer was involved as a supervisor in the Master Thesis and as a cowriter in the public paper, Räsänen et al (94).

This study endeavours to include theoretical background in the treatment of the empirical findings. The theories which can be found in the literature form a base to construct a model of alternative paths of the engineering companies in Finland. A deductive argumentation is used to construct a model for studing the empirical observations. The preunderstanding and the view, what the relevant matters to be focused are, result from the preceding works.

This study uses a longitudinal observation relating to companies and industrial evolution. The data and cases principally include the entire life time of most of the companies studied which, in general, means 30 - 40 years, with a few exceptions of longer observation. The engineering companies have only existed during this period. This study does not include descriptions of economic history, the period since the 19th century, as the preceding analysis, Kässi (96). The learning of the the past is available from the preceding studies. The strength of longitudinal analysis is that it offers the advantage to study underlying linkages between technological change, organization processes, and innovation, according to Tushman and Nelson (90). The scholars had exceptionally long time series in the observations of their study. The cross section analyses are made in addition to illustrate the changes of the structures in an industry.

This study is to result in a report with an argued theoretical base and conclusions from the empirical data and the available case material. The background to be created would allow a base for the continuation by a quantitative data collection, and a more complete analysis of the engineering industry.

Figure 2.1 Summary of progress of the series of studies including this work.



As mentioned the empirical data has been collected in the preceding works. It has been fully published by Räsänen et al (94) and Kässi (96). The data is discussed in a separate chapter.

2.2 Selection of research strategy

The decisive issues in the selection of the reseach method are the empirical material available, the purpose of the study, and the pre-existing knowledge base.

The empirical material of this study is for the minor part quantitative, for the main part qualitative, and in addition a set of qualitative company case descriptions. The existing knowledge base for the study was mainly knowledge learned by the experts in the field, but very limited written information or analysis was available.

The purpose of this study was formulateted in the introduction chapter as the objectives of the study as follows

- to clarify the alternative mechanisms in which engineering companies may emerge
- to understand and describe the development of individual engineering companies within the industry and
- to describe the roles of engineering companies in different stages of their company development, and in respect to the development of their customer industries.

The purpose is to study the engineering companies in their industry context. Their current position and the future opportunities are clarified. When the development of the individual companies is known well enough, some conclusions can also be made regarding the engineering industry. In this way the study functions both at a company as well as an industry level. The technological context and the one involving the cluster structure form the background of the work. In addition to this, three specific research questions were formulated and additional questions to be considered.

The interest of the knowledge is to clarify and to diagnose as an academic purpose. But based on the results, the conclusions should be made for practical purposes for management and of industrial policies.

The research strategies are traditionally categorized into four separate groups: the conceptual analytic, the positivistic, the decision-making methodical, and the culture research strategy, Neilimo and Näsi (80). The list has been later on supplemented with the constructive research strategy approach, Kasanen, Lukka and Siitonen (91). This terminology is most settled in the Finnish research spheres. The conventional researches in economic sciences have mostly followed the positivistic paradigm. Its antithesis is the culture approach. In the culture and constructive approaches, the researcher is involved with the research object. In the economic sciences the choice of research strategy depends on the context. The positivistic approach fits many study objects, the culture approaches are typically used in the contexts of case materials and normative purposes, Olkkonen (93).

This study, as often is the case, uses different research strategies in different parts of the work. The figure of the four-scale table presents the approaches and assists to understand the differences between them.

Figure 2.2 Different research strategies in economic sciences, Kasanen et al (91, p. 317).

	THEORETICAL	EMPIRICAL
DESCRIPTIVE	The conceptual analytic paradigm * Purpose constructing, conceptual systems	The positivistic paradigm * Purpose explicating, causal relations The culture paradigm * Purpose understanding, diagnosting, normative
NORMATIVE	Decision-making methodological paradigm * Purpose speculating, problem solving methods	The constructive paradigm * Purpose solution or construction, normative, diffusion

The conceptual analytic research strategy

The purpose of the conceptual analytic approach is to create new theoretical concepts, concept entities and hypotheses. These are of help when the business phenomena and changes are analyzed and arranged. The work is mainly based on the already existing conceptual analysis. The objects of the study can be facts, values, and norms. The results are proved by argumentation. The conceptual analytic research seldom uses empirical material, see further Neilimo and Näsi (80).

The concepts used in this study of engineering are those normally used in the industry.

The posivistic research strategy

The posivistic research is perhaps the most common in the economic research. The purpose of the posivistic approach is to show the causal interdependencies between different phenomena of the economic life. In the explanations the positivistic approach can use the laws that have been already verified. The phases of the posivistic research strategy are the conceptual, the empirical, and the argumentation phase. An empirical material is very essential in the approach, and a vast methodological literature exists relating to the use and norms of the empirical material. The positivistic research approach relies on the observations whether observed, measured, or statistical. The results are derived from the observations like in the natural sciences.

The conventional industry studies basically use the positivistic approach. They rely on the data, often the aggregated data, and try to make conclusions about the whole industry. The argumentation is inductive starting from empirical details and aiming at general conclusions. The empirical material in this study can be criticized for its statistical limitations, therefore it is important to note here that the analysis is not left to a conventional industry study.

The decision making methodological research strategy

The decision making methodological research aims to develop a method for solving problems. As background theories, it uses among others micro, decision making, and game theories. The method follows the principles of logics and mathematics. Very often the result of the research is a mathematical computerized model for solving a particular problem, see e.g. Heinonen (94).

The purpose of the decision making methodological approach is the problem solving. The argumentation follows the deductive reasoning from existing general to detailed models. In these two aspects the present study resembles the decision making methodological approach, although the present work is qualitative. In the theoretical model construction the argumentation of this study is deductive and close to the decision making methodological approach which element also is present in the constructive research strategy.

The culture research strategy

The culture research strategy is an antithesis to the positivistic approach. Its background is on teleological explanation and hermeneutics. The objective of the approach is understanding. Its objectives are also normative. The culture approach often aims to a change. The research method emphasizes the importance of the human sciences and the values and the researcher as a part of the study object. The significant difference with the positivistic approach is the relationship with the empirism. The conceptual systems of the functional culture research are created through the diagnosis of a few targets which are supposed to provide a deeper and more comprehensive understanding of the objects. The posivistic research relies mostly on the large amount of empirical observations.

The culture approach is particularly recommended to the studies of a management, where the environment and goals are constantly changing. The time limits the possibility to follow the positivistic chain of reasoning: a theory, a test, a new theory. The empirical material is often soft and includes values. When the purpose of the approach is a change, it is often more important to understand and analyze the need for a change by analyzing the target setting than to try to explain the phenomena of the past, Heinonen (94).

The typical features of the culture research strategy are a dialoque, a formation of an objective reality in the intersection of the subjective realities, a holism, an interaction between the researcher and the research objects, a desire of all the parties to commit themselves to a change, and different roles of the researcher in different phases of the study. The verification of the results would require to include some posivistic parts into the study, Olkkonen (93, pp. 52-56).

The qualitative and normative nature of this study suits well the culture research strategy. The use of case material means that the researcher is strongly involved with the object of the study. In this case the role of the researcher is to observe the object in an interview and to write the descriptive company case. In the analysis and writing phase, the role of the researcher is to interprete the information. The purpose of the culture research strategy is an understanding and an explanation which suits the purpose of this study of clarifying and describing.

The constructive research strategy

The constructive research strategy is a normative research approach. Basically it belongs to the development of the problem solving methods. In this respect it is related to the decision making methodological approach. The base of the constructive research strategy is the theoretical derivation of a normative result through an analytic and a deductive argumentation. The verification of the result often happens by the logical reasoning and, in addition, by an applied example. The verification resembles the one of the decicion making methodological approach. In the constructive approach an innovativeness, a creativity, and a heuristic thinking are emphasized, see Kasanen et al (91).

The constructive rersearch strategy also approaches the culture research strategy. The case method is a typical feature to both of them. The purpose of the culture approach is mostly an understanding, and possibly a development of the theory, whereas the purpose of the constructive research strategy aims originally at the solution of the problem or at the development of the problem solving methods. The constructive method has clearly the features of the applied planning science. A criterium of the results in the constructive approach is the verification of the utility of the results. The verification is related to the practical applications, Olkkonen (93).

The legitimation of the constructive research strategy resulted from the need to have a closer interaction between theory and practice. The constructive approach in a study often tries to find a solution or a construction to some explicit problem.

The constructive research strategy differs from the consulting, since it is linked with the theory with respect to the information acquisition and the validity assessment. The consult solutions do not normally show any evaluations how widely the solution is applicable. Another borderline has to be mentioned. The scientific problem solving produces the result through a scientific method, but the solution applies only to one particular problem. See Kasanen et al (91, pp. 311-318).

The constructive research strategy normally includes the following phases, Kasanen et al (91, p. 306).

Characterictic steps to the constructive research strategy

1. The search of a relevant and scientifically interesting problem.
2. The tentative understanding of the research problem.
3. Innovative phase, a construction of the solution.
4. Testing of functionality of the solution, i.e. the proof of the validity of the construction.
5. The indication of both the theoretical connections and the solution and its scientific novelty value, and
6. The consideration of the scope of a generalization of the model.

The basic design of this study mainly belongs to a constructive research strategy. The purpose of the study, the research questions, and the type of the available empirical material necessarily lead to a normative study. The other researh strategies are parallelly used in the work as mentioned before. The purpose and the objectives of the study have a major influence on the selection of the research strategy, Mäkinen (80, pp. 47-50).

2.3 Practical design of the study

To construct a theoretical framework for the study of alternative paths in an engineering industry is the main theoretical effort of this study. The base of the model is compiled from the existing pieces of theoretical approaches including theories of a firm, theories of industrial evolution, research of technology and innovation, and management studies. All the pieces are to be found in literature, but the integration of them to a tentative unified model of industry paths for an engineering industry is carried out in chapters from 3 to 8.

The framework consists of two parts, an endogenous evolution, and an exogenous development of the industry paths. To make the picture very concrete, the industry paths are understood to be a curved cylinders in a multi dimensional space, and they are moving from one point of time to another. In addition the paths, i.e. the cylinders may cross each other, or may depart to two or more branches in their evolution. The endogenous evolution is occurring within the cylinder, and the exogenous development determines where the cylinder is located. The individual companies live and develop within the industry paths, and they seldom change the path in the course of time. In this study, the empirical data and cases mainly relate to the period between the birth and the mature state of the engineering company when the company has probably been drawn into an industry path. Therefore the transfer of an engineering company from one stage to another is discussed in a length-wise manner in the study.

To describe the evolution of a company within an industry path, theories of a growth of a company, theories of an endogenous evolution of an industry, and a theory of development of a knowledge-based company are used. The theory of an endogenous evolution of an industry emphasizes the internal evolution in an industry, and depicts the structural changes over time in an industry. The approach developed from Porter´s cluster theory underlines the relationship between the engineering company and the environment as a precondition for the development of an engineering company to a mature stage as a company in its own strategic group. Together they enrich our understanding of the industry and company evolution within an industry path.

The consideration of the theories of a company and an industry together gives light to the internal evolution of an engineering company within a path and to the period before an entry into a path. A thorough discussion of a change of a technology and an innovation is behind the evolution of industries, since the technology is a driving force for the changes in structures of industrial evolution models, and since the technology is arguably a factor in the engineering companies.

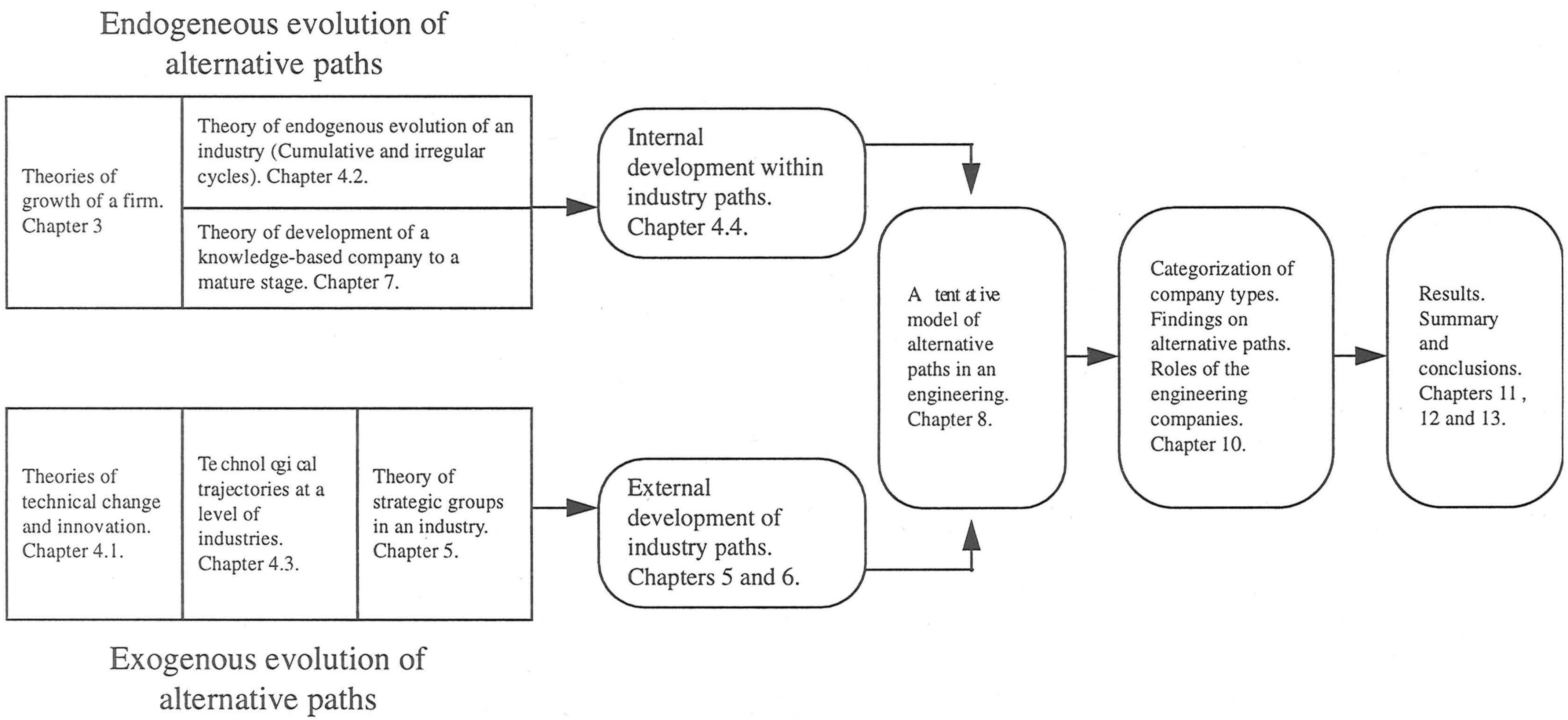
The external development of a path, i.e. the location of the path over time, will be developed on the base of theories of technical change and innovation, and the studies of strategic management. More closely the basic technological trajectories give the model for the company paths within an industry. The technological trajectories and the strategic groups depicted by strategic maps in an industry are merged into industry paths. The point of view of business activities is brought into the technology-based industry trajectories. The industry paths can be seen as longitudinal illustrations of the alternative industry paths. At the same time, the cross section pictures of strategic maps locate the industry paths into a space describing a strategic behaviour of the groups of companies.

As the model of internal and external developments of industry paths in an engineering industry has been developed, they are combined into one whole. The cross section picture of mature engineering companies, i.e. the locations of the industry paths in an engineering industry are attained from the European empirical and theoretical study, and the types of start-ups of the engineering companies from an empirical Finnish case data available. The meaning of this phase of theory building is to form an engineering industry model of development paths.

The development of an engineering company is not a deterministic occurrence. The companies do have a freedom of choice. However, there seem to be certain rules or a logic, how the past and the surroundings stochastically determine the evolution of the companies towards certain definite alternative paths in an industry. As a consequence these industry paths really exist. The understanding is that the individual companies mostly remain within the industry paths of their own. Only in abnormal cases a company may change its path or drop out of it.

The time is a complicated matter in the context of industry paths. Actually there exists no one point of time when all the companies are in an initial phases of their company development, and even at the point of time of "mature outcomes" there are companies in the initial stages in an industry. The reference of time in the previous meaning is made to the absolute time concept. However, if and when the sample of engineering companies includes individual companies with a definite point of start-up and a point of maturity in a company life, a relative time can be used as a dimension of a company life cycle. The absolute time dimension is used, when an industry is studied with numerous cross section observations.

Figure 2.3 **The logic of the research design to construct a tentative model of company paths in the engineering industry.**



The studies of a technological change and an innovation are strongly behind both the endogenous and exogenous evolutions of industry paths. The technology is a driving force in the evolutional theory of an industry, and therefore an important determinant for the internal development of industry paths. On the other hand, the technological basic trajectories which give the theoretical idea of building industry paths for engineering companies have been constructed on the basis of innovation statistics. Therefore the model of external development of industry paths can also be claimed to have a technological base.

The technology is by definition an endogenous factor in the evolutionary theory of industrial development in the school of economics. The companies can then have influence on endogenous factors like technology, as it is understood here. The basic technological trajectories of industries are, however, exogenous factors from the point of view of an individual company, most of the time. This is in a congruence with the view of a technological change which is basically understood to be determined by the internal technological causalities, but at the same time it is also affected by complicated feedbacks from a market and needs of the customers.

The summary of the logic of the research design is presented in Figure 2.3. The explanation of the research design makes clear that there are certain original determinants that have influences both on the internal, and the external development of industry paths. The two most important of them are the influences of technology change and market development. They influence both on internal and external industry paths.

The thorough discussion of taxonomy of the engineering companies, strategic groups, and dimensions of industry paths gives a chance to locate individual companies and groups of companies into the model of industry paths.

The construction of a model of industry paths in the engineering is presented in Figure 1 in the introduction. Figure 2.3 covers the right part and the conclusions of Figure 1 in the introduction.

Theoretically the construction of the model of alternative paths is the main effort in this study. The work gives, however, as byproducts two additional models, the eight determinants for evaluating the preconditions of a knowledge-based company development to a mature stage in its own strategic group, and a model to the development of new clusters from an engineering base.

2.4 Data collection and analysis

The collection of the data in a qualitative study like this is not a very straightforward operation. The actual work process is, however, seldom described in the literature. Therefore this phase of work is presented by steps to show, what it really means in this kind of work. Subsequently a base to continue the discussion is given on the reliability and the validity of the data.

1. The data were originally collected by a student of technology for his Master Thesis. Before collecting the data the following steps were preceding

- the student of technology prepared the questionary form together with the advising group which consisted of qualified experts with experience in the industry[1]
- the questions were tested by a few interviews and minor corrections needed were made
- the student interviewed the remaining companies and gathered further information about the companies
- the student ended up with two kinds of information: 1) quite obvious quantitative data including information on personnel, turnovers of companies, the years of start-ups of the companies, etc., and 2) written cases from all the individual companies. An additional problem was that some of the data was not complete due to different reasons, the information was not given or received
- all in all, the student did not get exactly the information he originally wanted, but he was sensitive enough to listen to the interviewees and diligent enough to write down what he was told.

1 The group consisted of the supervising professor of the study, Dr. Esa Jutila, Mr. Matti Pietarinen, and the writer.

2. This led to a problem. The student had incomplete and partly non-systematic tables of data and cases of engineering companies. He had to write a report but the material available did not seem to fulfil the requirements. The advising group, after having acquainted with the material and the case reports from the interviews, decided that certain data will be generated from the cases. If some individual information was missing, the cases, the hand written notes, and other sources were used to generate the missing data - as well as possible. In this way the tables and graphs were generated for the report, Räsänen (94)[2]. The student also utilized some citations from the interviews to underline certain aspects in his report.

3. The same data was reprocessed for the wider study, see Kässi (96). New tables of data were produced from the same basic information. The intermediate reporting gave a perspective on the important dimensions to be drawn out the information. The company cases were polished by language, the interviewees reread the cases and made some corrections to them and accepted the cases. The cases were published as an appendix 2 to the study, see Kässi (96).

4. In this study, the empirical research data is not any more profoundly reprocessed. The existing data is published in a new and more complete form. The interpretation of the data includes at present all the understanding which has been accumulated during the whole process of analysis and data generation.

The reader should notice the words "generate data" and "produce data" which describe the reality with the qualitative studies. The description has been written carefully, because this story is seldom told. Due to the high appreciation of the quantitative study approach, the scholars often do not disclose the process of the qualitative approach. Important characteristics of a researcher are a sensitivity to listen to signs of the study object, and a preunderstanding of the phenomena he is studying. These properties can also produce an understanding of the phenomena, Gummesson (93).

As regards to the reliability of the data it is secured in this case through the process. In the first place, the student generated the information together with the interviewees, in the second phase, the intermediate report,

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[2] The same information was disclosed by Räsänen et al (94).

Räsänen et al (94), was read by the respondents. Further reprocessing of the information was again produced based on the responses, and the company cases were polished with the interviewees from the companies, and the result was published in Kässi (96), reread and checked by them. The data and information of this study was checked by the interviewees twice for the part of individual company data, and twice as the part of the whole in the form of published reports. A researcher can hardly do more to secure the reliability of the data generation. The stepwise process of the study is a guarantee of the reliable generation and processing of the information.

The same process also secured the validity of the study in this case step by step. The validity of the issues of the study was checked by intermediate reporting and publishing the results. Then experts in an engineering have been able to read the results and give response for the use of the next stage of the study process.

In the study process, the phases of a data generation and an analysis of the data are not separate phases. The analysis and conclusions are started during the data generation and continued afterwards, see e.g. Yin (94).

When the study process is carried out, the results in this kind of a study are qualitative by nature. The information is also subjective depending on the choices of the researcher. The information includes necessarily hard facts, interpretations, and values. Because of the selected research strategy and the characteristics of the data, the study is normative. The summary of the whole process of the data generation and the processing in presented in Figure 2.4.

The empirical material of the cases consists of 22 companies or organizations in the field, a part of them are engineering design companies, another part represents engineering project companies. Some divisions and subsidiaries of large industrial companies which supply design and project management services to their own mother company and outside customers are included. The engineering design companies are, all except one, members of Finnish Association of Consulting Firms SKOL[3], and only one of the engineering project companies is the member of SKOL.

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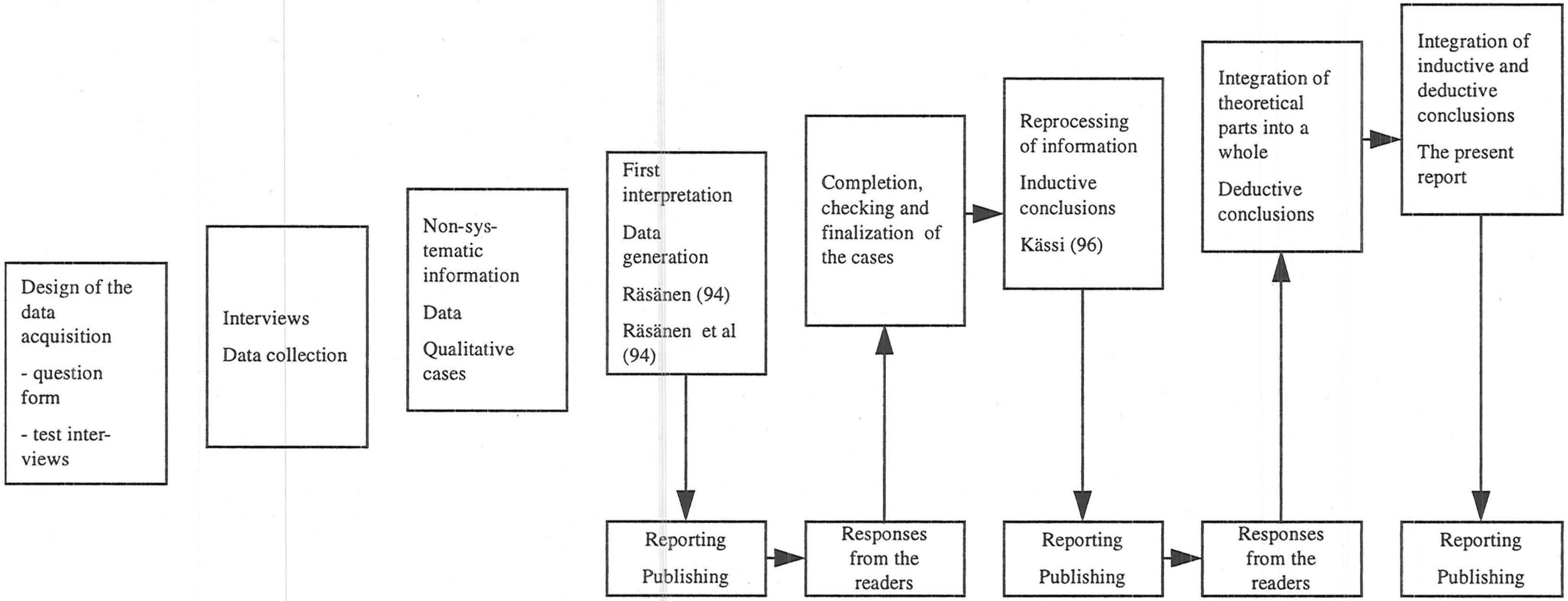
[3] Finnish Association of Consulting Firms SKOL is in Finnish Suomen Konsulttitoimistojen Liitto SKOL ry.

Figure 2.4 **Data generation and processing of the previous studies and the present study.**



The Finnish Association of Consulting Firms SKOL has altogether 200 members and a group of associated members. They are, in general, engineering design companies. The study concerns partly the members of SKOL but the engineering project companies are also consciously included .

The group of empirical company examples can be considered big enough to represent the industry in certain aspects, particularly in foreign operations. It has been estimated that the sales of the companies in the sample represent 80 per cent of the total sales of the industry, the personnel 80 per cent of the total personnel, and the export 90 per cent of the total export correspondingly. The data was collected directly from the enterprises mainly in the fall of 1993 and 1994. The data represents fairly well the industry in the mentioned respects. The technology potential is also well included. The companies and cases have been published by Kässi (96).

A remark is needed about the size of the group of the studied companies. The group is clearly too small and biased towards international activities to represent well the whole industry. Also the large engineering companies are over represented. The examples have been purposefully selected in this way and focused from the very beginning on international activities, export markets and activities in the technology field. The engineering project companies of large firms are well represented in the examples. They also form a special group in the study. The number of the example companies was 22 altogether. The number of the engineering design companies totals approximately 200. In addition to them there exists a dozen of engineering project companies.

The total number of the companies studied remains under 10 per cent of the whole. Conclusions in the conventional industry study related to small and medium sized companies are of limited reliability due to their limited representation.

The size of a group of companies is small for the purposes of a conventinal industry study where a statistical empirism is a concern for the reliability of the results, for the objectives of a study. In the application of the case examples to the developed frameworks the companies represent themselves. The number of the companies is small but so is often the case in the reality in the industry, too. The conclusions are made from the companies and concern mostly the same companies. This is the feature belonging to a constructive and culture research strategy.

2.5 Evaluation of the results

The evaluation of the results belongs to the constructive reseach strategy as the last step of the study. In this study the evaluation part is exceptionally located in the Methodology chapter even though it would belong to the end of the report. The reader may read this part after having reviewed the results of the study.

Academic contributions

The research strategy selected for this study is in the first place a constructive research approach. As often is the case in practice, this study does not exactly follow the sequence of any research strategy. It includes a part of the conventional industry study. This part can be described as an inductive empiristic study with minor explicit theoretical connections. This work also has some connections with the other research strategies like the culture approach. The steps performed in this study have followed the sequence of the next box.

Steps performed in this study

1. The search of a relevant and scientifically interesting problem.
2. The tentative understanding of the research problem. The clarifying and the specification of the research questions based on a preunderstanding from the earlier studies.
3. Innovative and theoretical phase: a construction of a solution. A deductive phase of integrating the pieces of theories to a construction model.
4. The phase of a conventional industry study. Inductive and empiristic phase to make some generalizations from the material.
5. Testing of the functionality of the solution, i.e. the proof of the validity of the construcion.
6. The indication of the scientific novelty of the constructed model.
7. The consideration of the scope of generalization of the model.

To make the comparison the steps of the box have to be compared to the characteristic steps of the constructice research strategy, Kasanen et al (91, p. 306), presented in chapter 2.2, too.

The performed sequence of steps resembles the sequence of steps of the constructive research strategy. The first two points are exactly the same. In the third point, this study proceeds as a theoretical integration of the existing pieces of theories into a model of alternative paths of engineering companies in the course of time. The essential matter in this context is that the argumentation was deductive starting from a general level, and aiming at the details of the model. Afterwards it is easy to see that the argumentation was teleological when constructing the model. The constructed model had to be built from fairly many pieces of theories, this could be considered a sign of an innnovative approach which is a feature here referring to a constructive research strategy.

In this study, the part relating to the conventional industry study, chapter 9, was included because it gave some additional views on the industry. Methodologically it has not any tight and explicit theoretical connections. The argumentation in this part is empiristic and inductive by nature starting from a level of details aiming at some general conclusions. The results of the study are drawn both from the inductive part and from the testing of functionality of the constructed models.

As the models were built making the reference to the theory connections, no expanded clarification of the theory connections was needed. The scientific novelty of the findings is discussed in chapter 12. The only thing remaining, is the discussion on the scope of the generalization of the model.

As indicated before, the research strategy used includes features from other research approaches besides the constructive research strategy. The deductive part in building the model reminds of the decision making methodological approach which is mostly the mathematical model building approach, whereas the approach of this study is qualitative. The resemblance is in the deductive argument in the model building, Olkkonen (93, pp. 42-63).

In the culture research strategy the purpose of the study is understanding, diagnosing, and a normative purpose, whereas in the constructive approach the purpose of the study is to develop a solution method for a problem, or a construction for certain types of problems, Olkkonen (93, p. 43). The results of this study are theoretical models and the conclusions from them. The nature of the model is descriptive, namely the model of alternative paths and the evovolution of a new cluster from an engineering base. This refers to a culture reseach approach. The normative conclusions for decision making from the models are made afterwards by the writer which refers to a constructive research strategy.

The model of the eight determinants of the know how based company evolution is a normative construction, an evaluation model fulfilling the requirement of the constructive approach. The results have been made as practical as possible and in that respect they can serve the problem solving.

Generalization of the results

In generalization of the results an utmost careful approach is necessary. The first limitation is the industry-specific nature of the study. The discussion about the alternative paths, the industries, the companies concerns only the engineering industry. The results have no validity concerning other industries.

The model of the industry paths was developed only relating to the Finnish engineering industry. Therefore the model is country-specific in principle. However, the European industry-specific strategic groups were used, as well as the country-specific technological basic trajectories for building the model. The argument was that these particular aspects are not so specific to the geographic areas, and therefore can be applied in Finland. The argument must be true to the opposite direction, too. The conclusion is that the model of the industry paths is not as strongly country-specific as it is industry-specific, but could be considered to be used in similar countries, e.g. at least in the other Nordic countries.

The discussion on the company environment and its impact on the development of the knowledge-based companies, and an engineering company based new cluster has a validity in all the other knowledge-based companies including the engineering companies, and in other industries - with the general limitations that the diamond model of the industrial cluster has. The positive point, however, is that the step from a small diamond of a company is short to the diamond of a cluster. This easily allows the expansion of the consideration from a company level to an industry level.

In general, the proposed model of the industry paths should be applied elsewhere than in Finland with an extraordinary care, and it should not be applied outside the engineering industry.

The validity of the research includes the validity of the concepts and the validity of the content. The validity of the concepts means that the phenomenon is described with the essential characteristics, and the essential characteristics can be derived from the theory. The intermediate reporting of the results by Räsänen (94) and Kässi (96) is to secure that the researchers analyse and write about the essential issues for the engineering industry. The both reports were inductive in the meaning that conclusions were made from the basic original company data. The results were approved by the companies. In this way the first part of the requirement of the validity of the writing about essential issues and using conceivable concepts were fulfilled. Only in this study a theoretical model was built. The concepts of a model, the essential characteristics were derived from the pieces of theory and integrated into a whole to serve the second part of the definition, the validity of the concept.

The validity of the content means that, besides the validity of the concepts, the research has to capture the expected issues with the questions in data collection. The applications of the company cases into the model of alternative paths were carried out. The application showed that the constructed model worked for the applied cases.

The external validity of the model framework was secured by a number of cases applied to the developed frameworks, and discussed above.

The validity also means that the study should concern relevant issues. The criticism of the main stream economics arouses from the suspicion that the results attained by it, particularly in the field of the behaviour of companies and industries are not relevant, because the models seem to be too far from the reality, see e.g. Lovio (89a). The industrial dynamics as a part of industrial economics emphasize the importance of validity in the research of companies, even at the cost of reliability. This means in practice that the studies have to handle relevant issues even though that would happen at the cost of exact numbers and tight definition, see a domestic discussion in Räsänen (89), and Lovio (89b). The case is often that the absolute requirement of exactness may prohibit the whole study.

At the international level the works of Michael Porter are examples of applying qualitative methods. His earlier works were more explanations of tools and approaches, and also some reporting of the research results, see Porter (80) and Porter (85). But ten per cent of the last work the Competitive Advantage of Nations is quantitative and ninety per cent qualitative. It is based on case studies made in ten countries and the previous works of the scholar, Porter (90). Still he claims to be able to present a general theory of competitive advantage of nations for all the countries.

The model of alternative paths in an engineering industry has been found valid only in the Finnish industry. The further validation should be considered in the similar types of countries by the structure of industries, e.g. the Scandinavian countries. The wider confirmation of the model and its enrichment in details should be performed in Finland with a wider empirical material.

The models of the eight determinants affecting a knowledge-based company, and of the evolution of a new cluster from an engineering base should also be validated in other countries than Finland.

In a quantitative research much discussion is given to the reliability of the results. In physics the test results have to be presented in a way that somebody may repeat the test. In social sciences and in management studies this seldom is possible. The treatment of data has to be correct and transparent, see the preceding chapter.

The reliability of the data was secured in this series of studies through the process and by company responses. In the first place the researcher generated the information together with the interviewees, in the second phase the intermediate report was read by the respondents. Further reprocessing of the information was again reproduced with the interviewees, and the result was published, reread and checked by them. A researcher can hardly do more to secure the reliability of the data. The stepwise process of the study was a guarantee of the reliable generation and processing of the information.

2.6 Connection with other research

As pointed out earlier the evolutionary school of economics was born from the dissatisfaction of the micro economic theory in the main stream economic tradition. A good overview of the new tradition is given in the book Technical Change and Economic Theory, Dosi et al (88).

In congruence with the evolutionary economics, the theories of the growth of a company and the theories of the evolution of an industry are used. The technology change is the driving force behind the change of the industries. The research of technical change and innovative activities contribute to the development of the alternative paths in an engineering industry. Particularly the papers of Pavitt on the innovative activity in the industries are of invaluable importance for this study, see e.g. Pavitt (84) and Pavitt et al (89).

The third corner of the model development in this study relates to the literature of management and strategy. The widely used source is Michael Porter whose three books form a kind of reference frame for this work. The two earlier books, Porter (80) and Porter (85), are used more in this study than the last one, Porter (90). The last book was a reference in the national project recently performed in Finland. The preceding study on the engineering was parallel to the study Competitive Advantage of Finland.

The main academic effort of the study, a development of a model of alternative paths in an engineering falls to the triangle of the three theoretical approaches: the evolutionary theory of economics, the research of technology and innovative activities, and the writings and studies of management. The work also discusses a model of eight preconditions for a knowledge-based company development, and an emergence of the new engineering based cluster, both mainly from the base of Porter´s writings.

Actually this study has still another tradition, the conventional industry studies. The conventional studies of industries do not often have any particular or explicit reference to a theory. The studies are made in order to meet the actual needs of the information with the available data, and resulting in the varying results. Based on the fairly new tradition of the evolutionary economics some new types of industry studies have been made, see e.g. Lovio (93). This work includes a chapter of an industry study carried out in a conventional manner, and another chapter in which the developed model is illustrated. The results are parallelly drawn from both traditions.

The study produces a qualitative and normative constuction. Its purpose is to clarify and describe the engineering industry, and to make certain recommendations for the management and the decision makers of the industrial policies.

The industry studies have been criticized for trying to present industries in a too simplified manner. The industry is understood and explained as a single structure without paying too much attention to details and often even important features. In this work the starting point is that the industry is not forced to a strict formula, but differences and contradictions are allowed and understood as significant features of an industry.

In the works of Pavitt et al (89) and Dosi (82) the industry trajectories and company trajectories are referred to as possible constructions. These writers have examples on the technological trajectories. The industry trajectories or paths, company trajectories or paths are not found in the literature as constructions.

There are, however, exceptions on the references to the technological trajectories, see e.g. Demarchi et at (96), where the technological trajectory model was found valid in Italy, too. The articles of Pavitt (84) and Pavitt et al (89) have been frequently cited in the innovation literature since publishing. The actual models of company paths in various industries have been treated only indirectly in the management studies referring to strategic maps. The numerous case libraries seldom include many enough company cases in the same industry which would fulfil the resemblance requirements for the comparative study needed to formulate the company paths in an industry.

3. DEVELOPMENT OF A SMALL COMPANY

3.1 The start-up of a new engineering company

As the topic of this study relates to engineering companies, it is evident that the newly started engineering companies are a subgroup of the study. Especially this is true for technical design companies as the entry barrier is low to the technical design service industry. But the research object also consists of other kinds of companies. Some established machinery producers start selling turn key projects based on their competitive products. For this purpose they need some additional design and implementation organization. When they establish these functions and start selling projects they represent one type of engineering companies. In some cases a company may even begin to manufacture a product, a technical design and simultaneously implement the department of sales of the turn-key projects just after having established its activities. Large multidivisional companies have always had their own engineering departments for the internal investment activities. Many of these departments have been now made profit centers or corporated. They are selling their engineering services to the mother company and as well in the external markets.

3.2 Development stages and crises of a company

The Greiner Model

A life cycle has been an inspiration source for many scholars for the models of a new company. These models have been presented and used for the last 20 years in different variations amounting to about 20 altogether. According to Greiner (72), in Myllyniemi et al (90), a new enterprise develops through various development phases. Between these phases it has to change structurally to get into the next phase. The phases in the Greiner model are called the Growth through creativity, the Growth through direction, the Growth through delegation, the Growth through coordination and the Growth through collaboration. The self explanatory names tell the content of the phases.

In the Greiner model the phases of management style and structure are changing in waves, when each mode becomes insufficient for the organization and activities of the developing company. Many other scholars made minor changes to the Greiner model as well as also empirical research on these models.

The Churchill and Lewis Model

Churchill and Lewis (83) have developed a five stage model to categorize the problems and growth patterns of small companies. Each of the five stages has been given an index of size, diversity and complexity. They have, in addition, been described by five managerial factors: managerial style, organizational structure, extent of formal systems, major strategic objectives, and owner´s involvement in the business. The model was developed on the basis of the works of Steinmetz (69) and Greiner (72) with some major modifications. Further changes to the model were made after a preliminary empirical survey.

Existence

The first stage of growth in the Churchill and Lewis model is the Existence stage. The problems of the company are then developing products, finding customers and delivering products and services in order to become a viable business. The owner does himself operative tasks from marketing to product development and product deliveries and administration. If the company gets through the Existence stage it arrives at the Survival stage. It has succeeded in delivering its services to the customers and in satisfying them. Now the objective becomes not merely the existence of the company but also the fair relationship between revenues and expenses. It is important to generate enough cash flow to stay in the business.

Survival

In the Survival stage the organization is growing, but all the formal systems are minimal. Formal planning consists at best of cash flow forecasts. The owner still is the key for the business. The company may grow in sales volume and profitability, and move to the third stage, or it may remain at the Survival stage. Insufficient cash flow may be the reason for the company to remain in the Survival stage for a longer period.

Success

At the beginning of the third Success stage the decision facing owners is, whether to exploit the accomplishments of the company and expand or to keep the company stable and profitable. In the latter case, the company could give a base for the alternative owner activities. The model is divided to two parts in this stage III. In the substage III-Growth, a key issue is how to use the company as a platform for growth, whereas in the substage III-Disengagement, a key issue is how to use the company as a support for the owners as they completely or partially disengage from the company.

In the Success-Disengagement stage the company has attained true economic health, has sufficient size and product-market penetration to ensure financial success. The company can stay at this stage indefinitely, if the market niche is not destroyed by an environmental change, or the incapable management has not reduced its competitive abilities.

Organizationally the company has grown large enough to require functional managers to take over the every day operative tasks which were earlier performed by the owner. The company has a good cash flow, and the important task is not to let a cash drain in prosperous periods to the detriment of the ability of the company to withstand the unavoidable hard times. As the business matures, the company and the owner grow inevitably apart. Many companies may remain, for longer periods, in the Success-Disengagement substage, e.g. the product-market niche does not permit growth without changing basic elements in the business.

If the company can adapt to changing conditions, it may continue as it is, be sold or merged at a profit, or subsequently be stimulated into growth. If the company cannot adapt to changing circumstances, it will either fold or drop back to a marginally surviving company.

In the Success-Growth stage, the owner takes the cash and other resources of the company and provides all of them for the growth of the company. Important issues for the management is to make sure that the basic business stays profitable and to avoid the outrun of cash resources. When the growth starts the requirements for the personnel are high.

The management systems are to be reviewed and developed to the level that they can handle the growth. Operational planning does not differ from the Success-Disengagement substage but the strategic planning is more extensive and involves the owner. If the company is successful in the Success-Growth substage, it may proceed to the next stage. Often the Success-Growth substage is the first attempt at growing before commitment to a growth strategy. In the failure from the Success-Growth substage the company may move back to Success-Disengagement substage, if not to the Survival stage.

Take-off

In the Growth stage the most important problems are how to grow rapidly and how to finance the growth. The key issues are then

a. Delegation. The owner should be able to delegate the responsibility to other persons to improve the managerial effectiveness of the fast growing company and increasing complexity. The owner should be able to a true delegation with controls on performance and to a tolerance on mistakes made.

b. Cash. Will the cash flow be sufficient to satisfy the great demand that growth brings. The effective control system is needed to avoid the erosion of the cash flow in the periods of a rapid growth. The owner possibly has to tolerate a high debt-equity ratio, and not to make ill-advised investments in the impatient atmosphere of high expectations.

The organization is decentralized and possibly divisionalized. The responsible managers are managing their own fields fairly independently. Both operational and strategic planning are made and specific managers are in charge of these activities. The owner and the business become increasingly separate. The company is still dominated by the owner´s presence and stock control.

The stage is a very demanding stage for the company. It may become a big business. If it does not grow as expected, it is often sold - at a profit - providing that the owner recognizes his limitations. Very often those who bring the company to the Success stage are unsuccessful in the Take-off stage because of trying to grow too fast and running out of cash or being unable to delegate effectively and to let the company grow. The company may pass the Take-off stage with the new management. The entrepreneur is often replaced voluntarily or involuntarily by the investors or creditors of the company. In the case of failing to grow fast the company may still reach a state of equilibrium or to drop back to a lower level in the scheme.

Resource maturity

The greatest concerns of the company entering to this stage are to consolidate and to control the financial gains brought on by the rapid growth and to retain the advantages of flexibility and entrepreneurship. The management enforcement is a necessity for the company reaching the Resource maturity stage. The management systems have to be developed to the level as the company level demands.

Table 3.1 The characteristics of small business at each stage of development according to Churchill and Lewis (83, p. 38).

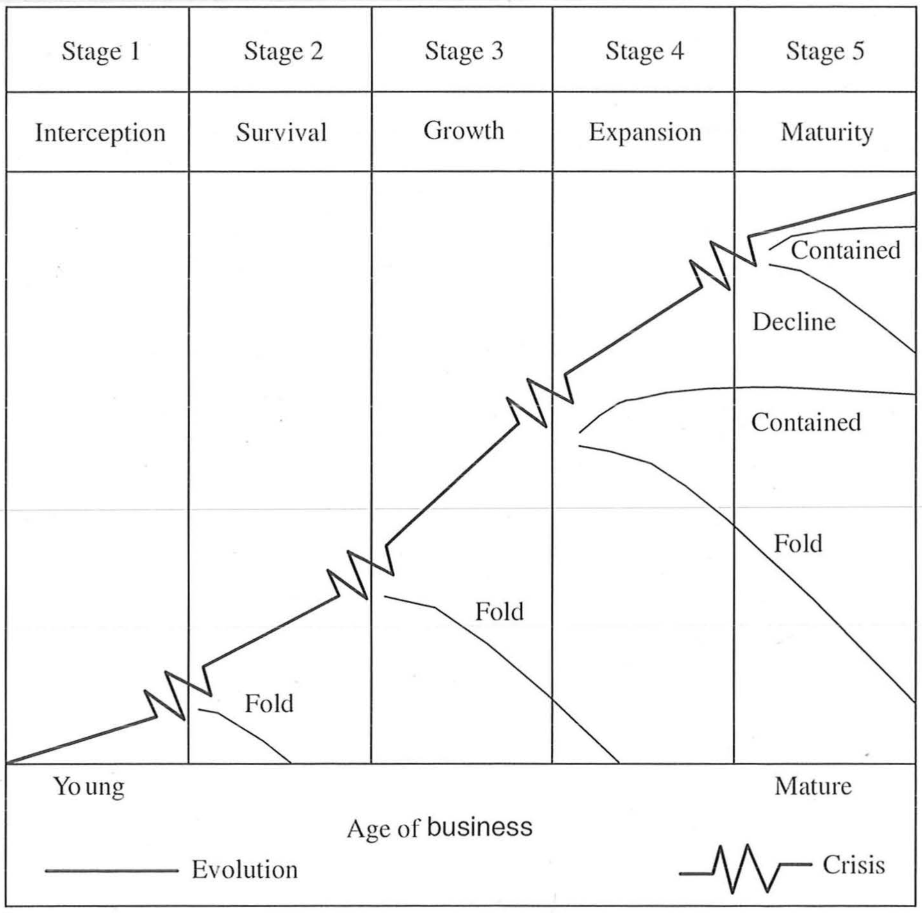
	Stage I Existence	Stage II Survival	Stage III-D Success-Dis-engagement	Stage III-G Success-Growth	Stage IV Take-off	Stage V Resource maturity
Management style	Direct supervision	Supervised supervision	Functional	Functional	Divisional	Line and staff
Organization	Simple	Simple and growing	Growing	Growing	Maturing	Sophisticated
Extent of formal systems	Minimal to nonexistent	Minimal	Basic	Developing	Maturing	Extensive
Major strategy	Existence	Survival	Maintaining profitable status quo	Get resources for growth	Growth	Return on investment
Business and owner	Owner is the business	Owner is still synonymous with the business	Owner wants to disengage, performs certain duties	Strategic planning extensive and deeply involves owner	Owner reasonably separate from business	Owner and business quite separate

The company has now the staff and resources to engage in detailed operational and strategic planning. The company has now arrived at the stage where it has all the various resources to preserve an indisputable position at the market place.

The Scott and Bruce model

In their company model Scott and Bruce (87) have built extensively on the model of Churchill and Lewis. The Scott and Bruce model is based on five subsequent stages and for crisis in the traditional product or business life cycle curve. These scholars point out that there are no single measure of the company size that pushes the company from one stage to the next one. There are rather several measures that are accompanied with the company related internal factors as well as external factors like entries of new competition and a change in technology. Scott and Bruce use the following names for the subsequent stages in the company development: the Interception stage, the Survival stage, the Growth stage, the Expansion stage and the Maturity stage.

Figure 3.1 The five stages of life cycle according to Scott and Bruce (87, p. 47).



Scott and Bruce emphasize that the company has always to pass a crisis or a change before reaching the next stage. They have characterized the crisis between the different stages in the company development.

Table 3.2 Characterizations of crisis in the course of the company development. Adapted and applied from Scott and Bruce (87).

	Characterization of crisis
Crisis between Interception and Survival	1. The need for sufficient cash flow. Otherwise the company disappears. 2. The need for more formalized systems by the increasing amount of business activities and the push for profits. 3. The need for a change in management style. The supervisory tasks are to be delegated and a change needed in organization.
Crisis between Survival and Growth	1. Overtrading and uncontrolled growth are causing concern. 2. Due to the drive for increased sales, new market areas or new products are needed. Changes in conducting the business and management are needed. 3. New competition enters the market. The company has to improve its competitive strength to maintain its present market share. More sophisticated management systems to be applied. New equity capital needed. 4. The pressures to improve the information and cost control systems. The changes call for changes in management style, prevailing ideas and values of the company.
Crisis between Growth and Expansion	1. Due to the growth in the industry demand calls for new and stronger competition to the industry. Price competition appears. Product differentiation and response to the price competition needed. 2. The need to expand to new markets and products. The key issues, how to finance the growth and how to maintain the control of operations. The organization needs to be replaced from entrepreneurial to managerial approach. A certain decentralization needed.
Crisis between Expansion and Maturity	1. The need to handle with the growing distance between the top management and the activities. 2. Up to this time the company has focused inward, often the product orientation has dominated. As the industry matures and consolidates, product differentiation is more difficult. The environment calls for more emphasis on monitoring the environment and adapting the management style.

Table 3.3 The growth stages of a technology-based company according to Kazanjian (84).

	Pre-start-up	Start-up	Growth	Maturity
Problems for organizational decision	- Invent and develop product technology - Build prototype - Define business idea -More prototypes	- Develop production - Acquire facilities and plant functions - Refine design - Meet demand - Acquire talent	- Avoid shake out - Maintain growth momentum position - Attain profitability - Balance profit vs growth	- Dominant marketing niche - Develop second generation - Balance bureaucratic vs innovative tasks
People	Generalists Technologists Non-professionals Consultants, part timers	> ------------------ > ------------------ > ------------------ > ------------------	> ------------------ > ------------------ > ------------------ > ------------------	Specialists Bureaucrats Professionals Career employees
Structure	- Informal - Market reliant - Group centered	- Formalized - Centralized - Functional	- Formalized - Decentralized planning and budgeting	- Formalized - Decentralized - Profit centered
Rewards	- Equity for few - Ground floor opportunity - Non-bureaucratic setting	> ----------------- > ----------------- > -----------------	> ----------------- > ----------------- > -----------------	- Compensations - Career development - Stable, secure
Planning process	- Informal - Centralized - Short range, single time horizon - Integrated	> ---------------- > ---------------- > ---------------- > ----------------	> ---------------- > ---------------- > ---------------- > -----------------	- Formal - Decentralized - Specialized - Multiple - Integrated

According to Scott and Bruce small companies are not following necessarily the development paths suggested by the models. In fact there may appear the characteristics of two or more stages simultaneously.

The Technology-Based Models

A survey of existing company development models indicates that a few of them have paid any attention to technology-based companies. Kazanjian (84) has proposed that a new technology-based company has an additional introduction stage.[1] The characteristics of this Pre-start stage differ from the early stages of four or five stage models presented before. The differences derive from the fact that the Pre-start company does not normally have a defined product to offer in the market. Kazanjian has proposed to have more comprehensive and integrated view on the organization rather than focusing only on in a single driving factor like size, leadership or structure. Kazanjian (84) (according to Myllyniemi et al 90, pp. 30-33) has proposed a model that distinguishes four stages of growth and consists of a number of dimensions.

As this study handles engineering companies, it is obvious that the companies to be studied have a technological dimension. Therefore there is a reason to consider this Kazanjian model, too.

Kazanjian formulated his model after a careful review of the existing life cycle models amounting to about 20 pieces. He also made an empirical study to modify his model. He noted that the stage models provide primarily a description of structure. Only a few focus to any extent on non-structural characteristics of the company at different stages. The models are typically inflexible. All the companies are assumed to proceed through all stages in series.

3.3 Areas for concerns in company development

The life cycle models easily give the picture that the development of a company is a very mechanical and even a deterministic path for a firm. Only the decisions and the ambitions of the entrepreneurs may influence on the paths of the development. The diversity of the types of companies, the entrepreneurs, the products and the markets is lost in this view.

Patterns of company growth

It is worth while to take up a simple empirical categorization of the small companies. In theory small companies being established can be divided

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[1] In Finland a proper review was recently made on these models by Myllyniemi et al (90). This study was related to new technology-based companies.

into several categories based on their assumed future growth possibilities. If a consideration is made which companies could be of potential interest to a potential professional manager, the great majority of the companies started each year would not arouse any interest in them. According to Lilles (74), in Myllyniemi et al (90), the share of these non-interesting marginal companies would amount to three quarters. When considering the type of companies which could provide potential career alternatives Lilles characterizes a group of companies of ten per cent as "high potential companies". These companies are stated with an ambition of rapid growth in sales and profits, and with an expectation that it will become a large corporation.

The third type of companies with less striking by character than the high potential company, can also be of interest to many potential entrepreneurs. Lilles calls this type of companies "attractive companies", amounting up to 15 per cent of all the started companies. Unlike the potential companies the attractive company has not been started with an expectation of becoming a large corporation. The attractive company can provide comfortable salaries, desirable prerequisites and flexibility in life style, unlike the marginal companies.

The slowly growing companies have an important role in the growth of technology-based, rapidly growing companies. According to Autio et al (89) the slowly growing companies can help the rapidly growing companies to grow even faster. In the empirical data Autio et al (89) show that the rapidly growing technology-based companies can absorb competent employers from the slowly growing companies.

The reasons for company growth and change

In the presented models, growth and profitability are the often agreed main overall objectives of a company. In the real life as well as in the literature the growth motive has been questioned, see later Davidson (87). Growth is an effect, not a cause, of the success of the company. The growth may be realized, if the product has demand in the market and if the company has internally ability and willingness to grow. The company may grow in such a way as to increase its turnover, unit sales, net worth, profit, and personnel, all or part of them at the same time.

Evans (87a, 87b) has studied the dynamic development of companies. According to his findings the company age is a major factor of company dynamics. The probability of failure, company growth, and variations in company growth were found to decrease as the companies become older. The second finding was that the growth of companies gradually slows down.

The growth and success of new technology-based companies depend on a large group of factors. Funkhouser et al (85) have pointed out that the driving forces for growth can be divided to two groups: 1) exogenous circumstances and 2) endogenous person related factors in the context of the company. The exogenous factors are many like discovery of the market, growth of the existing market, increase of the purchasing power of the market, product innovations, process innovations, improvements in administrative and marketing efficiencies and marketing innovations enabling the company a better service to the customers.

Many factors influence on the growth of small companies. Some factors are external to the company, e.g. product market, labour market, financial market, legislation, taxes. Some factors are internal to the company and to the entrepreneur. According to Davidson (87) all the determinants on Table 3.4 may affect either to the ability to grow or to the willingness to grow or both.

Table 3.4 Factors potentially affecting small company growth according to Davidson (87).

Factors related to Factors affecting	The individual	The Company	The Environment
Ability to grow	- Competence of managers	- Internal financing - Internal human resources - Internal material resources	- Product market conditions - External financing - External human resources - Taxes
Willingness to grow	- Goals and needs of managers - Attitudes and beliefs of managers - Other psychological characteristics of managers	- Goals, needs, and attitudes of business partners and employees	- Taxes - Legislation - Persuasion - Other environmental influences

The growth and the evolution of the company require change. Proceeding from stage to stage becomes a challenge for the company and its entrepreneur when the company grows. According to Churchill and Lewis (83, p. 42) in the early development stages the most critical determinants are the owner´s ability to do diverse things, the control of cash and the chances of the company to attain resources. In the later stages the quality and diversity of the people, the systems of control, the ability of the owner to manage through a delegation are growing in importance. The management of cash and liquidity are important in the beginning and critically decisive in the Success-Growth and Take-off stages. The matching of the business and personal goals of the owner are important as long as the owner has a key role in the company.

Intermediate summary: the theory of a growth of a firm

The examination of the theory of a growing company has led us to the life cycle models of the company. The variation of the models has not considerably increased our understanding of the engineering companies and the engineering industry.

What is known from the literature about the engineering companies and their development stages ?

1. A reasonable model for an entrepreneurial engineering company, if the company is successful in its development.

2. A theoretical model for the start-up, growth, and development through various stages of an entrepreneurial company.

3. The literature acknowledges the existence of companies without any growth motive. Either they have not ability or willingness to grow or they deal with in the industries where the growth is difficult.

Which topics does the so far presented literature say little or nothing about?

1. Little is known about the destination of the unsuccessful companies or the companies with less striking development and growth.

2. The theories of a growth of a company do not disclose the influence of technologies on the development of the company or the industry.

3. The industry specific factors in the engineering industry are not treated in the presented models.

4. The influence of the competition and other characteristics of the industry on the individual companies are not determinants in the presented literature, as well as the influence of the customer industries is unknown.

5. No idea of the industry specific characteristics as expected in the companies belonging to the engineering industry comes up.

This chapter has referred to the literature. However, there is a reason to remind that there are many views and facts that are known through everyday life and still not reviewed in the literature. In the next chapter the theory of an industry will be reviewed. It will enlighten some of the issues relevant to the research of the engineering companies.

4. EVOLUTION OF AN INDUSTRY

As the theories of a firm appeared insufficient to explain the evolution of engineering companies, an effort is made in this chapter 4. to study models of industrial evolution, and to draw conclusions from them to the level of engineering companies and industries. The basic thoughts of evolutionary economics are first presented in chapter 4.1, to serve as guidelines for further discussion on the level of industry. The focus of industrial dynamics is on the companies and the technology evolution. Chapter 4.2 depicts the cycle models of industrial evolution. The technology change is presented as a major determinant of evolution of industrial structures. Chapter 4.3 underlines the industry-specific and partly even company-specific nature of technology. In chapter 4.4 the conclusions of the theory are made for the purposes of this study.

4.1 Determinants behind industrial evolution

Schools of economics

The main stream economics does not devote enough research or pay attention on the industry or production. Its interest is concentrated on fluctuations of demand and supply, i.e. market. The role of a company is minimized to a production unit in the treatment of neoclassical economic micro theory. The technology is taken as given as an external factor in the treatment.

The alternative school of economics, the evolutionary economics, see e.g. Nelson and Winter (82), Freeman et al (82), Dosi et al (88), takes the technology and changes in the technology into the focus of research. It tries to understand the relationship between the economic development and the technological changes. In evolutionary economics, the key to the economic development and to the industrial evolution is the technology development.

The main features of the approach to the evolution, technology and economy are according to Freeman (88):

a. Technical change is a fundamental force in shaping the patterns of transformation of the economy.

b. There are some mechanisms of dynamic adjustment which are radically different in nature from the allocative mechanisms postulated by the traditional theory.

d. These mechanisms have both to do with technical and institutional change or the lack of it. As to the former, it is both the disequilibrium - and the source of order for the change and "dynamic adjustment process", as the new technologies diffuse through the national and international economies.

e. The sosio-institutional framework always influences and may sometimes facilitate and sometimes retard the process of technical and structural change, coordination and dynamic adjustment. Such acceleration and retardation effects relate not simply to market imperfections, but to the nature of market themselves, and to the behaviour of agents.

Freeman (82) states that these hardly surprising propositions are nominally accepted by the mainstream economists, but the theory and most of the modelling have in practice divorced economics from these crucially important processes of change. The changes in technologies are carried out by technical inventions and put in the market place as innovations.

Taxonomy of innovations

The evolutionary economists suggest and often use the taxonomy of innovation, which distinguishes between (1) Incremental innovation; (2) Radical innovation; (3) New technological systems; and (4) Changes in techno-economic paradigms. This innovation taxonomy remains on the technical levels of changes.

(1) Incremental innovations. These types of innovations occur more or less continuously in any industrial and service activity. The innovations differ in rates in different industries and different countries depending on a combination of demand, socio-cultural factors and technological opportunities. They may sometimes occur, not so much as the result of any research and development activity, but as the outcome of inventions and

improvements suggested by engineers or others directly engaged in the production process, as the result of initiative and proposals of the users. The whole theory of technology diffusion falls into this category.

(2) Radical innovations. These innovations are discontinuous events. In the recent times they are usually the result of a deliberate research and development activity in enterprises and/or in university and government laboratories. As examples of radical innovations could be mentioned a nylon yarn process as it replaced (partly) rayon process and woolen industry, and nuclear power as it (partly) replaced conventional coal and oil-fired thermal power production. The point here is that there was no way to reach a nylon process from rayon process by steps of incremental innovations, nor the nuclear power technology from conventional power processes by incremental improvements.

The key word in the radical innovation is "discontinuity". Innovations bring about structural changes but in terms of their aggregate economic impact they are relatively localized, unless a whole group of radical innovations are linked together in the rise of new industries and services, such as the synthetic materials and semiconductor industry. The radical innovation is seldom to be seen beforehand. Later on it can most probably be measured by a quantum jump in productivity which is made possible by the key factor fulfilling the following conditions:

a. Clearly perceived low - and descending - relative cost,

b. Unlimited supply for all practical purposes,

c. Potential all-pervasiveness and

d. Capacity to reduce the costs of capital, labour and products as well as to change them quantitatively.

(3) Changes of "technology systems". These are far reaching changes in technology, affecting several branches of economy and giving rise to entirely new sectors of industry. They are based on a combination of radical and incremental innovations, and affect several firms together with organizational and managerial innovations, Freeman and Perez (88, p. 46).

(4) Changes in "techno-economic paradigm", ("technological revolutions"). Some changes in techno-economic systems are so far-reaching in their effects that they have a major influence on the behaviour of the entire economy. A change of this kind carries with many groups of combinations of radical and incremental innovations, and may embody a number of new technology systems. The characteristic of the techno-economic paradigm is that its effects emerge in the whole economy. It affects directly or indirectly most branches or sectors of the economy through new products, services, processes. An up-to-date and known example is the information technology of the 1980s and 1990s.

Another dimension to the taxonomy of the concept of innovation was introduced by Perez (86) as she argues that accomplishment of radical innovations also demands social innovations and institutional innovations. Only the accomplishment of these three components may become a driving force for the change. Freeman and Perez (88) write about the same matter, but use the names techno-economic innovation and sosio-institutional innovation. It is evident that the simultaneous presence of these determinants is necessary for large changes, for instance for the emergence of a new technological paradigm. However, we do not understand the causalities between the different components of innovation thoroughly. Dosi (86, p. 63) gives two examples: "The reader may think of the enormous social need of labour saving innovations of the 15th century in Florence[1] or the desperate requirement by the Roman Empire of a modern telecommunications system." The social and institutional preconditions seem to be there but the technological innovations did not appear.

The idea in the taxonomy of industrial innovations is that with the separation of innovations it is possible to divide the proceeding evolution in the industries to periods. The smooth period of incremental innovations in an industry is often described by the growth and maturity phases in the life

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[1] This gives a possibility to deviate to the history of Florence in the 15th century for a while. The City of Florence was living her best period of the Renaissance. The trade, banking and wool industry were developing rapidly. The arts were blooming and reaching the best ever achievements. The social structure of the City was divided, and the internal contradictions were deteriorating the social structure of the City. The technology of the time was inefficient, and required plenty of labour for the wool indusry. Then the City had to accept new labour and social stresses.

cycle curve of an industry[2]. In the phase of stagnation the competition becomes tighter in the market and the sales volumes or at least the market shares start to fall. The radical innovation in an industry causes a point of discontinuity. It may start a new life cycle for the development of the industry. This may reflect as a new life cycle, as a new growth, or as a S-type curve in the sales or market shares, Foster (86). The growth path presented on a logarithmic scale may give a direct line which has been called a learning curve and proposed to be a managerial tool. In addition forecasting of the technological discontinuities has been propagated as a management tool.

Current theories concerning the nature of technological change

The objective of this research is to study the alternative paths of company development in engineering industry. The need to construct a theoretically based framework for the engineering companies has led us to determine the factors of technological change and innovation. The deviation to theories of innovation is due to technology affecting strongly the evolution of industries.

Conventional theories of technical change have generally been classified into two broad categories, namely "demand-pull" and "technology-push" theories. The distinction is self-explanatory, and is related to the degree of autonomy of the innovative efforts from the short term changes in the economic environment. A critical review of this discussion is given by Dosi (82). His conclusion (and also e.g. Dosi´s (84), Nelson and Winter`s (82), Freeman et al´s (82) conclusion) is that both theories are insuffiencient to discover the nature of innovation.

Some space to the critique of demand-pull and technology-push theories is given, because it serves us a deeper understanding than before, for the discussion on the technological opportunities through technological systems and trajectories. The demand-pull theory would claim in general that the needs of the users (the consumers) are reflected to the producers´s activity to develop new kinds of products through market mechanism. The

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2 The reader should notice that the life cycle models in Chapter 1 are relating to one company. Here the question concerns industries. The concept has been adapted to the analysis of industries due to the easy adaptation.

theory has three basic weaknesses on different levels: 1. The concept of passive mechanical reactiveness of technological changes vis-a-vis market conditions; 2. The incapability in defining the why and when of certain technological developments instead of the others; 3. The neglect of changes over time in the inventive capacity which does not have any direct relationship with changing market conditions.

It is also to be remembered in the critique of demand-pull approach that the theory of innovations has to be able to explain both incremental and radical changes in the technology. Logically it is quite difficult to see how the price mechanism could anticipate beforehand the breakthroughs of technology.

As regards to the factors of technology-push theory, the role of science and technology has increased all of this century, and therefore empirical work has been done to prove the effects of the effort. Some aspects of the supply-side factors are fairly well established. 1. The role of the inputs of science and technology for the innovative processes has risen during this century. 2. The increased inputs and sophistication of the research and development have become a long term effort which is planned and managed as a result oriented work. This witnesses against a hypothesis of prompt innovative answer by producers on the changes in market conditions. 3. A clear correlation between research and development efforts and innovative output has been established in several industrial sectors, as well the absence of evident correlations between market and demand patterns on the one hand, and innovative output, on the other. 4. The intrinsically uncertain nature of the innovative activity is an established fact.

In the theory of technology-push it has been difficult to combine the complexity of the innovation process with the relative autonomy and the uncertainty of the technical change and innovation. The problems have arisen from the obvious fact that the economic factors from the market have to be taken into account. Dosi (82) draws a conclusion that the theory of innovation should be a complex structure of feed-backs between the economic environment and the directions of technological changes. A tentative theory of technical change should define the nature of these interactive mechanisms. The demand-pull and technology-push theories appear to fail to do this. One-directional theories of innovative process, and particularly those assuming "the market" as the prime mover, are inadequate to explain the emergence of new technological systems.

The concept of technology was earlier understood as a very versatile and responsive system which could be directed with limited effort and cost to one direction or another. For the old school of technology studies "freely available" technology represents a given set of combination of factors, which are defined in relation to certain outputs. For the current school, technology is a set of pieces of practical and theoretical knowledge, know how, methods, procedures, experience of success and failures, and physical devices and equipment. Existing physical devices embody the achievements in the development of a technology in a defined problem-solving activity. A technology still includes a disembodied part of knowledge and experience on the achievements of "the state of art", Dosi (82).

In the latest research of technology studies, the technology is given a more specific nature. A summary of the technology features in the book of Dosi et al (88) would be

1. Technology has sector-specific degrees of appropriability and levels of opportunity of technological change.
2. Technical knowledge has a feature of partial tacitness.
3. There is a large variety in the knowledge-base and search procedures for innovation.
4. Technological innovation is intrinsically uncertain.
5. Technological advances are irreversible, i.e unequivocal dominance of new processes and products over old ones, irrespective of relative prices.
6. Endogenous nature of market structures is associated with dynamics of innovation.
7. Permanent existence of assymmetrics and variety between firms and countries in the innovative capabilities, input efficiencies, product technologies and behavioural and strategic rules.

Consistently with the previous statement Pavitt (90) presents four key characteristics of innovation activities as follows: 1. Innovative activities involve functionally and professionally specialized groups: R&D, marketing, finance and strategy; 2. Innovation remains profoundly uncertain; 3. Technological activities are cumulative, each achievement is based on the previous activity; 4. Technological knowledge is differentiated and specific to a company. Pavitt emphasizes the need of organizational and institutional continuity in innovative activities despite of technological discontinuity.

Paradigms and trajectories

In these circumstances companies and industries function having a set of technologies available for their disposal at the certain point of time besides carrying out their research and development programmes. They are in a continuous learning process in applying the technologies. Every time the technologies develop along the relatively ordered paths shaped by the technical properties, problem solving approach and the cumulative expertise embodied in the technological paradigms. Each paradigm consists of a definition of the relevant problems that must be tackled, the tasks to be fulfilled, the pattern of inquiry, the material technology to be used, and the types of artifacts to be improved and developed.

A technological trajectory is the activity of technological progress along which the economic and technological trade-offs are defined by the paradigm, Nelson and Winter (82), Dosi (84), Dosi (88), Sahal (85), Soete (86). The trajectory is within a paradigm and relates to specific field of technology and/or industry, whereas the paradigm is like a vision dominating many sectors and industries. When writing about the ordered paths within paradigms and the trade-offs within trajectories it is reason to point out the presence of uncertainty in all the innovation activities. Even though some technological paths can be foreseen on an industry level, the innovation remains very unpredictable and non-deterministic by nature on the level of technological projects and individual companies.

In the economy there are different types of industries in respect to the roles these industrial branches take at each period of time concerning the technology change or innovation, Perez (86, p. 34). They influence on the shape and rhythm of the economic growth in the economy in the period. The industries as such do not act, but the companies within the industries are the actors and the agents of the technological change.

a. Carrier branches. These industries make intensive use of the key factor, are best adapted to the ideal organization of the production, induce a great variety of investment opportunities and generate the economic growth.

b. Motive branches. These industries are producers of the key factors or other inputs directly associated with them. Thus the motive industries create the conditions for the development of the prevailing technological system. The growth of the motive industries depends on the rhythm of diffusion of the technological system across the industries.

c. Induced branches. These are often a consequence of and complementary to the growth of the carrier industries. These industries may reach their full flourishing and multiply in bandwagon fashion once the necessary social and institutional changes have opened the way for the upswing and generalization of the new technological system.

Conclusions from evolutionary theory of economics for industrial dynamics

The deviation to the evolutionary theory of economics and technology theorizing from the mainstream economics can be defended by the fact that the evolutionary theory as such is based on the reconsideration of the exploitation of the technology and the technology change in companies and industries. Secondly the argument for the deviation is that obviously the technology is a driving factor in the evolution of the industries besides the economic factors. The economic change is often a reflection of technological, political or some other change. Thirdly the argument is that the engineering companies are change agents within the industries. The point of view of engineering is shortly stated as investments, technological development and change which overlap the interests of evolutionary dynamics.

The starting points in the evolutionary dynamics are the following:

(1) The development should not be analysed as a growth but as a change process, where the new products and even technology are replacing the old products and technologies.

(2) The new products developed through radical innovations are essential for starting new industries as well as the improvements of old products through incremental changes or improvements of productivity.

(3) The technological change is not even but varying in the course of time. There are seldom periods of rapid and revolutionary change, and there are more often periods of smoother changes.

(4) Most of technological evolution is cumulative by nature, all what comes later on is exploiting the learning from the past. Then the change occurs within the existing industrial trajectory. In the cases where the discontinuities of radical innovations or the new technological system replace partly or totally an existing technology, the technological change may not be cumulative, but discontinuous. They may start a new technological system.

The technological changes are not carried out in a vacuum state as results of engineers and natural scientists, but they are a part of the social and societal change processes. The economy is not made only from investments, plants and money flows. It is also a field of social activity. Therefore the institutions, actors, evolutions are important in addition to technology change.

At least three kinds of institutional determinants are important according to Lovio (89).

a. The development in the firms requires new ways of operation on the enterprise level. This may include new style of management, new operational organization, new priorities of the matters or new strategies.

b. The changes in products and technologies require new strategies, i.e. perhaps new alliances, new network relationships, new markets, new customers, new competition. The capability to exploit changes rapidly requires the companies to establish good network relationships with the other companies.

c. The environment for the technological change is also vital. The projects have to be financed, the education and specific training have to be able to follow the requirements of the time and the governmental actions have to occur at the right place and time. The evolutionary dynamics should include these aspects of institutional development, too.

The last but not least requirement for the framework of the industry analysis is that it should not be in a contradiction with the idea of the endogenous growth, but in accordance with the evolutionary theory of economics. This endogenous growth means that a growth path is not given for the industry or the economy, but it is an effect which is dependent on the activities within the companies and the speed of change.

4.2 Frameworks for the analysis of an industrial branch

The Albernathy and Utterback model

The life cycle model has been applied to the development of industries with a success for a while, Utterback and Albernathy (75). As a life cycle seemed to be a relevant model for a few companies it is not surprising that many industries also seemed to follow this model. The Albernathy and Utterback model suggests that a major product innovation inaugurates the cycle. The output rate is stimulated by minor innovations in technology before major process innovation emerges. The scholars divided the development of innovation to three stages and named them the fluid, transitional and specific patterns. In the infancy of an industry (i.e. in the fluid pattern) the companies are small, informal, flexible and entrepreneurial. The product diversity arises from the fundamental differences in technology. The competitive advantage is obtained by a technical superiority.

According to Albernathy and Utterback (78) akin to Uusitalo (95) process and incremental innovations may have equal and even greater commercial impact than radical innovations. The design usually creates a number of proven concepts and is seldom in advance of a state of art. The emergence of specific design alters the pattern of technological change. The key technological development after the specific design is a cost reduction due to a learning.

The Albernathy and Utterback model which recognizes the cumulative nature of the technological development originally viewed the technological progress as a single cycle leading to more process and less product innovation and culminating in the productivity dilemma. More recent updates of this model in the early 1980s conclude that the technological change is cyclical - dematurity can in effect set the clock back and return an industry from a specific to a fluid stage, Albernathy and Clark (85).

The Foster model

However, it became more and more evident that in many cases the life cycle model was not sufficient to explain the observed reality in many industrial developments. Foster´s (86) depiction of technological progress through a series of S-curves suggests that the technological change still follows the cyclical pattern. In a way Foster´s model digests the life cycle and develops it further. According to Foster (86, p. 102) the S-curves almost always appear in pairs. The gap between the pair of S-curves represents a technological discontinuity - a point where one technology replaces another. Foster could show examples which followed the pattern of his model, e.g. in man made yarns industry and in micro chips production.

The rationale behind Foster´s thinking was that in the beginning of the S-curve the companies are careful in their development of new processes and products, and the development is slow. The development speeds up in the course of time due to the accumulated learning and gathered knowledge. Finally the technical development becomes more difficult even with greater input to the research and development work. The S-curve sets the limit to the particular technology.

The new S-curve is started by the effort of companies to find alternative technologies for the development as the old S-curve matures.

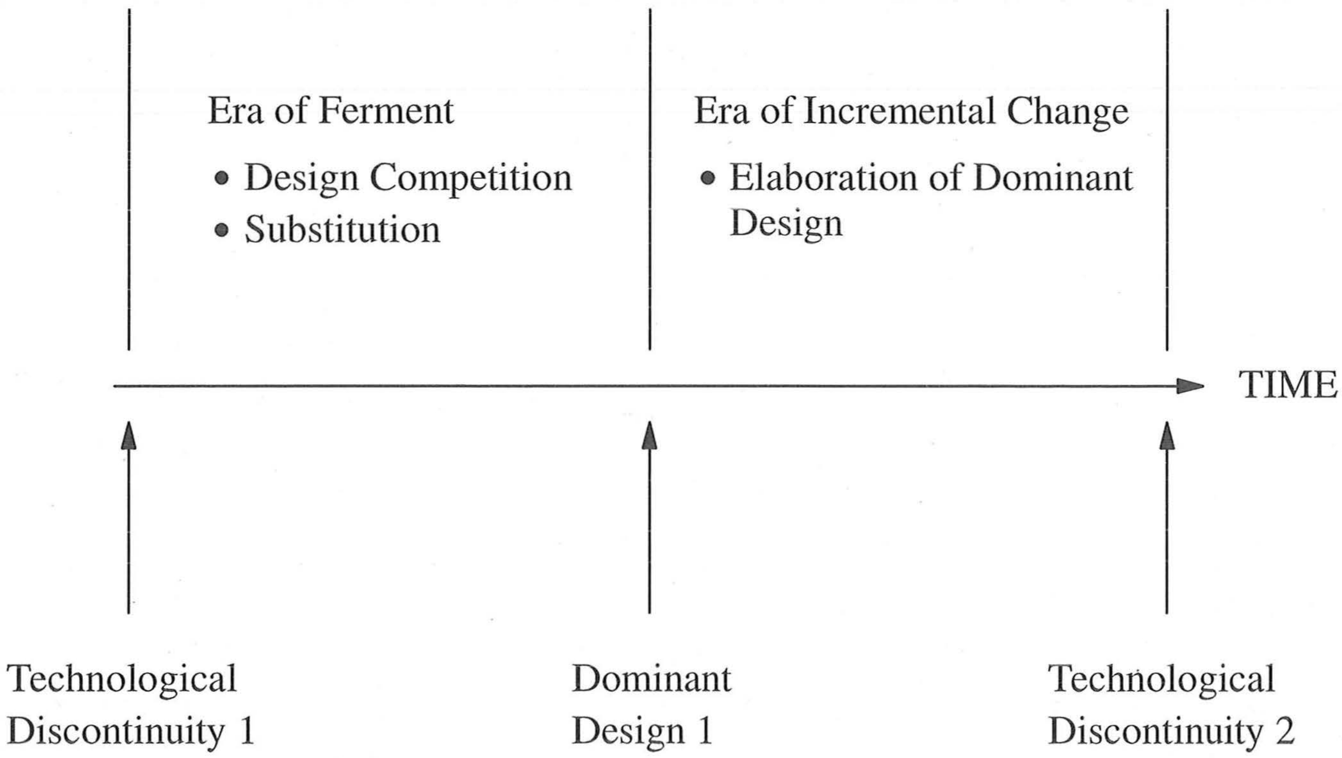
The Tushman and Anderson model of cyclical technology change

The idea of technological discontinuities and cyclical development within industries was first put forward by Tushman and Anderson (86). Anderson (88) published his dissertation with a wide longitudinal empirical data from three industrial branches consisting of cement (1888-1980), glass (1893-1980) and minicomputer (1958-1982) industries. Anderson and Tushman (90) rewrote the results emphasizing now the technological discontinuities and dominant design. They also specify “A model of Technological Change”. This model concerns industries.

Technological discontinuities

Anderson and Tushman (90) argue that “a breakthrough innovation inaugurates an era of ferment in which a competition among variations of original breakthrough culminates in the selection of a single dominant configuration of the new technology. The successful variation is preserved by the incremental evolution of this standard, until a new discontinuous

Figure 4.1 The components of the model of cyclical technology change by Tushman and Anderson (86). Notice the concepts Technological discontinuity, Dominant design, Era of ferment, and Era of incremental change, and their location in time.



Source: Tushman and Anderson (90, p. 606)

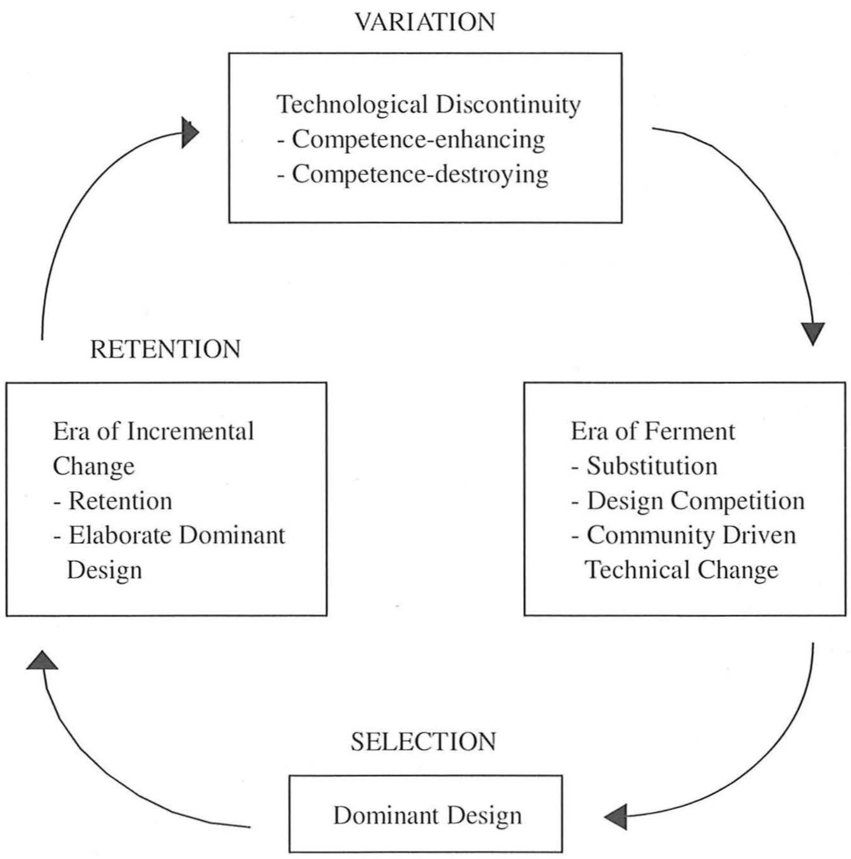
advance initiates a new cycle of variation, selection, and retention." Figure 4.1 illustrates the parts of the technology cycle. The key concepts are technological discontinuities and dominant designs. These limit the eras of ferment and eras of incremental change.

The model assumes that the technological cycles can continue forever. The breakthrough initiates an era of ferment. A competition between the companies leads to a convergence and to a substitution of technology by a new one.

The major technological shifts are classified to two groups: competence-destroying and competence-enhancing, because they either destroy or enhance the competence of the firms in an industry. A competence-destroying product discontinuity either creates a new product class or substitutes for an existing product. A competence-destroying process innovation represents a new way of making a given product. A competence-destroying process of discontinuity may involve combining previously discrete steps into a more continuous flow or may involve a completely different process. Competence-destroying discontinuities are fundamentally different from previously dominant technologies so that the skills and knowledge-base required to operate the core technology change.

Competence-enhancing discontinuities are order-of-magnitude improvements in price/performance relationship or in productivity of production processes that build existing know how within a product class. Such innovations substitute for older technologies. However, they do not render obsolete skills required to master the old technologies.

Figure 4.2 Technological stages in the cycle form.



Source: Tushman and Rosenkopf (92, p. 317)

The cycle of Tushman and Anderson

The technology cycle consists of the following stages:

- the discontinuity which is starting the variation of technologies
- the era of ferment which is composed of two parts, the first part is an era of substitution and the second an era of design competition

- the dominant design is gradually emerging through design competition and market selection
- during the dominant design the technological development continues through incremental changes until the next technological discontinuity takes place.

It a reason to remind the reader when considering Figure 4.2 and reading the text that the points of time of discontinuity and emergence of a dominant design are or can be fairly short. But an era of ferment and an era of incremental change are long lasting.

Era of ferment

The introduction of a radical advance increases variation in a product class. A revolutionary innovation is a great chance and a challenge for the organizations in the field. They are pushed by the innovation to absorb or to destroy the innovative technology. The era of ferment is characterized by two types of selection processes: a competition between the different technological systems and a competition within the new technological system. The period of substantial product class variation ends with the emergence of a dominant design.

Older technologies seldom disappear quietly. The competition between old and new technologies is often fierce according to Foster (86). New technologies may have a drawback, if they are introduced too early and unproven in the market or if they are based on the competence that is inconsistent with the established technological system. The response of the existing industry is to increase the innovation and efficiency of the current technological system.

While the discontinuous technological advance does not always become dominating (e.g. a bubble memory and a wankel motor), the empirical research of technological substitution has shown that substitution follows a classic logistic curve. The technological substitution does not immediately follow the appearance of a radical innovation. It is often necessary to prove the feasibility of the technology and the particular design before having any chance to obtain the position of the dominant design. In certain industries and fields of heavy investments this may require tens of years. The emergence of new technological systems to a dominant design may also be delayed due to the lack of economic, institutional and social preconditions, even though the technical feasibility is fully proven a long time ago. The substitution process of the technology may also be fast after the superiority of the new technology is established.

The first innovator company is seldom the final winner in the market. The winner is a good follower, it is often among the first five companies to adapt the new technology system. The technology finally adapted to a dominant design is seldom technically the best or represents the frontier technology, but it lagged behind the state-of-the-art when they appeared. An industry typically pushes the state-of-the-art forward during the era of ferment, and then standardizes a design that is behind the leading edge of the technology, Anderson and Tushman (91).

The variation and selection pressures are substantial characteristics during the era of ferment due to both substitution and design competition.

The length of the era of ferment is dependent on the type of discontinuity. When a technology builds on a completely new knowledge-base, many competing designs appear, and it will take more time the market forces to sort out the dominant technology design variants than in the case of a competence-enhancing technological innovation. The firms confronted with the choice of abandoning the existing technology and knowledge-base in the face of competence-destroying technical change will defend older technology tightly and thus prolong the stage of uncertainty about the future dominant technology.

In the case where a breakthrough innovation is built on existing know how the era of ferment may be short. The effect on technology is cumulative in this case. A series of major advances may all enhance an established body of know how. Successive innovations are then increasingly well understood and fitted into the institutions. The competence-destroying innovations only interrupt the accumulation of the competence building mode.

Dominant design

A dominant design is the second landmark event in the cycle of technology development, marking the end of the era of ferment. A dominant design is a single architecture that establishes a dominance in a product class, Uusitalo (95), Sahal (85). The future technological progress consists of incremental improvements within the dominant design and the technological system becomes more orderly as one design becomes a standard expression.

Many scholars have incorporated the dominant design into the models of technological evolution. For example the original ideas of Albernathy and Utterback (78) were related to a single dominant design and evolution within this. They emphasized the transition of an industry from a fluid to a specific stage. Henderson and Clark (90) supported these ideas.

The dominant design remains standard until the next technological discontinuity. It is unclear beforehand and even simultaneously which innovations are to prove radical causing discontinuity and ending the dominant design. While only known in retrospect dominant designs reduce variation and uncertainty in the product class. The dominant design permits the component producers to standardize the designs, to design interchangeable components and thus to reduce costs. This allows more stable and reliable relationships between suppliers, vendors and users. From the customer´s point of view the dominant design will reduce the product class confusion and promise a dramatic decrease in product costs due to a learning curve.

Once a design becomes an industrial standard, it is difficult to be replaced. The firms cut their costs by applying the experience gathered by cumulative learning. As more users gain experience with a product the supplier gains a better understanding of maintenance and reliability requirements. Learning by doing starts only after an emergence of a dominant design, since before that no design achieves much cumulative production volume.

When the competition process is artificially hindered, dominant designs may not appear. Such cases may arise under regimes of a high appropriation. In these cases firms may be able to build a patent cover or other product cover for their technology and control its diffusion via strategic licencing decisions, Teece (86, p. 285). In these cases the owners of the product rights are able to attain most of the innovation returns. In other cases the rivals may gain at least some part of returns via imitation.

The emergence of a standard is a precondition to mass adoption and volume production of a new generation of technology. Dominant designs are not simply an artifact of the way in which the innovation diffuse but they are also related to the acceptance, and maybe changes, of the innovation socially, institutionally and economically. Therefore the emergence of a dominant technology cannot be considered as a function of technological determinism. It does not appear, because it is a single and one of the best ways to implement the product process. Rival designs may sometimes be superior in one or more performance dimensions.

A single technological design seldom dominates on all important dimensions of merit. Social and political processes give a chance for multiple technological possibilities. If the emergence of a dominant design is an outcome of the institutional or political process and as such a compromise between various factors, the standards are not simply known beforehand. The concept of the dominant design brings the technological evolution into the social and organizational realm. The activities of individuals, companies, networks of organizations shape the dominant designs.

The dominant design has been referred by the name a technology system, and in the wider context also by a techno-economic paradigm. Dosi (82) has used the name technological trajectory following Nelson & Winter´s (82) idea that the technologies evolve according to natural trajectories, arguing that these trajectories are shaped by technological paradigms. The term technological system is used following Freeman and Perez (88), and the term paradigm is reserved to even wider technological and economic changes, and then the term techno-economic paradigm is used. Normal technological activity consists of progress along a trajectory defined by a technological system equivalent to a dominant design; extraordinary innovations overthrow the system and a new techno-economic paradigm starts.

Era of incremental change

After a dominant design has emerged technological progress is driven by great number of incremental innovations. Variation occurs now in the form of elaborating the retained dominant design, not challenging the industrial standard with new rival alternative designs. The focus of competition shifts from higher performance to lower cost and to differentiation via minor design variations and strategic alterations. Social structures are now in the state that they reinforce this stable stage. Organization structures, which are partly dependent on the dominant design of technology, and institutional structures supporting the norms are both factors to stabilize the technological regime.

A great number of empirical studies has been made on the incremental improvements. At a time this learning became a continuously repeated mode in the management training. But even lately some scholars have criticized the attitude that the great leaps of technology are sought instead of continuous series of small, step-by-step advances, Gomory (89).

Such an overall empirical study, where the relative importance of the changes of radical innovations and continuous incremental innovations would have been compared, has not been made. Empirical work has proceeded in small pieces, which makes it difficult to summarize the relative importance of innovation types.

The cumulative and irregular cycle model

Lovio´s (93) main interest in the electronics industry of Finland is the evolution of the firm community in the course of time. The evolution pattern of the community with entries and exits is important for Lovio. He wants to formulate his model so that the accumulation of technology and the cyclical nature of technological change are both explicitly presented in the model.

The drawback of the Tushman and Anderson model is that it looks like accumulating forever the technological know how, even though the explanation uses plenty of space for a competence-destroying discontinuities. Lovio constructs a model which he names the cumulative and irregularly cyclical model, and includes a competence enhancing and destroying phenomena. The technological life cycle in the Lovio model consists, instead of one regular life cycle, of a life cycle comprising several irregular cycles. His main interest in the structural evolution of the firm community is described by the fission/fusion model, Lovio (93, p. 242), presenting typical development paths of new firms.

Popularity and criticism of cyclical technology models

The cyclical model has got wide popularity among scholars of industrial dynamics. A long list of quotations for its use is given in Van de Ven et al (94) article. In our view, the main reason for the popularity may lie on the fact that there are not many models available which would allow and take variations and alternative possibilities into account which certainly characterize the reality seen in the industrial developments.

Tushman and Anderson (86) was republished as a chapter in Pettigrew´s (88) book. Pavitt (88) criticizes the approach in the same book. According to Pavitt

1. Accumulated incremental change over a long period can be difficult to distinguish from radical change, since an incremental change can lead to a new product, even for new market, designed and made with different mix of new skills. As an example Pavitt uses the development of cassette-video recorders, which was a result of a long incremental improvements and still a major innovation.
2. Major technological innovations often grow out of experience in the use of earlier vintages in technology and cumulatively build on them.
3. Very often the exploitation of major innovations critically depends on subsequent incremental improvements, if the exploitation has to be competitive with the existing vintages. The commonly held assumption (shared by Tushman and Anderson according to Pavitt) is that the new vintages of technology immediately reach economically superior performance is rarely borne out of practice.
4. Even when major innovations do comprise some radically new technology, they seldom displace all the skills and knowledge related to earlier vintages of technology.

The negligence of patent protection by Tushman and Anderson (86) has been criticized by many scholars. Pavitt (88) proposes that the degrees of the appropriability by innovators should be included in the models. Uusitalo (95) finds many shortages in the treatment of the patent protection in the studies of Anderson and Tushman. The importance of patent protection is evident for the engineering industry as well other technically oriented industrial branches.

Pavitt (88) draws five conclusions:

1. The first adopters of major innovation do not grow fastest, since the economic exploitation often depends on subsequent improvement in the technology, where followers rather than the leader may perform better.

2. According to Pavitt we should expect relatively few competence-destroying innovations, given the mutually dependent links between major and incremental innovations and the complementary links between old and new technologies.
3. The organizations with strong and varied in-house technological capabilities are less likely than the others to be surprised or defeated by unforeseen or unmastered major innovations developed elsewhere.
4. Tushman and Anderson model can be made, in Pavitt´s view, more robust by dropping the distinction between competence-destroying and competence-enhancing innovations, and concentrating on the positive links between major innovations, munificence, and uncertainty.
5. In Pavitt´s mind, a satisfactory theory to describe the essential characteristics of entrepreneurial function - or the capacity to deal with both incremental and continuous change - within the firms does not yet exist. Especially the existing models lack the ability to explain the capability of large and established firms to undertake both major and incremental innovations, and even establish new divisions and products based on them, over very long periods.

DeBresson and Lampel (85) have also criticized the life cycle models. According to them different production modes do not follow each other as suggested by the life cycle models. Instead a coexistence of different types of competitions and production modes is most common. Even the life cycle model will logically show parallel operation stages in empirical cross section figures from an industry, because all the companies in an industry did not start at the same time, nor do their life cycles follow the same pattern.

Dominant types of companies at the different stages of industry evolution

Many scholars of innovation and technology have taken the view that different types of companies have different roles in innovation activities. The opportunities of different kinds of companies for successful actions in innovation are varied and dependent on the stage of development of the particular industry, because they have different advantages and disadvantages. A conventional view concerning small and medium sized, and large companies is that small and medium sized companies have an important role in the starting phase of an industry due to their dynamic, flexible and innovative management, and good internal communication. The old and large companies have their strengths in innovation in the mature market due to wider resources in research an development, better external communication and more systematic approach in R&D management, Rothwell and Zegweld (82), and Rothwell (86).

This is the type of conventional wisdom that has been questioned. The following questions have been asked: 1) What exactly are the roles of new small companies and large companies in the emerging period of new industries and in later eras of technological discontinuities, and 2) which kind of firms are the typical winners in the mature industries, Lovio (93, p. 38).

The electronics industry has been particularly the object of empirical research owing to the rapid growth and seemingly fast changes. Pavitt (86, p. 51) considers the industry cycle model, where the fast-moving technologies emerge through small companies and product innovation, and where the companies gradually stabilize technologically into large firms concentrating on process innovation, inadequate. He emphasizes in a strong way the role of large companies in the very emerging phase of an industry. The argumentation of Pavitt arises from the nature of innovation activity which according to him is realistically possible only in a large company most frequently for most radical innovations. The arguments of Pavitt (91, p. 41) are:

1. Technology development and innovation have a specific, differentiated and cumulative nature. The range of choices about both product and process technologies that are open to a company depend on its accumulated competence.
2. Large companies have a capability to attain and maintain a functional and professional specialization needed for management and implementation of technological choices. Large companies have an opportunity to combine and organize know how across disciplinary, functional and divisional boundaries for the technological development activity.
3. Due to the cumulative nature of development and the uncertainty, always present in the innovation activity, only large companies can have resources for maintaining the improvement in the competences, and in continuous and collective learning.

4. Technical function in large companies does not merely consist of the implementation of innovations, but also the definition of appropriate divisional objectives and boundaries, the exploration of radical innovations and the formation of technological objectives for the future. These activities are behind the allocation of resources in the company decision making.

Pavitt does not deny the importance of small and medium sized companies, but he emphasizes that they have not resources, material, technological and institutional, to carry out the type of activity required for modern radical innovations that are behind the evolutional development of industries.

Complementary roles of different firm types

An obvious reality is that the variations in the market and products are so wide in each industry that different kinds of firms have their place in an industrial evolution. Different types of companies being at different stages of development complement each other. As Dosi (88, pp. 234-235) states one of the main results coming up from the innovation studies is the permanent existence of asymmetries and variety between firms in their innovative capabilities, input efficiencies, product technologies, and behavioural and strategic rules. He even considers that the asymmetries are a major factor to change the market structure and market shares of individual firms.

There has been discussion about the types of innovation which different types of companies are producing. The hypothesis has been that in an emerging industry the innovations mainly concern product innovations, but in the later phases of an evolving industry the innovations mainly become process innovations. Rothwell´s (86) data from the U.S. would support this assumption. Rothwell emphasizes strongly "the complementary elements in the behaviour of large and small companies. Established technology based large corporations can be extremely effective in creating new technological possibilities; they are highly inventive. While they are adept at utilizing the results of their inventiveness in-house (new technology for existing applications), they are less well adepted at the rapid exploitation of their inventions in new markets (new technology for new applications). It appears that new firms, initially, are better adepted to exploit new techno/market combination; they are unconstrained by existing techno/market regimes within which established corporations might be rather strongly bound."

Rothwell (86) concludes his report on the U.S. CAD and semiconductor industry "a system of dynamic complementarity between the large and the small: both had their unique contribution to make; both were necessary to the initiation of the new techno/market combinations and their rapid commercial exploitation."

Intermediate summary of company life cycles and industry cycles

As a logical consequence from the life cycle models of individual companies and from the dynamic evolution models of industries a few separate points can be drawn:

- as there continuously are companies which exit the industry, some of the production factors come to the use of the remaining companies
- as some companies are winning in the emergence of a dominant designs, they are taking free factors of production from the market during their growth
- continuous exits and entries keep the industrial evolution proceeding, some concentration is often occurring in the number of companies reflecting in size of individual companies when the industry matures owing to either large technological efforts or cumulative learning and cost reductions
- always in the cross sectional analysis there are companies at different phases in their individual development paths.

Some answers have been found to be the questions to be put forward at the end of chapter 3. In the light of the cumulative and irregular cycle theory of an industry evolution it is known that most of the new companies which start from the beginning never reach the stage of maturity. At each of the crises points, many companies fail to proceed to the next stage of the development. They may remain on the same stage of the development, fall to the previous stage or totally disappear. In the cross sectional analysis, the companies which removed to various stages of development, or remained for a longer period on the previous development stage can be localized and understood in the structure of the evolving industry. The continuous entry and exit pattern in an industrial structure is now understood in principle and the reasons why this should be taken up in an empirical study.

4.3 Taxonomy of companies and industries based on innovation strategies

4.3.1 Influence of company age, size, diversification and market

The technological change has been determined to be a major factor to influence on the evolution of industries. The technology and innovation form the core of the evolution. In the following, some parameters are explored on a general level relating to market structures, firm size and conduct of the companies in the market, which all could shed light on the innovation. A further categorization of companies can lead to a more profound understanding of innovation and industrial development. The mere recognition of relevant differences between categories of companies develops an understanding on the matter.

The traditional discussion centered only on two types of companies, following the tradition of Marx and Schumpeter, in the market, Hagedoorn (89, p. 52) :

- "large dominant corporations, frequently science based
- smaller companies of different sizes which have either found particular market niches or provide supplementary services to the large dominant companies
- new companies and cross entry".

All these have to be seen in the light of two important aspects of industrial development:

- competition changes the relative positions of companies over time within each sector of industry
- in the process of creative destruction, sectors of industry are reorganized and new sectors are created through which the existing market structure and relations are fundamentally changed.

Young Schumpeter was prone to underline the importance of young, small and innovative companies for innovation. But old Schumpeter, as Marx, emphasized the role of large corporations.

According to Hagedoorn (89, p. 92) "both contributions (of those who emphasize the small and the large firms) arrive at a simple dictonomy of large versus small companies which is too simple for analytical purposes. The same holds for the theories in which companies are seen as either small or medium sized, efficient and innovative or large, inefficient and non-innovative." And he continues further: "In between the two extreme positions there are a number of theoretical nuances. Some state the advantages and disadvantages of both small and large companies in general; in doing so they present both sides of the argument. If these (dis)advantages are related to sectoral differences, for example small companies face substantial disadvantages in R&D and capital intensive sectors, then the argument is taken some steps further."

There is a vast literature of empirical innovation studies. The issues, among other things, have been: 1) whether or not the innovation increases proportionally with the firm size, and 2) whether or not the innovations increase with market concentration. This empirical research has been claimed to originate from the ideas of young and old Schumpeter. Cohen and Levin (89, pp. 1060-1098) are very critical on this discussion. Their critique concerns the results of the research noticing them as fragile, and the point that Schumpeter might not sign the hypothesis known by his name. Very little, in general, can be said on the correlation of innovation and company size and innovation and market concentration. The studies and conclusions have to be made by industries and maybe by company categories.

There are individual industry studies, where qualified taxonomies have been used. These studies referred to, serve in the following as a guide to the categorization need in this work.

Rothwell and Zegweld (82, pp. 45-54) conducted a research with a data of the U.K. innovations amounting to 2300 innovations altogether during the period from 1945 to 1980. The same results are referred to in Rothwell (86). Advantages of the small company were found to be

- their marketing skills for selected niches
- dynamic entrepreneurial management
- internal communication within the company.

As the corresponding disadvantages of the small companies the scholars list

- their shortage of competent research and development personnel
- shortcomings in external communications, particularly the failure to use technical and market information
- shortcomings in management skills
- constrained financial resources
- problems related to economics of scale, delivery of turn key projects and complete systems
- inability to cope with all the governmental regulations and benefits
- issues related to growth of the firm.

Rothwell and Zegweld notice - as pointed out also by Hagedoorn - that there is a mirror picture for the advantages and disadvantages of the large companies. From the study of Rothwell and Zegweld a conclusion is drawn that any taxonomy that makes sense in a concretical situation can be employed.

Even though many scholars discuss more widely about the possible innovation strategies of large companies and underline the problems of a small company, small and medium-sized companies may also have an active role in research and development. Freeman (82, pp. 132-134) mentions three categories of these companies for which research and development is essential and inevitable for their survival:

1. Companies which have recently started to develop or exploit a new invention and for which a high research intensity can be expected. The high research intensity may probably fall after successful exploitation of the invention.
2. Highly specialized, research-intensive firms which concentrate on narrow sectors of technology.
3. Companies in an industry in which a new product competition makes R&D effort increasingly vital. Here small companies can survive either by minimum threshold R&D, or rely on a cooperative research, or take high risks with an ambitious programme.

As noticed before all sizes of companies have a role in generating innovation. Their role may differ by size, by role in the market and by technological opportunities. If and when the differences are recognized e.g. by industries in the technological change, the field of study of innovation is opened for deeper and more versatile research. Freeman (82, pp. 170-186) takes a step to this direction recognizing six alternative innovation strategies.

1. The offensive innovation strategy which is aimed at achieving both technological and market leadership. An offensive strategy encompasses internal R&D efforts, information processing abilities and marketing facilities.
2. The defensive strategy does not imply a complete ignorance of innovative activities. It could be followed by companies that are more risk adverse and at some distance from the radical innovations. Such strategies can be expected from companies in mature oligopolistic market structures.
3. The companies with the imitative strategies are lagging at a considerable distance from the leading companies. In a competition with innovative companies, some companies have to rely on specific factors of production, and/or concentrate at a lower quality and price end of the market. For many multi-product companies their innovation strategy may be a mixture of offensive and defensive, and perhaps imitative strategies for various product lines.

The next three innovation strategies form a subgroup in the list of Freeman.

4. The dependent innovation strategy relates to some subcontracting relationship, where all initiatives come from customers.
5. The traditional innovation strategies are followed by the companies for which innovation is not necessary because of specific market conditions.
6. The opportunist innovation strategy reflects a search for particular market niches by imaginative entrepreneurs.

As a conclusion of the innovation strategies of Freeman (82) could be stated that the structure of the industry and technological opportunity leaves open a number of possible strategies for all the companies. The classification of innovation strategies and sizes of companies does not give any predictive statement generally on a company level. It may be even so that the classification is relevant and interesting only for the scholars of innovation. The management of a company does not start asking, whether the company should be a leader or a follower in its innovation strategy, or whether it should have an offensive or defensive approach to innovation. These strategies are largely determined by the firm´s resources and the nature of its accumulated technological competencies, which are jointly constrained by the range of potential technological and market opportunities to be exploitable for the company (Pavitt 90, p. 24).

Hagedoorn made an empirical study on process control technology. Hagedoorn (89, pp. 83-84) is arguing for the attention to the performance of companies and their strategic options. In addition he underlines the role of both different categories of companies, and different strategies and objectives which enable a more dynamic analysis of the industry. He argues that the important dimensions for categorization of the companies in the context of technology and technology diffusion study are 1) the age, 2) the size, and the rates of 3) diversification and 4) internationalization of the firm. Hagedoorn ends up to categorize his object companies in the following way:

- small or medium-sized companies which serve as subcontractors
- small (existing or new) or medium-sized "single product line" companies
- large companies with small numbers of divisions
- very large, multi divisional and multinational companies.

As regards the taxonomy of companies in the context of innovation the conclusion, mainly following some experimental studies, is that feasible dimensions for taxonomy of the companies are age, size, product range, rate of diversification, and rate of internationalization. The examples of many empirical studies show that a great flexibility is allowed as to the taxonomy of companies - partly due to the shortage of a rigorous theory basis.

The role of technology change and innovation has become crucial for the evolution of industries. A frustrating fact is that the empirical literature says in general very little unequivocally about the determining factors behind innovations, or if it says, it is under contradictions because of conflicting empirical results. Especially this is the case with easily measurable factors like age, size, and R&D effort of the companies, market concentration in an industry, and the effect of these on innovation. There is an indication that some correlation can be found if the studies of technological change are focused on specific industries. The following part focuses on the observations of technological change, and the opportunities of technology to succeed in different industries.

4.3.2 Technological systems and trajectories

In the following an intellectual construction will be built, which is based on sectoral findings of innovations and technological change as proposed earlier.

Techno-economic paradigm[3] is defined as a model or pattern of a solution of selected technological problems, based on selected principles derived from natural sciences and on selected tangible technologies. Techno-economic paradigm embodies strong prescriptions on the directions of technical change to pursue and those to neglect. Given some technological tasks (or generic needs) like transport, housing, production of steel, plastics and paper the paradigm would show which direction, at a time, solutions for the techno-economic problems should be sought out, Dosi (82).

According to Dosi following Nelson and Winter (82), and Freeman (82) a technological trajectory is defined as the pattern of normal problem solving activity (i.e. of progress) on the ground of a techno-economic paradigm. A technological trajectory (sometimes also named a technological pattern) is, to repeat, represented by the restricted movement of multidimensional trade-offs among the technological and economic variables which the paradigm defines relevant. A progress is defined as the improvement of these trade-offs or some of them. One could imagine the trajectory as a cylinder in the multidimensional space defined by technological and economic dimensions. The space and its dimensions are defined by the paradigm. The trajectory is a cylinder in a paradigm space.

Some features of technological trajectories can be mentioned

1. Most probably there are more general and more limited trajectories.

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[3] We have used systematically the expression techno-economic paradigm following Freeman. Dosi uses instead the expression technological paradigm in the same meaning. The paradigm is a concept with a very wide influence on most sectors of the economy. Technological system (following Freeman) has an influence e.g. mainly on one or a few sectors.

2. There often are complementarities between the trajectories. Developments or a lack of development in one technology may foster development in other technologies.
3. "A technological frontier" is the highest level reached on technological and economic dimensions within a trajectory.
4. "Progress" is often cumulative by nature within a trajectory.
5. Particularly when the trajectory is powerfull, it is difficult for a company to switch from one trajectory to another one. The dimensions may be different, and therefore the technological frontiers may not be comparable.
6. It is doubtful whether it is possible a priori to compare or assess the superiority of one technological path over another. The comparison may be possible with some rational criteria but in any case only ex post.

Techno-economic paradigm and technological trajectory entail a conceptualization that market-related (i.e. environment-related) forces are instrumental in shaping the rates of technical progress and the precise trajectory of advance, within the set allowed by given selection criteria among new techno-economic paradigm. Thus the concepts of techno-economic paradigm and technological trajectory resolve the problem of market-demand and technology-push driven innovations - at least to the extent that the concept is in congruence with the requirements and have the influence of technology and feed-back mechanisms from the market.

Based on the ideas relating to technological trajectories Pavitt made an extensive empirical research in the U.K. First he gathered the data of the years 1945 - 1979 and published in Pavitt (84), and then the data was gathered up to 1983 and published in Pavitt et al (89). Finally the data consisted of 4000 innovations from various fields of industry accounting for more than a half of the British manufacturing[4]. The most important

[4] 1) The innovation was defined as a new or better product or production process commercialized or used in the U.K. 2) singnificant innovations were identified by knowledgeable but independent experts. 3) The sample covers three and four digit product groups of the selected industries. 4) Experts defined the threshold of significance at different levels. Thus the sample of innovations cannot be used to compare the volume of innovations amongst sectors. The sample can be used to compare patterns of innovative activity within sectors. 5) The data measure the significant innovation in the U.K., not in the world. They do not capture either the incremental and social innovation that often accompany significant technical innovations.

classification of innovations was based on the industry branch categorization. Each innovation was given a characterization in terms of: 1. The sector of a production of the innovation. 2. The sector of use of the innovation; in particular internal and external sources, and of a product and process innovations. 3. The characteristics of an innovating firm, like the size and principal activity.

There was one deficiency in the data, particularly in the point of view of this study. The R&D statistics of the U.K. does not measure two important sources of technical change: the engineering departments of production intensive companies, and the design and development activities of small and specialized suppliers of production equipment.[5]

Pavitt et al´s (89) research is able to show that the sectors considerably differ from each other. The picture is complicated, and therefore it is ex post clear that the empirical studies of innovation in many sectors give fragile results as the samples included too varied items. Pavitt et al is able to categorize the innovations to major technological families to which firms belong. The emergence of innovations is categorized on an industrial sector level according to the origin of innovation, the use of innovation and the type of innovating firm. These families are presented in many papers of the scholars, Pavitt (84), Pavitt (86), Pavitt et al (89), Pavitt (90) and Pavitt (91). The families are based on the patterns of innovations, and the trajectories defined above are the major determinants in the technology based company families. Pavitt concludes that the cumulative and differentiated nature of technological developments themselves in the firms leads to these wide technological families. In Pavitt´s mind a management literature does not take into account the enormous variety of firms in sources of technological opportunities, and in the rate and direction of their development. In particular, technological opportunities are strongly conditioned by a firm´s size and by its core business.

The scholars use the categorization (i) scale-intensive sectors, (ii) specialized suppliers, (iii) science-based sector, and (iv) information based sector. The names are self-explanatory to some extent. Table 4.1 gives more specific characteristics about the technology families.

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[5] Pavitt notices that the statistics of patents capture the innovative activities from these sources better than does R&D statistics.

The basic technological trajectories as presented originally by Pavitt et al (89) have been described below. These descriptions follow the presentation of Table 4.1. The dimensions of trajectories in Table 4.1 are source of technology, technological pattern, core products of firms and characterization of management problems[6].

(i) Scale intensive sectors. Innovation relates in these sectors both to processes and products. Production activities involve in general mastering complex systems, economies of scale and the whole marketing setting. Most technology is developed, applied and improved in and around investment and production activities. Investments are often interdependent and related to large-scale production systems. The main sources of new technology are production engineering departments, design offices and suppliers of specialized inputs, all drawing upon a wide range of advances in knowledge and techniques. Threats of technology based on entry are small, given the small size of technology suppliers with exceptions, the complex and systemic nature of the processes and the differentiated markets. This group includes e.g. transport vehicles, electric consumer durables, metal manufacturing, food products, part of chemical industry, glass and cement.

(ii) Specialized suppliers. Innovative activities relate to product innovations which enter other sectors than capital inputs. Firm-specific technological advantage is based on the capacity to improve the performance of specialized inputs (machinery, instrumentation, materials and software). The main focus is product innovation, and the main sources of innovation are the design office and the production engineering and system activities of customers. The companies tend to be, in general, relatively small, operate in close contact with their users and embody a specialized knowledge in design and equipment-building. Opportunities for innovations are often exploited through informal activities of design improvements, introduc-

6 Pavitt et al (89) use the word trajectory in two meanings. The wider concept (the columns of Table 4.1) consists of the characterization of the innovation in the family of companies, including sectors of products, patterns of behaviour, sources of innovative activities and rules of the game (economic and technological trade-offs within the company family). The narrower meaning of the word trajectory relates only to the rules of the game or the decision rules for economic and technological trade-offs within each trajectory. There is an example of this, the second row in Table 4.1.

tions of new components and "informal activities" of technology improvements. Appropriability is based to a great extent on partly tacit and cumulative skills. The main threat of entry comes from technologically dynamic firms in the user sectors, from small companies that are spin-offs from the firms of the user sector.

(iii) Science-based sectors. In-house technologies are the basis for exploitation of generous core of technologies. The technologies are emerging from basic scientific advances like in physics, chemistry, biotechnology and medicine, and they make diversification possible into new product markets. The advances are often related to-day to electronics and chemistry according to the findings of the U.K. data. Appropriateness is arranged in many ways from patents to lead times and learning curves. Innovative

Table 4.1 Basic technological trajectories according to Pavitt (90).

	Science Based	Scale Intensive	Information Intensive	Specialized Suppliers
Source of Technology	R&D Laboratory	Production Engineering and specialized suppliers	Software / systems Departments Specialized suppliers	Small-firm design and Large-scale users
Trajectory	Synergetic New products Applications Engineering	Efficient and complex production and related products	Efficient (and complex) information processing, and related products	Improved specialized producers Goods (reliability and performance)
Typical Product Groups	Electronics Chemicals	Basic materials Durable consumer goods	Financial services Retailing	Machinery Instruments Speciality chemicals Software
Strategic problems for Management	Complementary assets Integration to exploit synergies Patient money	1. Balance and Choice in production technology among Appropriation (Secrecy and patents), Vertical Disintegration (Cooperation with Supplier), and Profit Center	2. "Fusion" with fast-moving technologies 3. Diffusion of production technology among divisions 4. Exploiting product opportunities 5. Patient money	Matching technological opportunity with users Absorbing user experience Finding stable or new product niches

activities are formalized in research and development laboratories and research programmes. The results enter to a wide number of sectors as capital goods or other intermediate inputs. The "big science" companies tend to be large - with exceptions. The major threats of entry come from similar science-based firms which are diversifying horizontally to related new product markets.

(iv) Information-based sectors. This group of technology families is based on the emergence of information technology based techno-economic paradigm. The new information and computing technologies are creating opportunities for software-based technical change in many fields of industry. The combination of various production technologies in industries and the information technology create new vast opportunities e.g. in steel, chemical and wood processing industries. Besides, it may concern also long series and "single product" manufacturing e.g. in mechanical engineering and textile industries. The concept flexible manufacturing system is partly related to this trajectory, Pavitt et al (89). The presentation of Table 4.1 emphasizes the service industries in the column of information-based sectors, like Barras (86), which is a relevant aspect but should not lead to an underestimation of industrial applications.

Dosi (88) has discussed about the trajectories. He suggests that "inter-sectoral differences in technological opportunities, appropriativeness of regimes and demand patterns jointly account for the observed inter-sectoral differences in the company groups of innovations, these same variables, together with sector-specific nature of the knowledge on which innovations are based, explain also the sectoral differences in the typical organizational forms of innovative search." Elsewhere Dosi (84) emphasizes the differences between trajectories. These basic trajectories are wide and to a certain extent they tend to be general. But within each technological trajectory there are more or less powerful trajectories consisting of narrower sectors or product areas.

Dosi refers to an inter-sectoral matrix of the origin and use of R&D in the US economy based on the inter-sectoral generation and use of a large sample of patents, Scherer (82) in Dosi (88), and the evidence Levin et al (84) in Dosi (88), and concludes that these broadly support the findings of Pavitt on the existence of technological trajectories. However, according to him the empirical evidence on the sectoral patterns and characteristics of the innovation is far from complete.

Based on the derived trajectories the policy implications and related analysis can be grouped around four key characteristics of technology:

1. Functional and technical specialisation in its production
2. Uncertainty in its outcome
3. Cumulativeness in its development
4. Differentiation and specificity in its nature.

In knowledge-based trajectories (e.g. in science and information based trajectories) it is important to notice that complementary assets of information and other resources are needed when a company wants to proceed from one trajectory to another. The additional resource can be e.g. marketing in the new customer group. In the scale intensive and information intensive trajectories a technological fusion may mobilise and create totally new competences and competitive benefits in a rapidly changing and

Table 4.2 Characteristic of innovative management and their implications, Pavitt et al (89).

Characteristics of innovative activities	Implications Objectives	for the firm Means
1. Functional and technical specialization	Quality in, and balance amongst R&D, production and marketing	+ Business innovator with strong knowledge of all functional areas + Horizontal links
2. Uncertainty in outcomes	Flexibility and speed in decision Cover contingencies	+ Decentralisation of implementation + Portfolio investment + Avoid "sophisticated" decision algorithms
3. Cumulative development over time	Exploitation of learning: - by doing - by using - by failing	+ Feedback from marketing and production to technical functions + Skilled work force in production and marketing + Creation of technological slack on product and process design + Patient money

growing market. Potentially, a technological fusion may not only lead to improvements in cost efficiency, but also to totally new product developments. Finally a remark is needed on the trajectories. A specific company may follow more than one technological trajectory. For example a basic metals producer may at the same time be on a scale intensive trajectory and a specialized supplier of metals and mining technology.

Intermediate summary of industrial evolution and technological trajectories

Important for this study in the presented evolutionary theory of industrial development is the role of technology change in the evolution. The innovative activities have been categorized into four groups: incremental changes, radical innovations, technogical systems and techno-economic paradigms. Radical innovations are fairly rare but they may start a new technological system for the industry. In the technological style a new dominant design (different from the old and earlier one) will emerge. In the technological system a continuous flow of incremental changes of technology improves the products and processes.

In certain cases, the radical innovations may be extraordinary great by consequences. Then the technological system may expand having effects on many industries. In that case it is called the techno-economic paradigm. The paradigm determines what the problems are to be solved with the help of technologies and where the solutions are sought. The paradigm also determines the pattern of inquiry of solutions and the cumulative expertise used in the problem solving approach. The technological trajectories are subsets of techno-economic paradigms. They are formed on the basis of the tentative understanding of innovative activities. The trajectory forms the set of decision rules in terms of technological and economic dimensions. The variations between different trajectories are greater than they are within each trajectory.

The trajectories are formed on the understanding that the technological and innovative activities in the companies are (i) firm-specific and based on functionally and professionally specialized groups, (ii) profoundly uncertain processes without any deterministic features at an enterprise level, (iii) accumulating technological knowledge and experience of all kind and building their advancement basically on cumulative knowledge, (iv) highly differentiated by knowledge. Trajectories are constructed on the basis of technologies but market demand, institutional and social factors have influence on the directions of trajectories. The trajectories indicate direction to the innovative activity within the trajectory. The individual companies have all the freedom in their decisions (of strategy and innovation) and they may succeed or not or even change the trajectory. The latter case is possible, even though less probable.

Radical innovations and even more the changes of technological systems may cause discontinuities in the evolution of industries. The emphasis is on the cumulative nature of innovative activities. The model of the cumulative and irregular cycles of industrial evolution takes into account both the accumulation of competence and possible discontinuities. The importance of institutional continuity is significant in the face of technological discontinuity.

The understanding achieved now from the literature on the technological trajectories can be summarized from the viewpoint of interests of the study

- technological trajectories are formed on the basis of innovative activities in various sectors of industry
- the industries differ very greatly from each other in terms of innovations
- based on relative similarities between certain industrial sectors and production areas distinctive groups of companies were formed. In the formation of these families of innovation the results of innovation studies were main determinants. In this respect innovation and technological aspects were and are crucial for the formation of technological trajectories.
- the theories of evolutionary economics on the technological change and on the evolution patterns of industries are in congruence with the presented theory of technological basic trajectories.
- each innovation in every industrial branch is effected by economic and institutional (or social environment), because neither companies nor technologies emerge from a vacuum. Therefore it is conceivable that some scholars underline, in addition to technology, also to market demand and organizational forms.

- although there were the conceptualization of techno-economic paradigm and trajectories before testing them empirically and although the theory was refined and specified with the empirical data the theory still remains to be tentative and partly dependent on the time and industrial structure where it was tested.

As regards the taxonomy of trajectories the topic will be continued in the next chapter. The conclusion of the treatment of taxonomy of companies is not very clear. The least one can say, is that the common sense is not forbidden. The examples of the empirical studies made show that anybody who would study this kind of companies would probably make similar choices on the categorization. As to the roles of different kinds of companies it is now understood better than on the basis of the models for company growth that the firms of different sizes play roles in the evolution of the industry.

4.4 Application of theoretical models

Theoretical models have been discussed as a theoretical background of the work. The review of theories has included

1. the growth models of a company,
2. the cumulative and irregular cycle model for an industry development,
3. the innovation-based technological development patterns for industries, and
4. the basic tentative technological trajectories of industries.

Finnish clusters of industry

For the evaluation of applicability of the theoretical models some widely known issues are brought up. The engineering companies are born from the evolution and structure of the Finnish industry. The base cluster structure of the Finnish industry can be described consisting of the following clusters:

- a cluster of forest industry,
- a cluster of forest machinery industry,

- a cluster of base metal industry,
- a cluster of energy technology industry,
- a cluster of telecommunications industry,
- a cluster of potential subareas of environmental technologies,
- a potential cluster of well-being,
- a potential cluster of chemical industries,
- a latent cluster of foodstuffs, and
- a latent cluster of civil construction.

The cluster structure and its interrelationships with the engineering companies were widely described in Kässi (96). A clear finding was that the engineering industry has emerged from the needs and demand patterns of the base clusters in the Finnish industries. The clusters grew and developed rapidly since the World War II. The engineering services were demanded during the booming investment periods of industrial development.

Observed roles of engineering companies

The object firms of the study are more specifically the technical engineering companies consisting of engineering design offices, engineering project companies, and engineering companies with own designs and/or products. The technology is a very basic component in the profiles of engineering companies as well as in the engineering field.

In the engineering service sector there are several kinds of firms supplying a wide range of services with different combinations. This results in many kinds of roles of engineering companies. A specific objective of the study is to construct alternative development paths for the engineering companies.

The roles of individual engineering companies vary widely in the market. Some of the following roles are included in the functions of an actual engineering company. The first five roles are most usual:

- a supplier of expertise (design services, project management services),
- subsupplier of projects,
- supplier of projects and subprojects on turn key basis,
- an intermediator of information, and
- an accumulator of information and technical knowledge.

Common, but not as frequent, roles of the Finnish engineering companies presented are also seen in the market: an innovator, a body for internationalization in a large company, a commercializer of technologies of a large company, an owner of technologies, and a producer or manufacturer of components and subdeliveries.

Some items are included, because many companies consist of departments or divisions of large companies which originally served only the investments of the own company. Later on these have, however, developed to subsidiaries.

Roles of industries in the context of technology and growth in the economy at each period differ by country and by industry. The industries influence on the shape and rhythm of the economic growth. The industries do not act as such. The actors are the companies and often also the agents of the technological change. In terms of technology there are three kinds of roles for different industrial branches: the carrier branches, the motive branches and the induced branches, as described in chapter 4.1.

Carrier branches. These industries make intensive use of the key factor or the key technology, are best adapted to the ideal organization of the production, induce a great variety of investment opportunities up and downstream, and generate the economic growth. The major clusters in the Finnish industry during the post-war period are good examples like forest industry, basic metal industry, generation of electricity and heat, chemical and petrochemical industry, and telecommunications industry. Their investment rates have been continuously high due to the commitment to these industries and to the fairly fast permanent growth pattern in the economy until the late 1980s. These investing industries and companies decide, at each case, whether to invest and in what kind of technologies. These industries have to live with the production investment for some next 20 years and they have to pay the credits back with the income earned by the products from these investments.

The Finnish investments in environmental technologies, in social infrastructures, like hospitals, schools, clean and waste water systems, social and health recreations, commercial sector services as well as in latent clusters of foodstuffs and construction have been at a high level, and created branches of carriers. These structures and industries have determined the investment level and thus the quality and quantity of the total investment.

As pointed out elsewhere the post-war period in the Finnish industry can be called an investment driven period of growth, see Hernesniemi et al (96). The growth of production was only possible by permanently high investments and continuously increasing export.

Motive branches. These industries are producers of the key factors or other inputs directly associated with them and therefore have the role of maintaining and deepening their relative cost advantage, e.g. at a time the low cost energy and raw materials like wood and today the electronic chips. Thus the motive industries create the conditions for the development of the prevailing technological system. The growth of the motive industries depends on the rhythm of diffusion of the technological system across the industries.

Induced branches. These are often consequential and complementary structures to the growth of carrier industries. These industries may reach their full flourishing and multiply in bandwagon fashion once the necessary social and institutional changes have opened the way for the upswing and generalization of the new technological system which could become gradually the techno-economic paradigm. The necessary social and institutional changes are often the preconditions for the growth in the use of the new technological system.

The first reflection is that the main role of engineering must relate to the notion of induced branch. The engineering companies are without doubt complementary and relating firms to the base clusters. The drivers of technology must evidently be the investing industries. The investors take the risks and they get the benefits in successes. But the roles of complementary firms can also be very essential. As noted before very often the engineering companies become focal bodies of coordination, collection and intermediation of information and technical knowledge.

Features to be included into the models

If an industry continuously invests more or less in numerous projects and if the investors are using a few specialized engineering companies, the engineering companies easily start accumulating information and technical knowledge from the newest projects. This knowledge is indispensably valuable for the investor starting subsequently an investment. The experiences from investment projects are known to the investor and the technical consultant. The component supplier is not expected to disclose all the difficulties which take place in the commissioning phase. In this case the engineering company starts the accumulation of technical experiences. After some projects the engineering firm is not any more a subcontractor having a helping role, but the key advisor in the important investment project of the investor.

In large companies engineering departments or divisions get easily a significant role, because many companies concentrate all the knowledge in investments to the engineering divisions. Large companies carry out their own research and development. All the experience and technical advancement in the R&D is implemented in investments to production by the engineering divisions. In this way the engineering gathers the best information both in technical design, implementation and process via experience. In an internal process a large amount of experience and know how concentrates to the engineering division.

It is worth while to notice that even small international engineering companies may reach a valuable experience base in a narrow niche market. Even a fairly small company may reach a high market share. The accumulated experience of this kind of a niche engineering company can be an outstanding competitive factor giving a key role for a company world widely.

The original wording of Perez (86, p. 34) "the induced branch ... opens the way for the upswing and generalization of the new technological style" refers most probably to technological system of the information technology, not to more conventional technologies represented by most engineering companies.

So far relating to technology, a reference is made to the technologies of the base clusters. Accordingly we have kept discussing the consequences of the induced technologies on the engineering companies. However, a technological change relates to the engineering industry, too. The computer aided design (CAD) has carried out many changes in the actual work process of the engineering offices. The efficience has raised considerably. In the exploitation of computer aided systems in services there are two kinds of delays which cause retardation. Firstly, there is a delay in adoption and, secondly, a delay between installation and exploitation of potential benefits, Barras (86). In an engineering industry the delay between installation and exploitation is particularly important due to the high labour intensity in the operational activity in the field. As the CAD techniques are used in all the competing countries, the competitive positions of different countries are not expected to change, nor the companies owing to this technique.

Application of models

The clusters in the basic trajectories

In the base industry clusters the growth theories of a company can be applied on the firm level. The Finnish strong or semi-strong industrial clusters, in general, have fairly long life cycles and due to this long traditions.

The theory of industrial evolution, the model of the cumulative and irregular cycles may describe the evolution of the base clusters in Finland in a long term. The features like entries, exits, and fissions and fusions of companies are needed to describe the evolution.

As regards the technology development, a tentative categorization based on Pavitt´s trajectory model is constructed for the Finnish industry. Variations in technology developments are supposed to be smaller within each trajectory than between them.

The basic technological trajectories are mainly assumed to be dependent on technologies, regardless of the country or the period of time. A profound survey of the innovations in the Finnish industries would be necessary to qualify the trajectory model for the Finnish industry and clusters. The conclusion, however, is that for the purposes of a qualitative study the similarities are sufficient to be used in a qualitatively argued model[7].

In Table 4.3 the clusters of industries which have induced or created technical engineering service companies to give complementary services for

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[7] The conclusion is that a general nature of industries is similar in the UK and Finland, for example scale intensive process industries and specialized equipment suppliers as well as science-based companies behave in a similar way in different countries.

Table 4.3 The basic technology trajectory model of Pavitt tentatively applied to the structure of the clusters in the Finnish industry[8].

The Clusters of the Finnish industry	Science Based	Scale Intensive	Information Intensive	Specialized Suppliers
Typical Product Groups	Products of telecommunication Electronics products Products of well-being Products of fine chemistry Some foodstuff products	Products of forest industry Products of base metal industry Power and heat production Products of traditional chemical industries Process products of environmental plants	Products of well-being Services in open sector and in public sector	Products of forest machinery industry Products of energy technology Products of environmental technology
Strategic Problems for Management	Complementary assets: in small firms for innovation and marketing, and large companies in innovation, reference building and institutional influence. Integration to exploit synergies e.g. between different divisions in a company, or between different technological systems, or between R&D and engineering. Patient money.	1. Balance and Choice in production technology among appropriation (secrecy and patents), e.g how much own production technology is needed. Balance and Choice in vertical disintegration, e.g. how much to be in co-operation with suppliers, or how much to use competitive bidding. Balance and Choice in engineering as profit centre versus own service department.	2. "Fusion" with fast-moving technologies, e.g in flexible manufacturing systems, or in production management. 3. Diffusion of production technology among divisions, e.g. between production and engineering, or between process industry and machinery manufacturing. 4. Exploiting product opportunities e.g. by using new automation for variations. 5. Patient money.	Matching technological opportunity with users e.g. in niche engineering companies. Absorbing user experience from process to machinery industry, e.g. in forest machinery industry or in base metal industry. Finding stable or new product niches.

8 The table form is from Pavitt (91). Assuming the technological basic trajectories to some extent general, Table 4.3 has been filled using the information of Hernesniemi et al (95) and of Kässi (96).

their main functions, belong to the scale intensive and specialized supplier trajectories. The nature of the information intensive trajectory seems to have various combinations with any other trajectories. The needs and problems which the engineering firms are requested to meet and solve are similar within each trajectory, e.g. in scale intensive process industries, even if the industries are different. Specialized suppliers in the case of Finland are, e.g. machinery suppliers of forest machinery cluster or, in more general terms, suppliers of single deliveries of capital goods. The categorization to the basic trajectories of the Finnish industry gives a sign of a kind of technology change to be expected in different industrial clusters. From the technological viewpoint the base clusters are the technology carrier industries.

If a cross section analysis is made almost at any point of time of a base industrial cluster, many sizes of companies are expected to be seen. The more mature the industry, the larger the average size of the companies would be, depending on industry. Each size of the companies would have its role in the evolution.

Technologically the time of a cross section would probably be a stage of incremental changes, because the radical changes are fairly rare and can be recognized only afterwards. Besides in certain cases, when the row of incremental changes proves to be a radical change. This is due to the cumulative nature of innovation.

The technical changes are mostly relating to the improvements of processes or to the so called process innovations. In most cases, the improvements are introduced to the scale intensive process industries by investments, either by investments of new plants or rehabilitation investments. The sources of innovations are either in the scale intensive process industries or in the laboratories of specialized suppliers.

Engineering industry

In engineering field the theories of the growth of a company are applicable. The barrier of entry is low in engineering. Therefore many small companies can be expected to enter the business, and then to grow through various crisis and growth stages, or to fall.

The theory of industrial dynamics takes into account the emergence of large, new engineering companies from the previous divisions of large firms. The internal nature of those companies can be understood as regards the technological inheritance through the trajectory structure. The strategic conduct of their internal customers is also understood from the same angle.

The explanation of the evolutionary dynamics is better visible in the evolution of the structure of the engineering industry than in the evolution of the base clusters, because the life cycle of most Finnish products is very long. The pattern of entries and exits, as well fissions and fusions are frequent in engineering.

The engineering companies are largely needed in different phases of investments. The point of view of the technical engineering service industry into the industrial base clusters can be summarised as follows, Kässi (96, p. 31):

1. An evolving industrial cluster invests and employs also the engineering companies.
2. The investments are the means to implement new technologies and innovations in the industry.
3. An investing industry gives new references to suppliers of components, engineering services and technologies. The references are important for the competiveness of the engineering and other industries.

The roles of the engineering company mentioned above are consistent to the interests in the evolution of the base clusters. In the different roles the engineering companies are involving themselves with the core problems of the investing companies. This is the case of an independent company selling its services to an investing company. The project supplier company gets acquainted with strategic thoughts of an investor already in the phase of bidding, negotiating and finally, in implementing the project. The subsidiaries of the large multi divisional companies are often already engaged with preparing the investments, and further on in the next phases. The purpose to emphasize the closeness between investors and engineering firms is to underline that the approach to investments and a problem solving in engineering firms is most probably induced from the investing companies, at least in technical problems. This is part of the organization culture in the complementary service organizations.

The closeness is a determinative factor in a problem solving approach also in the case that an engineering company serves a specialized supplier of components, or cooperates with it more or less permanently. As an intermediating body between the two types of technological trajectories, an engineering company probably is influenced by both technological approaches, or at least one of them.

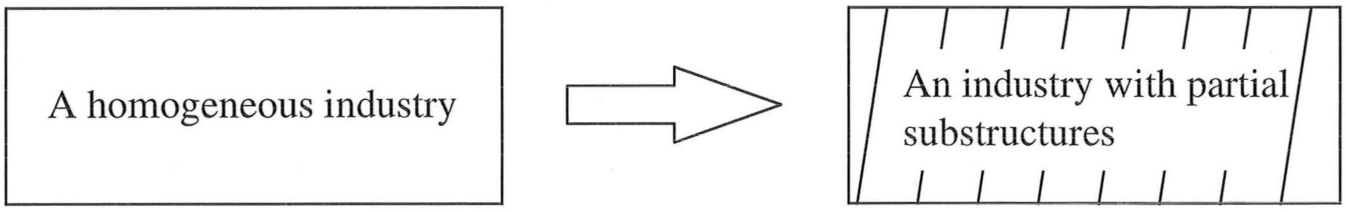
The investing industry is, in most cases, in terms of technology, a carrier industry and an engineering industry is an induced industrial branch. This means in practice that an investor makes the decisions and drives the development and an engineering company is a supplier of services in a helper´s role. Sometimes the radical innovations or the permanent accumulation of experience may change the roles so that an engineering supplier becomes a leading and dominant party in the process of investments - and innovation. The know how and knowledge are often people related matters and remain in the place where people stay.

The technological trajectories were introduced to analyze the British industries by Pavitt et al (89). In the same article Pavitt et al (89, p. 83) state that the trajectories or technological development patterns can be constructed on the level of industry, technology and firm. However, the empirical data does not exist, nor efforts to construct trajectories on the level of companies or industries have been made in the literature. The trajectories presented in chapter 4.3 are based on the data on innovations in different industries and on a very general company characteristics.

The purpose of this research is to construct trajectories or alternative development paths of individual companies in an engineering industry. The term development path is used to underline the time dimension to be included into the paths. The technology is definitely a dimension in the effort of developing company trajectories for these firms, because the firms are working with technology and are engaged with technological changes and finally their strategy and market are dependent on the state of art in technology. The idea of the technological trajectory as such includes market demand and institutional changes in the form of feedback to the technology induced development paths. As the purpose is to build firm development paths at a level of an industry, the idea of the trajectories is taken from Pavitt and the dimension of technology from his trajectories, but the intention is to include also other vital dimensions of company development into the development paths. The prerequisites for technology change have been discussed. This discussion warns about conventional wisdom which can be irrelevant, misleading or even wrong on the change of technology.

The whole theorizing of industrial evolution presented before shows that the characteristic features for the industries are a diversity and a variety of structures which are continuously evolving. The considerations of technology research including the technological trajectories referred to, in chapter 4.3.2, and the management studies to be referred to in chapter 5, show that an industry study aiming at a model of a homogeneous structure is not sensible. Instead there may be possibilities to build a model including partial structures within an industry. These substructures within an industry could be homogeneous enough to make some conclusions concerning them.

Figure 4.3 From a homogeneous structure to partial structures of an industry. A change in the emphasis of a model building.



So far the task has been focused to construct company development paths for individual companies at the level of the engineering industry. The next step is to examine what the management studies and the studies of company strategy could give us for building up company paths.

5. STRATEGIC MAPS OF COMPANY BEHAVIOURS IN THE ENGINEERING INDUSTRY

5.1 Strategic maps in general

The research on strategic groups originates mainly from two sources: the industrial economics and the management and strategy research. The term strategic group was first used by Hunt (72) in his study on the home appliance industry.

Michael Porter´s book Competitive Strategy, The Techniques for analysing industries and competitors presents a structural analysis as a tool for the competition to which industries may fall. The view of Porter is that a company should avoid competition to all extent possible. As competition is often unavoidable, a company should manage it as well as possible. Therefore competitive strategies are needed, and tools to be built up. Porter´s (80) approach starts from the five forces affecting competition. The structures of an industry and of dynamic competition are determined by these factors. The industry dependent factors determine which dimensions are crucial in each case.

Porter (80) gives a long list of the dimensions which may be crucial in determining the competitive strategy of companies. We repeat here a partial list of them.

- Specialization: the degree to which a company focuses its efforts in terms of product lines, customers and geographic markets.
- Push versus pull: the degree to which a company seeks to develop brand identification with the ultimate customers instead of the support of distribution channels in selling the product.
- Product quality: the level of product quality.
- Technological leadership: the degree to which a company seeks to lead a technology versus to follow or to imitate.
- Vertical integration: the existence of forward or backward integration within a production flow.
- Cost position: the extent to which a company searches for a low-cost position in manufacturing and in marketing through investment in cost-minimizing facilities and equipment.
- Price policy: the relative price position of the product on the market.

- Relationship with the parent company: the degree of strategic freedom a company has.

The idea of a strategic map arises from the existence of crucial dimensions in the strategy formulation of an industry. If there is a map (or space), which is formed by the crucial dimensions of the strategy of companies in an industry, each company has a point on this map. Assuming that the industry is homogeneous the points of the companies would appear spread all over the map. In such a case that there are subgroups of companies in an industry, where companies resemble each other they tend to be grouped on the map near each other. Such subgroups of companies in an industry are called strategic groups. The companies of a strategic group are closer to each other than other companies in an industry[1]. The presence of the strategic groups relates mainly to the barriers of entry and exit which differ from each other in different strategic groups.

Engineering design companies and engineering project supplying companies could, for example, be claimed to form strategic groups in an engineering industry. The crucial dimensions in this field would be a specialization in a certain field, and a risk taking ability and willingness in projects.

Porter (80) writes about the strategic groups as if the companies belonging to each of them must always operate in the same industry and compete with each other. The focus of the book was competition in an industry, therefore the strategic groups are presented as a phenomenon of one industry, see Porter (80). Later in the 1980s, the industry borders have been discussed whether they should be limited to national borders and whether strategic group could contain companies which do not compete with each other. The answer seems to be positive, one strategic group may consist of companies which do not compete with each other, McGee and Thomas (86), Hatten and Hatten (87), Thomas and Venkatraman (88). In case of the engineering industry, companies and strategic groups belong to the same industry, but the companies in the strategic group do not necessarily compete with each other. This is often true for the companies in the group of specialized supplier companies. However, when the companies operate

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1 The idea of strategic maps is a widely used aspect in management literature. Porter is referred to here since he seems to be the most influential of the writers.

in the same industry and in the same strategic group, they have often a possibility to enter to the competition with each other easier than companies from a distant industry.

The presence of more than one strategic group in an industry has implications for industrial competition in prices, market shares, services and other variables. Some of the structural features that determine the strength of the competition may apply to all the firms in the industry, and thus provide the context in which the strategic groups interact. Generally, the presence of strategic groups in an industry means that the forces of a competitive environment are not faced equally by all the firms in the industry. Four factors determine how strongly the strategic groups in an industry will interact in competing for customers, Porter (80, pp. 138-139).

- the market interdependence among groups, or the extent to which their customer target groups overlap,
- the product differentiation achieved by the products,
- the number of strategic groups and their relative sizes, and
- the strategic distance among groups, or the extent to which strategies diverge.

The most important factor influencing competition among the strategic groups is the market interdependence. If the customer groups of the strategic groups are the same, different strategies lead to vigorous competition. The second key factor influencing the rivalry amongst the strategic groups is product differentiation. If the products are seen to be far apart from each other, most probably the competition is not so keen. Thirdly, the more numerous and the more equal in size the companies are, the more their strategic asymmetry generally increases competitive rivalry, other things being equal. The many equally powerful companies are not able to see the transparency of the strategies of the competitors, and they easily fall to harsh competition. If the competitors are unequal in resources, power and market share, they do not fall to rivalry so easily, because the smaller company has not the possibilities really to compete with the bigger ones. The final factor, the strategic distance, is affecting competition. The firms pursuing widely different strategic approaches tend to have quite different ideas about how to compete and difficulties to understand the behaviour of each other, and to avoid mistaken reactions arising out of this rivalry.

In the engineering industry there are different strategic groups within the engineering companies. These groups have different strategic focuses. The customers of different groups are, however, potential investors in the same projects. The customer does not necessarily know beforehand, how to carry out the investment project, as a purchase of a turn key project or as purchases of subdeliveries with the help of a trustee engineering consult. In such an unclear case, the companies of the different strategic groups may fall to a fierce competition even before the bidding process. The other reason for an increase in the lack of clarity in the engineering industry may be the unclear limits of the product ranges in different companies. In this industry very different kinds of companies may be competing for the same projects.

The assumption is that industrial variations between strategic groups correlate with variations in the profitability between the groups, Porter (80, p.145-148). The variations in the profitability are explained by the hinders of mobility to and out of the strategic groups. The empirical results in this respect are, however, unclear, besides in obvious cases.

A company facing strategic options in an industry has strategic opportunities. By using these concepts the opportunities can be categorized in the following way:

- to create a new strategic group,
- to shift to a more favourably located strategic group,
- to strengthen the structural position of existing group or the position of the firm in such a group, and
- to shift to a new group and to strengthen the structural position of that group.

Opportunities also involve the risks. The risks facing a firm can be identified from the same concepts. They relate to the possible entries to and exits out of the strategic groups.

As more studies using the strategic group concept have been published, for an overview see Hatten and Hatten (86), Thomas and Venkatraman (88), the variation of the approaches has come up in them. The operationalization of strategy or the definition of the concept of strategy have proved crucial in the studies. Thomas and Venkatraman (88, pp. 538-41) propose two dimensions to classify the empirical studies in strategic groups:

1. Operationalization of the strategy (alternatives: narrow or unidimensional; broad or multidimensional) and
2. Approach to group development (alternatives: a priori, theoretically specified and maybe empirically supported; a posteriori, empirically derived).

With these dimensions four alternative methods to formulate strategic groups can be envisioned.

In this case the method includes a broad concept of strategy with many defining dimensions. The strategic groups were originally formed on the basis of a wide empirical work. In this work the classification of companies to the strategic groups does not happen with the statistical tools but with a holistic view and thumble rules. The argumentation concerning the dimensions behind the strategic groups in chapter 5.2 has been written later on for this study.

5.2 Dimensioning of strategic groups in the engineering industry

If we consider the engineering companies as a worldwide industry, some very general observations can be made. Perhaps the first finding about the market of engineering companies is that the market is very local by nature and therefore fragmented. The engineering services are easily bought from the experts who are known to the customers. The first reason for the fragmentation arises from the fact that the local needs are different in various countries. A second finding is that the volume of international trade in engineering is directed to the third-world market. Basically the fast growing newly industrialized economies are the best customers for the engineering companies. Engineering trading exists between the industrial countries but not to that extent as from industrial countries to developing countries. These features reflect the fact that an engineering industry is very dispersed, all the engineering companies are small, the market shares of the biggest companies globally are less than two to three per cent, see Idom (92), Kässi (96).

There are some obvious dimensions to categorize engineering companies. The first obvious one is the product range. A rough division of the product groups is: the design services (including other expert services), the services for project management (which also comprises basically the sales of services) and turn key deliveries. A second obvious dimension of categorization is the geographic spread of markets: the domestic market, the domestic and limited foreign market, and the global market. A third obvious and easily measurable dimension is the size of the company, measured either by the number of persons or by the turnover.

To sum up them, the dimensions for the categorization of engineering companies are:

- the product range: engineering design, engineering services for project management and turn key deliveries
- geographic market area: domestic market, domestic and limited foreign market and global market
- size of the organizations.

The fragmentation of the engineering market into submarkets was already referred. At the local and national level the locality and close relationship between the customer and the engineering consult is an important factor. At the international level there are projects where the availability of international finance and the size of the projects require very large companies as suppliers. The engineering organizations have to be large to provide in a short period of time the required resources for the large projects. The large projects may be transnational in that they have influence on many countries, or they can be large projects in developing countries to be financed only from international sources[2]. The polarization between the small and the large project sizes is clear. The increase in the size of the project increases the organizational requirements. Certain transnational projects can most easily be managed by large organizations which already have offices in the involved countries.

2 In industrialized countries even the large projects can often be managed by local forces. In Europe, where the distances are short between different countries, local project management but also project trade over borders were the custom to a certain extent already in the last decades. This can also be seen from the statistics of the exports between European countries. Nowadays the EU regulations require that all the public projects have to be set under an open tendering and competition process. This may increase the international market of projects within the EU.

From the previous discussion, the aspect of internationalization also appears. The choice of internationalization is clearly crucial for an engineering company. As a local and national company an organization is avoiding many problems, but the growth potential remains limited. The path of internationalization is long and by no means without problems. The aspect of internationalization overlaps with the dimension of market selection presented. As a summary for strategic dimensions from the consideration of a geographie area we should conclude

- fragmentation of the market: a need for local engineering companies, a need for national companies, and a need for large transnational engineering companies
- internationalization of activities and organization: only a domestic market, multi domestic markets with limited transnational involvement, and transnational or global markets.

A third group of logical dimensions relate to the degree of specialization of engineering companies. The specialization may develop at least in terms of customer industries and technologies. Clearly small and new companies would rather specialize only on one industry. In the course of time a company may grow and start serving more than one industry. At the same time the degree of complexity of the projects increases.

The second way to specialize is to acquire technological advantages. An engineering company may appropriate technologies only for its own use. This may happen by receiving patents to certain technologies or by unofficial ways. In certain cases engineering companies may also be manufacturers or rent out manufacturing of their own components. This kind of technology specialization is a strongly distinguishing factor between the companies. National and small companies are seldom specialized to narrow areas of technologies. They have to serve many kinds of customers in various problems. The national engineering company may receive competitive advantage by acquiring specialized technologies to its own use. The competitive advantage may be a precondition for it to become international. On the other hand, a specialized engineering company has to be international because the market for very specialized knowledge or products is limited almost in any individual country. The cause and the effect are not known in the matters of specialization and internationalization. Logically they are at least parallel phenomena.

Specialization strongly relates to the range of products. Project management engineering services require more specialized and experienced resources than engineering design. Turn key projects are supplied, or at least started as a type of project, by engineering companies. The specialization grows as the complexity of the projects increases.

As a conclusion regarding the specialization and complexity of projects we would conclude

- specialization by industries: one industry as a customer allows specialization, many industries as customers lead often to general design activities
- complexity of projects: specialization in technology brings increasing requirements to projects also in other aspects; complexity of projects increases with their size and the degree of internationalization.

The attitude to risks is basically a distinguishing factor behind the choice either to sell only services of technical know how or the turn key projects. The other factor may in some cases be the know how in operations of the whole plants. If an engineering company does not have it, the barrier to supply turn key projects is higher.

Intermediate summary of dimensions in a strategic map of engineering

We have discussed about obvious dimensions of strategic behaviour of engineering companies (size of companies, specialization and geographic area of the company). As discussed above the space of strategic behaviour of engineering companies at least consists of six dimensions or axes. This six axes space would be, however, difficult to describe. To make it easier the axes are reduced to three. The three remaining axes capture the space sufficiently well[3].

3 Here the source: Idom, Competitiveness of the European Engineering Services Industry, Commission of the EU, DG of International Market and Industrial Affairs, September 1992, is followed.

Table 5.1 The assumed interrelationship between different axes in the strategic space.

Main axis	In interrelationships strongly with axes
Size of the engineering company	Size of the company Spread of the product range
Specialization	Ability to take care of the project in one or more industries Ability to handle large, complex projects, coordinating many suppliers
Geographic area of the company	Fragmentation of the market: a need for local, for national companies, and for global engineering companies Spread of internationalization of activities: domestic market, multi domestic markets, and global markets.

The reference in Table 5.1. was made to the consultant study which extensively gathered empirical company material. The study used the dimensions on the left of Table 5.1 as assumptions. The material was statistically handled and the report in its conclusions results in these crucial strategic dimensions in world wide competition, Idom (92).

The Idom (92) report is a consultant report, and it does not give the argumentation for the hypothesized dimensions in the strategic map in order to formulate the strategic groups in the European engineering industry. Therefore the arguments above for the dimensions of categorization are reconstructed afterwards by the writer. The arguments are based on the general knowledge of the European and global engineering industry, Kässi (96), on the explicit statements of the objectives of the Idom (92) study, and on the theory of strategic maps.

The report is explicit in its objective to formulate and “analyse each strategic group, in an attempt to understand the underlying trends that explain the competitiveness of companies and groups in the long term"[4]. Besides the empirical data of the study and the verification of the hypothesis bear this out. The results of the Idom (92) study are utilized, although its reporting does not fulfil the requirements of traditional scientific investigation.

5.3 Strategic groups in the engineering industry

The European study gives four strategic groups in the engineering industry, as referred to in the previous chapter, Idom (92).

Global engineering companies

Description

- Large companies. Personnel more than 5000
- Large turnover, very diversified by industrial customers
- Significant number of offices and representative abroad
- Exports more than 50 per cent

[4] The data is drawn from the following sources: Commission of European Communities, CEBI (European Committee of Consulting Firms) and its National Assosiations, CEDIC (European Committee of Consulting Engineers of the Common Market) and its national Assosiations, World Bank, UNCTAD (United Nations Conference on Trade and Development), O.E.C.D. (Organization for Economic Cooperation and Development, Engineering News Record (ENR), McGraw-Hill Inc.

The methodology used to carry out the study required to establish a methodological framework in order to develop a working hypothesis concerning the competitive structure of the sector, in accordance with the following stages:

- To define key success factors for the engineering service industry using the inductive method from the previous data collection.

- To establish a reasonable hypothesis for grouping companies according to their strategic characteristics, using the concept of Strategic Groups.

- To analyze each strategic group, in an attempt to understand the underlying trends that explain the competitiveness of companies and groups in the long term.

Main activities

- Infrastructure, Architecture
- Chemical, Petrochemical, Pulp and Paper, Energy, Thermal and Nuclear Power

Competitive Advantages

- Capacity to assume large size projects (size, financing capabilities, risk assumption)
- Large number of references
- Areas of speciality often related to important interests in the country origin
- Taking advantage of financing by governments and multinational institutions.

National engineering companies

Description

- Medium amount of personnel
- Several local offices in the domestic country, and other offices or representatives abroad
- Exports 5 ... 15 per cent
- Size and infrastructure enough to begin an internationalization process

Main activities

- Very diversified
- Some speciality or techniques in which good references are available in closed geographic areas (domestic country and continent), used as a main reference for exporting market

Competitive Advantages

- Related to techniques in which some specialization is available
- Related to the domestic countries: former trade or colonization; financing conditions; language, customs.

Local companies

Description

- Small size, personnel under 40
- Local market based on local industrial network
- No exports

Main activities

- Specialized in small projects
- Engineering and architecture of industrial plants
- Civil works and infrastructure
- Piping
- Urban building installations

Competitive advantages

- The local niche of the group of companies is not a target for new entrants
- Intense competition coming from individuals working on their own

Specialized suppliers

Description

- Medium to large amount of personnel
- Very specialized market segment all over the world, special customers in the segment
- Area of specialization related to the competitive industrial sectors of the domestic country
- Ability to supply turn key plants

Main activities

- Process and detailed engineering of industrial plants in their specialization
- Turn key plants
- Detailed feasibility and industrial studies

Competitive Advantages

- Few suppliers of competitive technologies worldwide

- Intensive experience and R&D in the context of the customers of the domestic country and of the leaders of the worldwide sector
- Some hypothesis for the specialization of countries
  Japan: steel, shipyards, earthquake-proof buildings, railways, subways, dams.
  Scandinavia: paper plants, dams, bridges, hydroelectric power generation.
  Italy: roads and infrastructure, steel.
  Germany: chemical and metallurgy based process plants.
  United States: mostly extractive and manufacturing industry. Nuclear power plants.

The strategic groups can be presented in a graphic schema, too. In a two dimensional picture the reader has to imagine that the third axis points out from the paper. The given axes are the size of organization and the degree of specialization. The third axis is the internationalization, and becomes conspicious to the eye. The strategic groups in the engineering industry have been verified with the collected data. The groups differ significantly from each other, and are to some extent kinds of models which most of the companies follow. There are, however, certainly companies falling in the middle at least in some dimensions which also verify the presence of variations and asymmetries in the engineering industry.

Due to Finnish conditions a fifth strategic group has been added, market niche engineering companies, to the categorization. This is an assumption of the writer based on the case material, Kässi (96), having no qualified empirical test. The argument to add this category is the following. There are a few "innovative companies starting in garages" in any country. The steps to succeed after that kind of start-up is higher in a small country than in a big country due to its smaller market. In a big country an innovative company finds at least the first customers in the same market. For an innovative company in a small country, export and foreign sales become a necessity from the very beginning of a company's life. As the start-up and the first years are more difficult for the innovative company in a small country, the assumption is that the companies still remaining after that difficult period could be more competitive in the world market, in the particular market niche than the similar company of a large country. The market segment can be very narrow and limited but a company may, in the course of time, attain a significant market share in the segment. If an empirical test is put against these assumptions, the group can be merged to a group of specialized supplier companies.

Market niche engineering companies

Description

- A number of personnel is small or medium sized amounting from 50 to 200
- Selected market and customers: a narrow worldwide market segment. The segment is, however, big enough for a small company.

Main activities

- The technology is often sold as an embedded technology in the equipment and as a technology transfer in a training programme
- The technology is sold as a part of equipment in turn key deliveries.

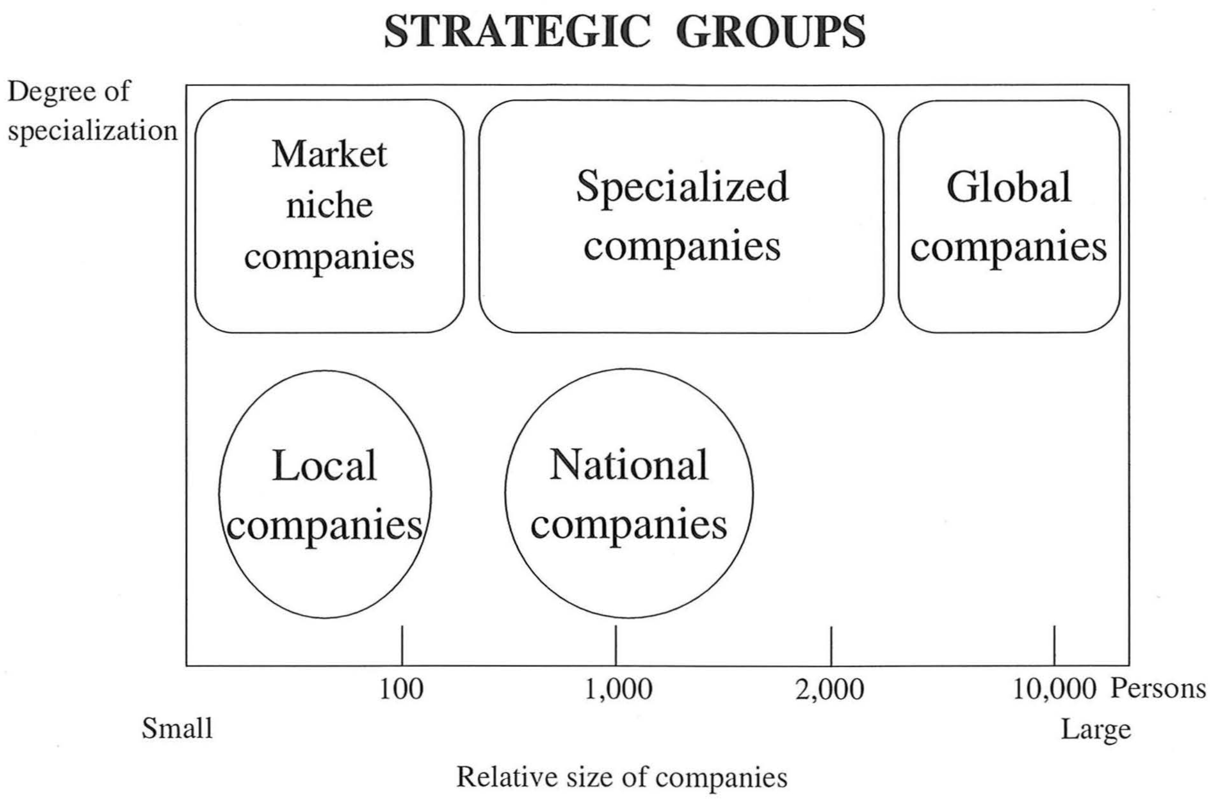
Competitive advantage

- Technology know how in a very narrow area
- Technology and innovativeness is often in the field of an equipment technology

We can understand that an innovative engineering company starting in a garage may, if it does not fail, become a market niche engineering company. In the case of a success it stays in the same market niche where it started. It has to succeed to avoid all the risks of internationalization, and to balance the use of resources between the growth and solidity of the company.

From the point of view of a strategic group relating to specialized companies, the group of market niche engineering companies is the same concept in a minor size. The market is, however, small enough not to raise the interest of larger companies with wide resources. Therefore a small company may exploit the market, and does not face a direct competition with larger companies. In the course of time a relatively large and significant learning benefit remains to an early starter company.

Figure 5.1 Strategic groups in the engineering industry, applied from Idom (92).



The hindrances of mobility between the barriers among the engineering strategic groups are significant:

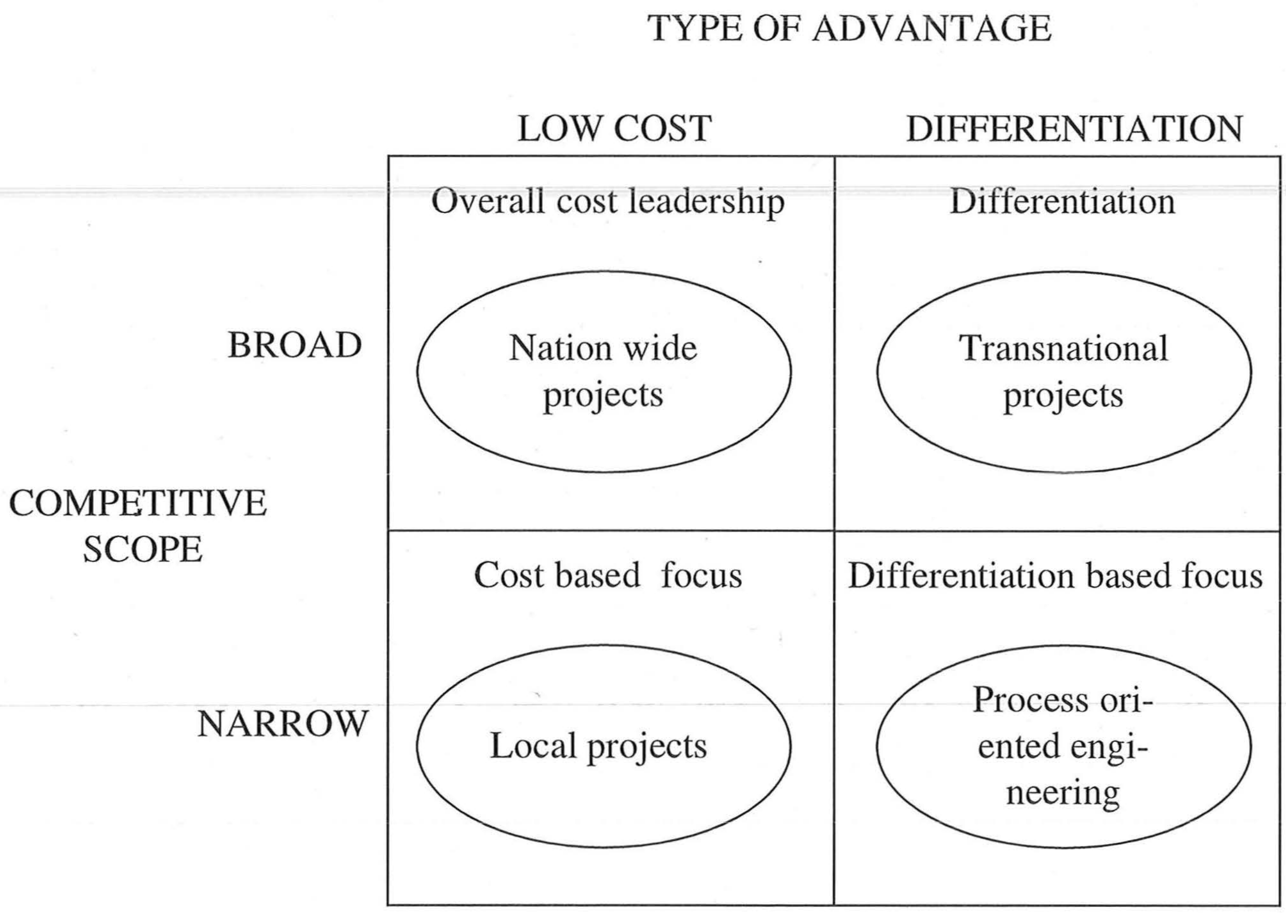
- References and skills in managing large projects are difficult to attain for companies without previous attempts to develop their skills in the particular strategic dimension. This constitutes an effective barrier for the entry to another group.
- Barriers to develop into the process-technology oriented engineering dimension are significant. Technological development, financial capacity, knowledge of the market, suppliers and technical cooperative relationships with the customers are important.
- Internationalization is not easy for the companies competing in the multi domestic segments of the market. Competing in global segments, thus achieving access to new markets, requires more effort in any of the other remaining dimensions. Competing in the multi domestic market is not a sufficient advantage for entering to the global projects. Sometimes the multi domestic markets can be seen as a step to global projects, Idom (92).

Generic strategies and types of products. Figure 5.1 shows the positions of different types of strategic groups on the strategic map. The description of strategic groups includes the characteristics of different groups as seen earlier in this chapter, e.g. the typical products and services in each group. Another point of view to look the different types of products and services of engineering companies is to adjust them to the categories of generic competive strategies of Porter (80, pp. 34-46). The dimensions on this generic map of strategies are the scope (or broadness) of the strategic target, and the cost versus product differentiation.

The engineering companies primarily offer many kinds of products and services, therefore the positioning of project types is easier than strategic groups[5].

The dimension of risk was not referred to after taking it up. The risk taking ability relates to the size of companies. Small companies are not able

Figure 5.2 Types of products and services of the engineering on the generic map of strategies. Applied and adjusted from Idom (92).



[5] The typical products and services are mostly related to certain types of strategic groups. Most groups have a dominating type of works they practically live on.

to take risks. Generally the engineering design offices have limited assets, and their risk taking ability and willingness are limited. Their business is to sell technical design and expertise mainly based on time-based charges. The research and development activity is fairly limited in engineering companies, which concentrate in engineering design. The engineering divisions and companies closely tied to larger companies take risks, having the assets of the mother company at the background.

The research and development including product development is a risk for any company. The companies in the group of specialilized suppliers are involved in this business. They can justify the expenses of development activities by being also in component supplying business. The deliveries of industrial and other plants in terms of turn key also belong to their business activities. The technical, financial and project management risks are always involved in turn key deliveries. It is the business of these companies to divide, remove, avoid and manage these risks.

The small and national design offices and the specialized suppliers of equipment, subprojects and projects in terms of turn key are perhaps at the extreme ends in taking risk. The global engineering companies are in the middle of the extreme. They do have very large and complex projects to manage. They, however, tend to sell design, and project management services and other expertise for time-based charges. The technical risks are most often left to the suppliers of machinery, components and other equipment. The basic risk of investment cost evolution is to be carried by the investors. In the management of project risks the large global engineering companies should be experts. They must have tools and methods besides experience to handle and manage the project management risks of large and complex projects.

5.4 Internationalization of an engineering company

A short terminological and factual note is needed concerning the internationalization of engineering business to chracterize the strategic groups.

The emphasis is expressed on the fact that an engineering industry principally is a local business. The customer contacts are easiest when the seller of the services personally knows the customer. This does not mean that the companies can be only local or national engineering companies. In the domestic market engineering companies may grow to a certain point either by serving many industrial branches which means working on a general level, or by specializing to one industrial branch or a strong cluster of a domestic market.

The need to grow, particularly in a small country, forces the engineering companies to seek for assignments in other markets. Then the thought of finding partners in the foreign markets is very close because the business is similarly local in another country. This is the start for a national engineering company to become international. The next step is to buy foreign companies to strengthen the cooperation links.

The evolution steps of the internationalization in a business development are according to Yip (92, p. 4):

1. Developing the core strategy, which is a basis for a sustainable strategic advantage. The core strategy is to be developed in the domestic market.
2. Internationalizing the core business, through international expansion of activities and adaptation of the core strategy.
3. Globalizing the international strategy, by integrating the strategy across the countries.

In the definition of strategic groups, a national engineering company may have 5 to 15 per cent of export or international business activities of its turnover. It becomes international as the percentage grows. The essential thing according to Yip (92), however, is the type of organizing the business. If the companies in different countries operate like local national companies, the group is international, or multi domestic, but not global. Even worldwide international engineering business in the engineering industry may remain multi domestic, due to the local nature of the business. The value chains remain domestic in each country. The employment of the home base company is not necessarily enhanced by this kind of operation pattern.

The worldwide business can be changed from international to global because of four motives or drivers, Yip (92, p. 8): market, cost, government, and competitive drivers. The local chains of values are then broken, and the whole is managed by the head office trying to optimize the whole. The local domestic companies lose some of their independence in this structure. The centralized structure allows, however, the company to specialize to very large projects, megaprojects. These projects can have influence on many countries, or to be transnational. Concerning the engineering activities there is reason to point out that internationalization is a necessary intermediate step to change the company from national to global.

Intermediate comparison: Pavitt´s trajectories versus Porter´s maps

In Pavitt´s basic trajectories, the customer industries of engineering companies are principally industries within the scale intensive trajectory. The engineering companies design, construct, and implement investments to build "efficient and complex production" systems in large scale. The systems engineering is important part of the design. The benefits of the economics of scale can be achieved only by exploiting a learning from experiences in production volume.

The trajectory of Pavitt´s "specialized suppliers" is directly one strategic group of engineering companies under the focus of this study. The characteristics of these companies in the trajectory are mentioned to be

- the sources of the technology: small firm design, or large scale users,
- main efforts: improved specialized products, goods with reliability and performance, and
- strategic problems: matching technological opportunity with users, or absorbing user experience, or finding stable or new product niches.

The third trajectory "information intensive" can feed inputs to both previous trajectories, the scale intensive industries and the specialized suppliers. This may open totally new kinds of opportunities for the existing trajectories.

At a principal level the difference between a trajectory and a map is great, because a trajectory depicts a longitudinal development from the point of view of technology, and a map is a cross section picture. However, it is clear that the specialized companies of the strategic map of engineering industry of Porter are surprisingly similar to the specialized suppliers of Pavitt. The whole structure of these two company categorization is the same, in spite of the different source of knowledge where the two structures emerge. The local, national, and large engineering companies all serve mainly the investors or companies of the scale intensive trajectory in terminology of Pavitt. The conclusion is that the two categorizations lead to the similar types of groups of companies.

6. COMPETITIVE PRESSURES OF ENGINEERING COMPANIES

6.1 Operative competition in the market

Engineering companies may consist of many kinds of firms and activities. The differences in company profiles also reflect in their competitive strategies.

A practical way to review competition in the market of engineering services and projects is to divide the discussion into engineering services and turn key projects. Consequently a distinguishing factor is their attitude toward a risk. The nature of these markets significantly differs from each other. The description of a competition in these markets gives an idea of the competition on everyday level.

An engineering design company sells mainly work or working hours. Aside from price, the buyer also takes qualitative factors into account when comparing offers. The qualitative factors are measured by references, the fame and knowledge of the bidder. The seller of technical services has to adjust the price to quality ratio to such as to attract the buyer. In general the quality and reliability of the offer are the most weighted determinants when evaluating the technical services. The services are generally relating to the first half of an investment cycle. The direct cost effect may be only from ten to fifteen per cent of the whole investment cost. With a design of good quality significant cost savings can be reached in the investment expenses and even later in the operation phase of the plant which makes the emphasis on quality conceivable.

The costs of engineering services are mainly dependent on the costs of working hours. In the high cost level countries the engineering work is more expensive than in the countries with a low cost level. Regarding the quality of engineering services, particularly in detail engineering design, the quality can be very high in newly industrialized countries where the cost level is much lower than in industrialized countries. As the consequence of this, technical engineering design services can be sold from the countries of high cost level only when the technology or industrial branch is related to strong clusters of the country or when very special services are needed.

International financial organisations are a special group of customers for engineering studies, feasibility studies and engineering designs. They have accepted the variations in cost levels in different countries. If they make an order from a country with a high cost level, for some reason, they are ready to accept the costs. The international banks have specific evaluation rules for the bids. The order of criteria in making the selection between bidders of engineering services are the following: the personal references of the experts, the references of the offering company, the quality of the offer and the price of the offer.

The products of an engineering project company in turn key projects or subprojects are evaluated on a totally different basis. Project management services are probably evaluated in the same way as the technical design services. Investments projects are often vital questions for the investors. Therefore certain preconditions have to be present for the engineering project company to get a chance to offer. The engineering project company has to be known beforehand as a reliable and competent project supplier so that the offerer can be accepted into the small group of companies to make final offers. It is likely that the acceptable offerers have built their local networks in the country where they do compete. The most essential dimensions according to Puskala (92) for the engineering project suppliers to consider in assessing their competitive position might be:

1. The adaptation of a technical solution and a whole concept to the conditions of the customer.
2. The knowledge of the local environment including the possibilities of sourcing components and subdeliveries, of the decision making procedures and cultures.
3. The commitment of the sales personnel which is shown in the quality and correct timing of the sales efforts.
4. The technologies, concepts, and references offered by the engineering company.
5. The support given by the offerer for the financial arrangement of a large turn key project.
6. The price of the project.

The modes of competition of engineering companies totally differ from the competition of the marketing mix models. The theory and practice of marketing capital goods in the long term relationship to the customers was recently enligthened by Alajoutsijärvi (96). His conclusions are parallel to a few points of Puskala.

The engineering project companies are competing in turn key projects with the component suppliers which may want to expand their delivery scope towards a turn key supply. The competitive dimensions of engineering design and consulting companies and engineering project companies differ from each other. The following table summarizes the two competitive modes of the companies. A competitive mode of an engineering design company, referring more generally to engineering services, is called a design mode and that for an engineering project company - a project mode.

The everyday behaviour of companies in the market forms a strategy which depicts their sectoral patterns. The design mode clearly concerns local and national engineering companies and concerns large engineering companies in the cases when they are competing at a multi domestic level. When a large global engineering company is competing on global or international projects, the complexity of projects make the competition resemble, in some aspects, more a project mode in competition[1]. The project mode in competition relates to specialized engineering and market niche engineering companies.

If the competitive modes of table 6.1 refer to the competition for works and projects on a day-to-day basis in the market, the competitive strategies can be described with the help of the generic strategies of Porter.

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1 When a large multi domestic engineering company supplies design work or project management for a paper factory in a country, it may compete with national engineering companies and the project is a national project. When the same large engineering company offers e.g. study of climate changes in East Asia or study on the expansion of deserts in Africa, the competitors are no more national engineering companies, but other large global engineering companies. The amount of companies which are taken into account in this class is not wide. Therefore they can be said to be in a differentiated market specialized in megaprojects, see also Yip (92).

Table 6.1 The dimensions of competitive evaluations for engineering design and engineering project companies.

ENGINEERING DESIGN COMPANY "Design mode" in competition	ENGINEERING PROJECT COMPANY "Project mode" in competition
- Personal references of experts - References of a company in the corresponding projects - Quality of an offer - Price of an offer	- Adjustment of a solution to the conditions of the customer - Knowing and exploiting local know how and conditions - Quality of sales and marketing and their correct timing - Risk free, high quality and beneficial technology concept - Price of an offer

Table 6.2 The competitive strategies and competition modes of the strategic groups of the engineering industry.

Strategic group of engineering companies	Competition mode on day-to-day basis in the market	The generic strategy of Porter (80)
A local engineering company	Design mode	Cost based focus
A national engineering company	Design mode	Overall cost leadership
A global engineering company	Design (in national works) or project mode (in transnational projects)	Differentiation or overall cost leadership (in a national projects)
A specialized company	Project mode	Differentiation or differentiation based focus
A market niche engineering company	Project mode	Differentiation based focus

These generic strategies were developed by Porter (80) from the analysis of five forces affecting the market structures. The strategic groups can be categorized according to the generic strategies of Porter, see also Idom (92). The strategic groups of the engineering industry "on the strategic map" are a cross section picture of the engineering industry. The generic strategies of Porter are known to the extent that their names in the context of patterns also express the content of the strategy. The competition in the market by the strategic groups gives two levels of characteristic features in competitive behaviour within the sectoral paths: the competitive strategy of company groups and the competition modes below them.

To be more specific, the strategic map of engineering industry is presented once again. This time the strategic groups are depicted by the key competitive factors and as a consequence by success factors. Very much of the argumentation has already been written before. The competitive success factors describe the corresponding sectoral paths of which they are intersections.

6.2 The long term creation of competitive capabilities in the market

Individual companies or industries have no possibilities to influence on certain factors in the market. This particularly concerns such factors as raw materials, aging of the population. Evolution of the markets are normally clearly out of the scope of the influence of individual companies. External forces in the market influence on technological trajectories and changes in them.

However, companies do have an influence on the competitive situation that they have to live with on a company level and a cluster level. In his latter book, Porter (90) is arguing for a competitiveness created by the companies in clusters. This competitiveness is not based on inherited factors of production, but on created specialized factors. The competitiveness is emerging at the level of companies and the specialized factors are basically created by them in competitive markets. The created factors of production are human knowledge, professional skills, technology, innovations, management, and generally factors depending on activities by people.

KEY SUCCESS FACTORS

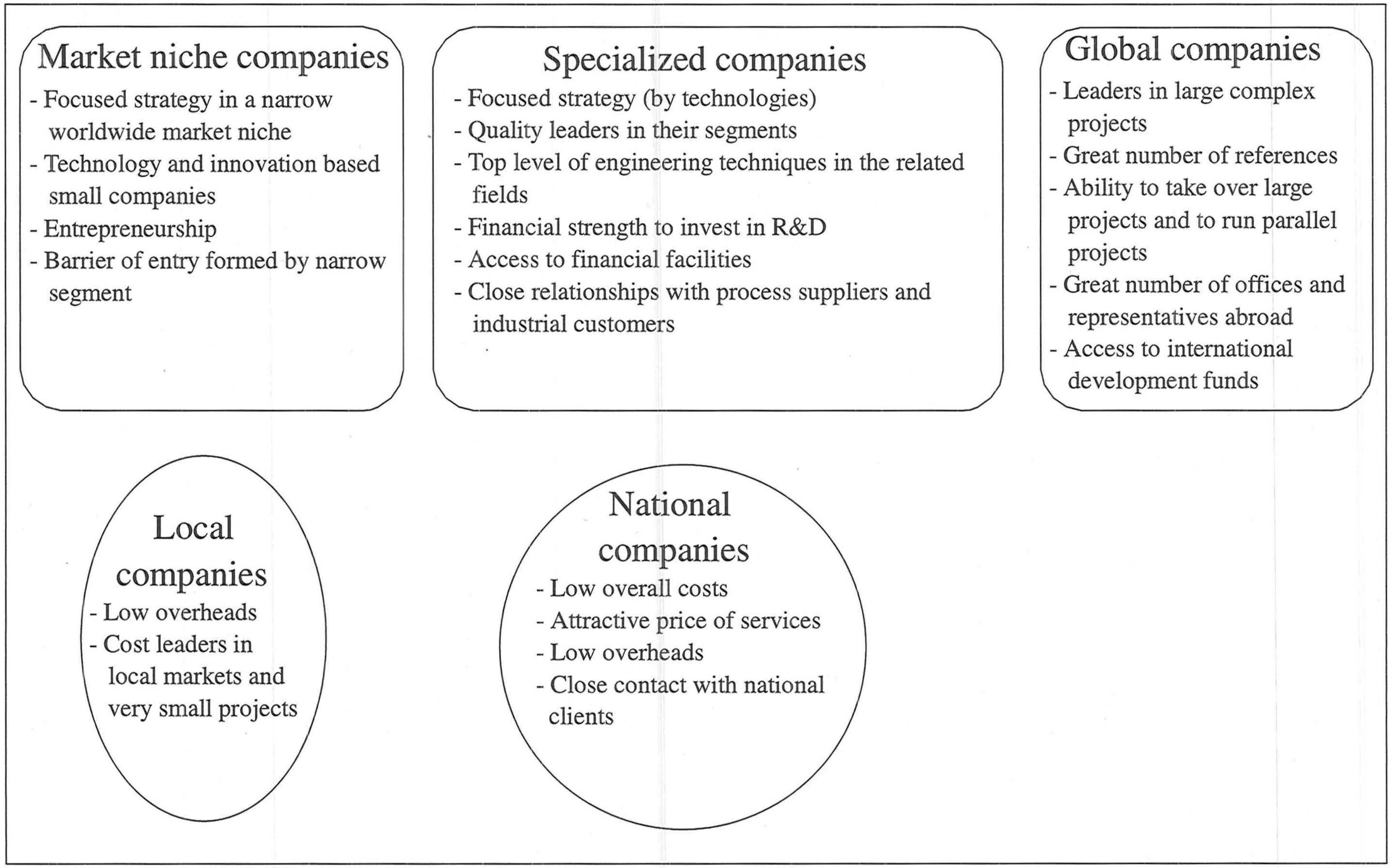

Figure 6.1 The strategic groups of the engineering industry and competitive success factors. Applied and adapted from Idom (92).

Evolution of competitive advantages in companies basically relates to learning on different levels of organizations. The learning on a management level may include strategic learning and possibilities to change directions of development. The learning on operative levels concerns improvements in everyday performances. The intention is not to go deep into the topic of learning of organizations. But the point is that the network interactions are an essential environment of organizational life and learning on which the engineering design and engineering project companies depend. The roles of an intermediator, a combiner, an accumulator and others related to information and technical knowledge are crucial for the learning of engineering companies. The management of interactions is an essential determinant of the creation of long-term competitiveness in the engineering companies. The management of networks and the definition of roles of an engineering company are the tools to influence on the learning and the future competitiveness of the engineering companies.

To connect the competitiveness with the technological framework: a learning by doing is normally the same as incremental improvement and technological changes within a trajectory. The engineering design and project companies that are serving scale intensive industries accumulate experience together with their customers and, in addition, the engineering companies in a specialized supplier trajectory are working with their clients in new investment projects. In many cases the projects of engineering companies continuously are in a particular field of industry which contributes to their potential for innovations.

There are seldom major or discontinuous changes in technologies that have long-term effect on the industries. These changes replace the old trajectories by the new ones including new dimensions. The major changes, whether in technologies or in markets, give a chance to the engineering companies. If they are involved with the first few investments when the new types of applications are introduced, they may have a chance to develop their capabilities within the selected paths. In these cases the exploitation of technology or market opportunities may lead a company, e.g. to evolve from a local to a national, from a national to a global, or from a market niche to a specialized engineering company. A discontinuous technical change may be a radical change. But more often today, it is an emergence as a result of a cumulative technical knowledge and experience. Technologically the last step is not a radical change, even though consequences of the change can be dramatic, as Pavitt emphasizes. We have underlined that a part of engineering companies being on a frontier of technology development may have a particularly good position to exploit the changes when they occur. This assumption requires a restriction, the meant engineering companies are those which either continuously gather front line experience from projects or which cumulatively collect experience from on-going research and development. The capability to follow technological changes may be possible only, when the accumulation of knowledge and experience is behind.

6.3 Adaptation of engineering companies to external cost pressures

A certain part of the market of the engineering companies has become international, and remains such as the customer industries are global industries. The global customer industries are exploiting freedom to sell their products in the markets which are most profitable and to buy factors of production from the countries which offer them most beneficially. The engineering services are then sourced from the countries where ever their price to quality ratio is the best.

The standard engineering design work can be carried out in many countries, industrial, newly industrialized and even in some developing countries. The cost of an engineering hour may vary in an order from one to five or even from one to fifteen. Therefore the competition may sometimes lead to situations where an engineering company from a high cost level country cannot and should not even try to compete. To understand cost relations of the company compared to competition, and to position itself strategically to the industry, i.e. to select the right strategic group is a necessity to succeed in short and long term.

Pictures of the value chain are used to analyze some emerging issues. The value chain is a cost map of a company[2]. The main operative activities and their costs are presented in columns. They are inbound logistics, operations, outbound logistics, marketing and sales, services. The cost drivers

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[2] Michael Porter uses a value chain in his book Competitive Advantage (85) to analyze a creation of competive advantages. The cost analysis as such is not a new thing. The presentation of Porter is used here.

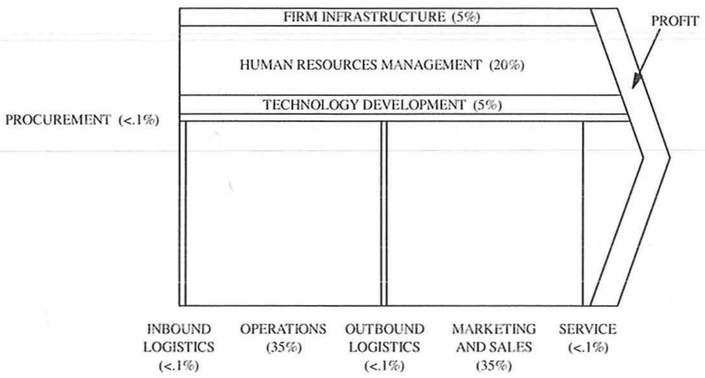
(or overhead costs) are presented in rows above the operation costs. If the profit is included in the figure, the area of the map presents the sales price of a product or a service.

For an engineering design company which mainly sells engineering services the cost structure is presented in Figure 6.2. The cost structure is typical of a western European engineering company, Idom (92). The share of human resource related costs is about 80 percent of the total costs. If the European company finds itself in a direct competition in non-differentiated market with companies of low cost countries, it has two major possibilities to improve its position. It can either transfer all or some part of its engineering design work to a country where the engineering labour cost is lower, or it can try to expand its services and the value added. The most direct way to increase the value added of an engineering design company is to start offering turn key projects, thus increasing the share of the engineering work and growing the value of the project at the same time. In bigger projects there may be available more space for competitive actions. Simultaneously the risk level essentially increases. Figure 6.2 shows tentatively a direction of changes that is possible to make to the cost structure of engineering design company by the proposed actions. The transfer of work to a low cost country represents a strategy of minimizing costs to remain profitable, and the increase of value in projects is an effort to differentiate the product from the ones of the competitors. The two upper figures exactly represent the same size. This comes from an assumption that the work is sold to a market in the same high cost level country. This is not always the case.

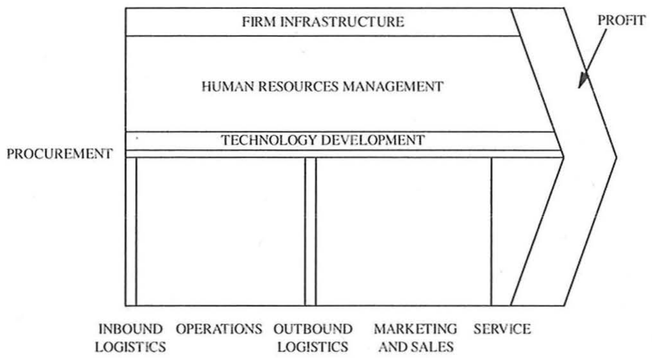
If an engineering project company faces competition where its cost structure cannot compete with the existing cost structure, it may try to change its cost structure by repositioning itself in the market. The first way is to minimize the costs of bought components. This option has probably already been used, but reconsideration of components from unconventional countries could be a solution. A remark on very wide range of costs is also valid for standard components of industrial processes, as it is for engineering work costs. If unconventional sourcing for components has already been tried, the remaining action for a turn key delivery company probably is to increase the share of own value added in the project by own products or by innovation. Having own products may give an engineering company some freedom of space to variate its pricing and the structure of offer and may be an edge for competitiveness. If an engineering company

Figure 6.2 Estimated cost maps for an engineering design company, the same with a transfer of work to a low cost country and the same with a start of turn key supplies.[3]

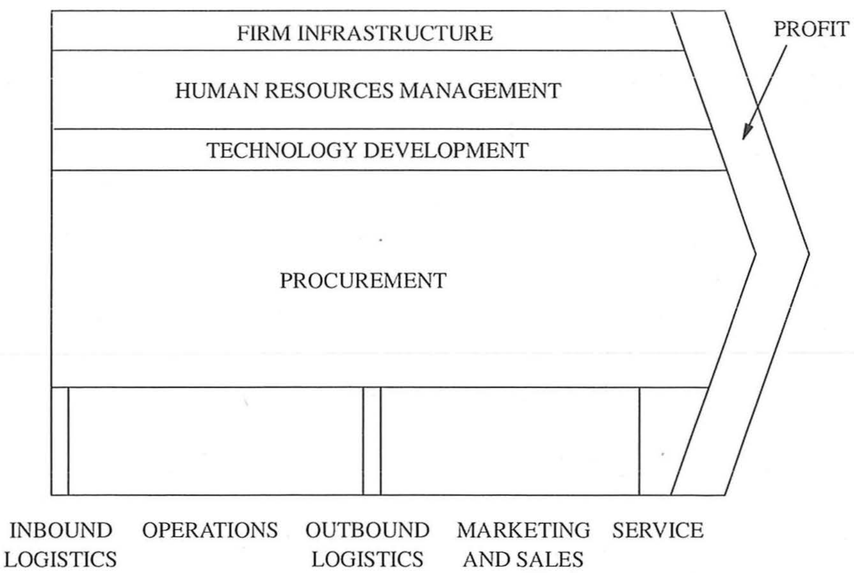
A basic case, an engineering design company.



An engineering design company using low cost work.



An engineering design company starting turn key projects.



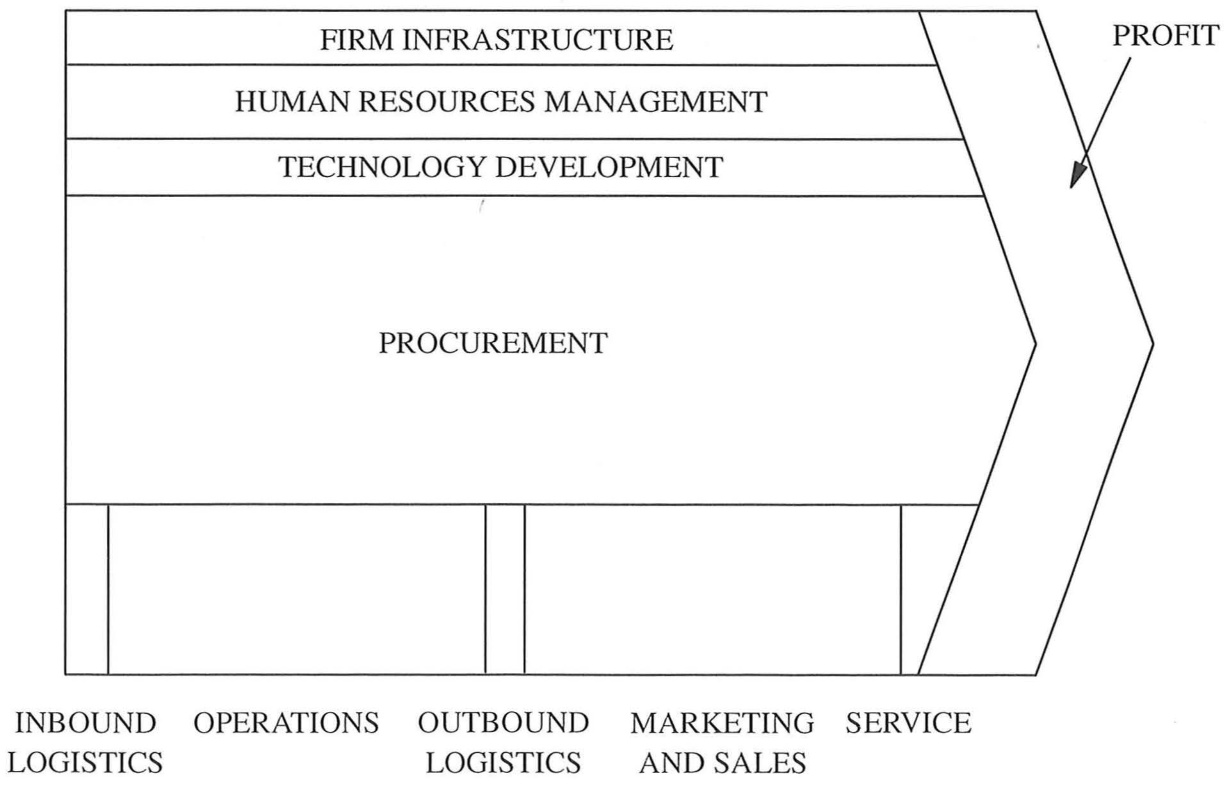
[3] The basic case, the cost map of an engineering design company, is adapted from Idom (92). All the other cost maps are possible estimations of the writer. They are to be understood as tentative descriptions.

has an innovative product or process to offer to customers, it may get a better price for the project or improve its performance in competition leaving some profit for the seller. The option leads the company clearly towards a new type positioning in the market. As discussed earlier the change in company behaviour is very significant, and not always even possible.

Figure 6.3 illustrates tentatively the cost position of a company. The share of procurement or the purchases of component is a great part of the total cost of an engineering project company. If the components can be bought at a lower price it may significantly improve the cost structure. If all or some part of the components are own, this part of costs is under own control. If the component is of innovative nature, the price of the project could be higher or the area of the map bigger.

As an intermediate summary Table 6.2 can be referred to in a short and long term strategies. Figure 6.1 discloses the competitive success factors by strategic groups. The discussion on the cost structures gives directions for the changes in the strategic positioning of engineering companies, when obvious activities are needed because of long-term cost structure issues.

Figure 6.3 The tentative cost map of an engineering company with main business in turn key projects.[4]



[4] See footnote 3 in this chapter.

6.4 Competition with component manufacturers

There are a few reasons to talk separately about the competitive threat of component manufacturers to the engineering companies, particularly the turn key suppliers. The first reason is that the component manufacturers are the main subcontractors of the turn key suppliers. In many cases the share of procurements of components for turn key deliveries is a half or more of total costs. In the market a common phenomenon is that component producers become competitors in turn key deliveries, particularly during tough economic periods.

The discussion in chapter 6 on the expansion of business activities of engineering project companies towards their own components or products brings them closer to component producers. The existence of the company family, the specialized suppliers within the engineering industry, illustrates the end result of an industry pattern. These companies have developed their strategy to the point where component manufacturing is an integral part of their strategy in turn key deliveries. There are, of course, a countless number of company specific combinations between turn key suppliers and component manufacturers.

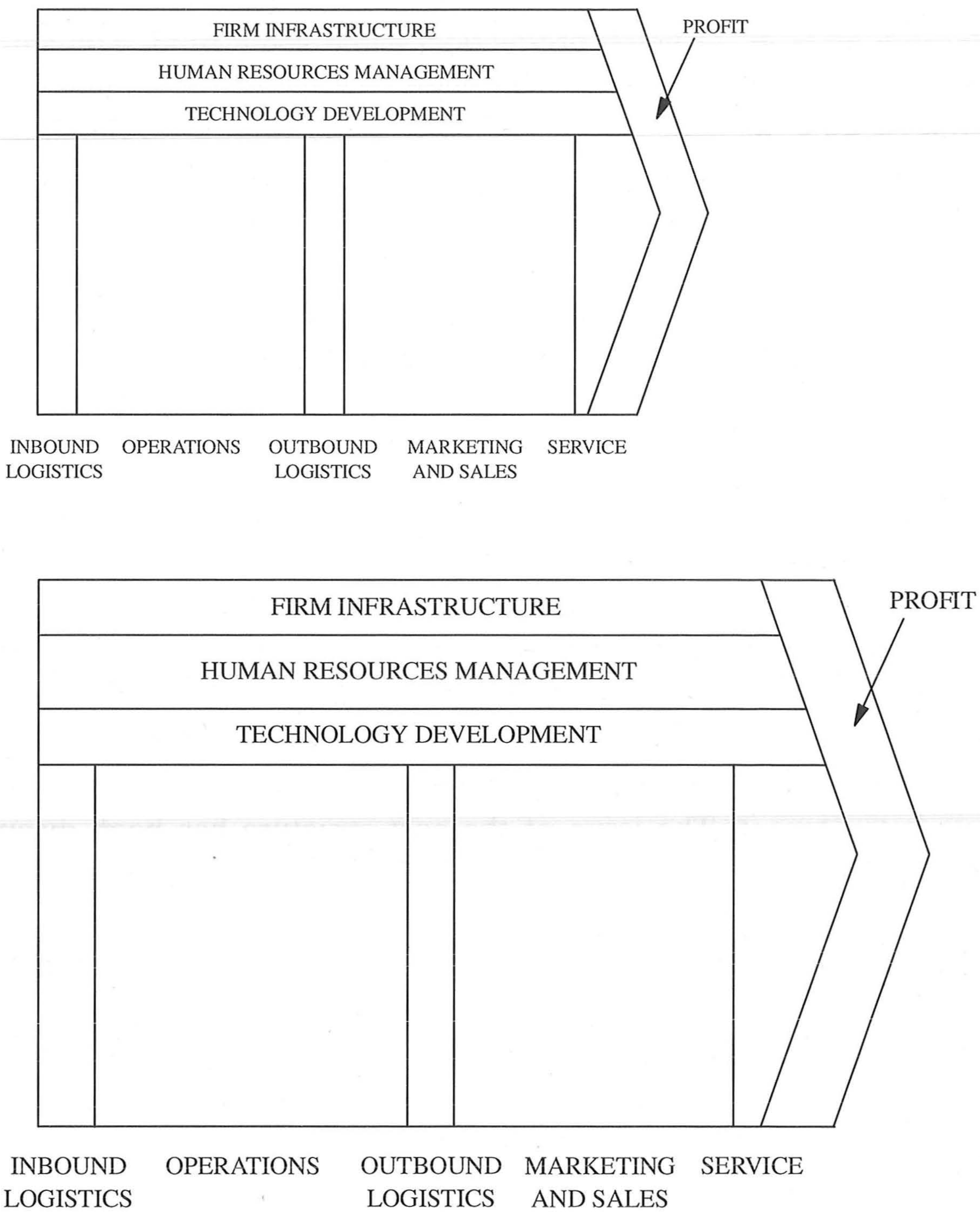
In the next chapter, a company type is introduced whereby an engineering company is separated from a manufacturing. In this case a manufacturing division in a large company receives aside an engineering organization. The engineering division takes care of marketing the particular products to selected customers and takes care of turn key deliveries. The engineering and manufacturing organizations are separate, but their operations are often common in the way that the engineering division uses the manufacturing as a subcontractor of components. The innovative companies in a garage have similar characteristics. The company may have an innovative product, and it starts to offer the product on a turn key delivery basis to the customers in the narrow, but geographically wide market. These two types of companies are examples of vague borders between engineering and manufacturing companies.

There is an additional trend related to manufacturing which lowers the barrier between it and engineering. The combination of conventional machine tools and automation, or more generally information technology, has created a production mode, a flexible manufacturing system (FMS). The flexible manufacturing system can be called a techno-economic system in the machine manufacturing industry, if not a paradigm, in the terminology used in this study. The idea of the FMS is that the modern machinery shops can produce almost any machinery, since the manufacturing technology is flexible enough to adapt to different designs. The alterations in the machinery can be made so easily and rapidly that the production system may offer the cost benefits of long series production and the individuality of batch production at the same time. The automation in manufacturing may be a significant cost factor for production, because the labour intensity has been high in machinery production. But more important in this context is that production capacity is available and can be rented. This allows an easier opportunity to engineering companies to own products, patents or other industrial rights and have them produced on a rent manufacturing basis. Then an engineering company does not need to acquire its own manufacturing capacity which would be an insuperable barrier in many cases to develop and own company-specific products.

In chapter 6.3 a reference was made to the directions where an engineering company may improve its competitive position. Many of these directions mean steps towards own products, own designs and perhaps manufacturing. These steps were presented as means of avoiding an impossible price competition. However, the similarities of profiles between engineering project companies and component manufacturers become evident and the engineering companies then face another competition in a new market segment. The issue of the cost structure has been discussed with value chain maps for engineering project companies in chapter 6.3.

The small sized cost map in Figure 6.4 for a component manufacture has to be looked together with Figure 6.3 which depicts the cost structure of an engineering company with the main business in turn key projects. Principally a small sized figure of the component manufacturer (Figure 6.4) should go into the procurement share of a big sized figure of a turn key supplier of Figure 6.3. The bigger sized cost map of a component manufacturer that started to supply turn key projects is equal to the size of an engineering company supplying turn key projects in Figure 6.3 as they are assumed to sell in the same market. The cost structures are different, primarily as the manufacturing costs are in operations within manufacturing companies but in procurements within engineering turn key suppliers. Another thing is that the cost structure changes when a manufacturing company starts to supply turn key projects which is depicted in the tentative Figures 6.4.

Figure 6.4 **A tentative presentation of the cost maps for a component manufacturer and a component manufacturer that started to supply deliveries on turn key basis.** [5]



Market niche engineering companies form their own story. Somehow they seem to be able to unite the benefit to the customer produced by an innovation and a manufacturing in a new way. The new solutions in manufacturing may be involved with subcontracting at the very beginning due to

5 See footnote 3 in this chapter.

the shortage of capital, with an assembly machine shop in order to save in investments, or with a team work applied to the assembly work or manufacturing. The small companies are also often forerunners in combining an information technology, design tools, management tools and a manufacturing technology. The systems are easy to build up from the beginning when there are no costs for replacing the old ones. This is often competitive edge of the innovative companies and is seen in the different cost structures compared to the ones of older companies. What is said, could be partly true for the specialized supplier companies, too.

An intermediate summary of competition between engineering companies and component manufacturers

The tentative analysis of cost structures in engineering companies and their potential competitors, component manufacturers can be summarized as follows.

1. The national engineering design companies in high cost level countries often internationalize to follow a minimum cost strategy.
2. When a national engineering company has internationalized so far that it works in a network of national engineering companies or as a multi domestic company, the individual national companies are mainly working in domestic countries as they did earlier. In some cases a multi domestic company evolves a global or transnational engineering company. Then the internationalization is an important dimension but, in addition, the company needs to have a few specialization areas in order to get the chance to attain experience in very wide transnational projects.
3. The engineering project companies minimize their procurement costs by out sourcing from countries of a low cost level. They try to increase the value added of their projects by introducing their own process technologies, products, and procedures to the projects in order to compete with component manufacturers. In succeeding in this way the engineering project companies profile themselves gradually to specialized supply companies.
4. Some component manufacturers want to expand their business by becoming turn key suppliers and in some cases entering a new field of component manufacturing.

As regards the model of industry paths the conclusions of chapter 6 are parallel and by no means contradictory to the ones of chapter 5. These conclusions can be easily adapted to the industry paths.

7. EVOLUTION OF ENGINEEERING COMPANIES IN A SMALL DIAMOND ENVIRONMENT

In the preceding chapters theories of an industry have underlined the internal or endogenous evolution of an industry. This chapter deals with the external factors affecting the evolution of the companies. The purpose is to develop the framework of a cluster analysis towards a method for considering development preconditions of an engineering company. An engineering company is seen here as a knowledge-based company.

7.1 Framework of industrial clusters

International competitive advantage of an industry relates to surviving and growing over long periods of time in a competitive market. In international competition the companies exploit the skills which also drive their home market success and which are built on the company´s special capabilities, knowledge or other sources of strengths. At a company level competitive advantages imply a capability to create a more efficient resource combination than the competitors in respect to the relevant opportunities in the industry. The concept of competitive advantage refers to a longer term than the term competitiveness.

According to Porter (90) a competitive advantage of a country depends on the formation of industrial structures within a nation. Competitiveness is created by companies which are integrated within the structures of clusters in a country. The internal structures of clusters are preconditions for the creation of competitive power in a nation. The ability of a nation to develop creative industrial structures determines the long term competitiveness of a country.

Porter compares the industrial environment to a diamond which consists of the four basic and two additional determinants of competitive advantage. These determinants shape the environment faced by local firms in the way that either promote or prevent the creation of competitive advantage:

1. Factor conditions: a nation´s position in inherited and created factors of production as basic elements of competitive strength,
2. Demand conditions: the nature and structure of domestic demand for the products of an industry,
3. Related and supporting industries: the presence or absence in the national environment of related and supporting industries that themselves are internationally competitive,
4. Firm strategy, structure and rivalry: the conditions governing how companies are created, organized and managed in a nation, and the nature of domestic rivalry.

The two exogenous variables, the role of government and chance surround and influence these factors.

One of the main contentions of Porter is that the determinants of the diamond are coordinated with each other in such a way that the value of the whole is more important for national capability than the value of the determinants. The interrelationship between the factors is underlined by Porter in many ways.

Critique on the Porter´s diamond

Porter applied his approach to ten countries in his original work. Since publishing the book of Porter (90) at least another ten Porter´s competitive advantage of nations related country studies have been made in different parts of the world. The experience on the model has been gathered and, at the same time, the criticism on the approach and proposals for improvements have been presented. Some of the presented critique on Porter´s diamond model is reviewed. The points are selected in the way that the essential features for this study can be discussed and that the discussion serves as a background for the development of the framework.

Two aspects, the pressure and the proximity are fundamental assumptions in Porter´s thinking on the creation of competitiveness. The cluster collects the relevant factors of production together and forms an environment where the specialized factors may develop and further upgrade. This is possible only, because the geographic distances are short. The proximity makes the competition between the neighbours particularly hard and this is the reason for continuous upgrading.

Location of a competitive advantage.

According to Porter, an advantage arise when the most dynamic environment for innovation is present. By locating together product line management, R&D and some part of the production in the same environment, the preconditions for rapid innovation are present. This location is the driving force for global strategy and activities located elsewhere can be used to reinforce and support the home base, through tapping into labour pools, or resources and securing market access. The problems of coordinating dispersed production, R&D and product development among equal subsidiaries in different countries are next-to-impossible problem. The company with a clear home base in a dynamic location will always innovate faster than the company which is trying to coordinate[1]. Porter´s argument for strong localization, the home base, is really based on the rapidity of innovation which he sees possible only in a localized diamond.

Reinert (93) in Penttinen (94) and Rugman (92) have criticized Porter that he sees the world too much from the US point of view. Even in the North America Canada is an exception because, as the scholars note, the Canadian clusters are strongly dependent on the US clusters. The opposite proposition is that the national clusters have already developed or are developing into transnational clusters. The firms can source factors, seek for related and supporting industries and meet demand and rivalry in clusters that cross national borders.

Dunning, an authority in the field of international business and multinational companies, argues strongly for transnational diamonds from which the international companies may draw benefits. Dunning considers that the diamonds of different countries are open and form the basis of the competitiveness of multinational companies. In addition, he claims that the multinational companies can be responsible for fostering the networks of national diamonds of competitive advantage, Dunning (93). According to Dunning (91) and Dunning (93), the diamond of Porter should be included by an additional exogenous factor, foreign direct investments. But Dunning concludes that the principle of the diamond may still hold, but its geographical constituency has to be established on a very different crite-

[1] Porter according to Penttinen (94, p. 22).

ria. The thoughts of globalization of a business referred earlier to, Yip (92), are also built on the idea that a company may source in different countries to the extent that the chains of values can be competitively combined from different countries. The conclusion was not made as a reference to any of Porter´s works.

In his original text Porter was ready even to limit the geographical area of the competitive advantages, i.e. the area of the diamond to a region or a city which only points out his notion of proximity of the locus of competitive advantage. Porter has later on responded that the diamond can extend over the national borders where the culture and institutions on the both sides are similar and the physical distance short.

The critics conclude, if the geography of the diamond can contract to a region, why the diamond could not expand over national borders. Also the expansion in a more abstract way has been proposed. Rugman and D´Cruz (93) have proposed a double diamond model to the North America between the USA and Canada. Perhaps the most general model is the one proposed by Cartwright (93), the multiple linked diamond. There the national diamonds are defined as Porter does but, in addition, the interlinks between the national diamonds have to be studied and understood. The setting of clusters is then an international network where the companies live.

Important in this discussion is that the locus of a diamond depicting the competitiveness of a cluster may differ by geography and nature.

<u>Issues of small open economies.</u>

The whole approach may require alterations in small open countries where the size of the economy simply limits the markets, the number of companies and alternatives. The following issues have been taken up in the literature: the issues of small home demand, weak rivalry between domestic companies, mergers between domestic companies and the important role of resource industries for many small countries.

Reinert (93) for instance believes that the firms of a small country (e.g. Norway) find their most demanding customers abroad. He does not see that the demanding customers should locate in the domestic country and not e.g. in some other neighbouring country. He emphasizes that the companies of small economies from the very start orientate towards the international market, often to narrow niche segments.

In this matter Porter keeps to his original argument. He argues that even if some industries from small countries may export four fifths of their production, their basic ability to innovate lies in the home base and in the domestic demanding customers.

Rivalry.

The critics have pointed out many examples of successful companies from small countries which lack competition in the domestic market. These companies found the market for their products from abroad from the very beginning, and they have succeed to find demanding customers and necessary feedback for their products in international market. On the other hand, there are examples of firms in a large country that have competed very hard, but are not more competitive internationally.

Mergers and acquisitions.

The size of market in small countries limits the number of companies. The examples of industries in highly developed countries, in a fairly close connection with a large international market place,would show that the international market can keep the life of the national champions tough enough to remain competitive after national mergers. The Nordic countries and many internationally competitive companies in them are good examples of this according to Scandinavian scholards, see Penttinen (94).

National resources.

Daly (93) notes that a fairly common feature in the export of these small countries is that a relatively high proportion of natural resource products dominates the export. In such countries the share of export of the total production is high. The individual companies are, however, small in market share. The macro economic factors, like exchange rates or market turbulence of the raw materials, may have major influences on these companies.

National culture.

A national culture is an interesting aspect in the theory of Porter´s diamonds, because it has arisen comments from two directions. Tryggestad in Penttinen (94) writes that it is tempting to interpret Porter to assume that there are specific national companies, secured by nationality of ownership and/or management control and that these companies participate in a system of a higher order that seeks to raise the standard of living for the nation. Tryggestad even claims that Porter formulates "a theory of national cultural homogeneity, that is, a theory of consensus over roles and goals of a nation". Tryggestad argues that a nation may have many subcultures and the subcultures may be closer to other ones in different countries. This argument is meant to point out the transnational nature of diamonds.

But all the scholars do not read Porter in the same way. Van den Bosch and van Prooijen (92) consider that the national culture is not sufficiently included or discussed in the diamond model. They state the cultural setting works through all the determinants, not isolated from them. Therefore they do not want to add the fifth determinant to Porter´s model, but strongly emphasize the importance of the national culture when explaining the differences in the international competitive advantage.

Porter (92) responses to the cultural aspect. The cultural factors often lead to sustainable competitive advantages, because the companies of other nations are unable to duplicate them quickly. The impact of the culture is not direct but occurs through the four determinants of the diamond. The cultural differences are often possible to trace back to the economic performance in a country. The culture and the economy are interrelated. The culture has to be looked from the point of view of a specific industry. A culture fostering one industry may be retarding another industry. And a culture is not static but is changing in time and can be changed. As regards to Europe, according to Porter, there are many cultures and economic areas which have to be discussed separately.

Dynamism.

Porter´s study has been criticized for concentrating on existing industries and not explaining how to commence new clusters. The second feature in Porter´s study is that it concentrates on the relationships between the companies and the markets and on the external competition in general. Porter explains the dynamic changes in external competition and the positive upgrading of clusters in this competition. Porter is generous in explaining how the clusters evolve and how the competition in limited geographical areas promotes evolution of individual companies and industries.

As little as Porter writes about the inter-firm rivalry he explains the internal upgrading phenomena in the company. Due to the shortages in the model of the diamond in understanding the international business, as discussed earlier, Porter does not discuss the international companies and the way they tap their competitive advantages in many countries, see Yetton et al. (92). Porter´s only model for international company is a centralized way managed multinational with a strong home base. Even that is dealt as having a side role in an international market.

According to Yetton et al. (92) Porter has not a theory for a company development. Porter´s work say little about either the dynamics of creating a diamond, or which type of firms might seed it, how they might emerge, or their subsequent pattern of growth and the factors vital for that. Porter does not address how to ensure that more new companies emerge in the upgrading industries, or deal with how to ensure that more new upgrading companies become strategic exporters. Chapters 3 and 4 have particularly discussed these aspects.

The theory of Porter on sequential development of the economy from a raw materials driven growth to an investment driven growth and further to innovations driven growth has also received critical remarks. The general pattern is, however, valid at least in many industrialized countries. For instance the patterns of industrial development in the Nordic countries have followed the model in general terms. As regards to the evolution models of the industries, reviewed in chapter 4, we can understand that individual industries have at any point of time many kinds of companies, but certain types of companies may be dominating at a time an individual industry. In the same way the whole economies may be dominated by one or more individual industry(ies). Porter´s terminology has to be understood on this general level.

Where the critique on Porter´s approach has been weakest ?

The book of Michael Porter (90) is a milestone in the economic theory. The distribution and the repeated applications in different countries guarantee already now the position for the book. The many applications and references make also necessary the misunderstandings and misuses of the theory. The wide exploitation almost necessarily guarantees the criticism which as such has its place.

The next list is gathered on the aspects where Porter is criticized least.

1. The holistic view of Porter on a competitiveness has probably given the book its position.
2. The approach emphasizes the interrelationship between the evolution of industries and the economic development.
3. The whole message of innovation integrated with the upgrading of the factors of production has served an understanding of industries in the development process of economies of nations, particularly on industrialized countries.
4. The evolution and innovation aspect underlines the importance of the specialized factors of production for the competitiveness.
5. It is widely accepted that Porter´s approach is most relevant to mature manufacturing based economies.
6. The point of view of international markets is accepted to be of major importance to the analysis of national economies and industrial developments. The technical way of including the international business is criticized, not the point of view.
7. The approach emphasizes the relationships between the companies, the markets, suppliers, customers, and other companies, i.e. in one word the network. This modern view allows to combine many new aspects to the model.

7.2 Evolution of clusters

Porter identifies two basic types of competitive advantage: cost leadership and differentiation, i.e. price competitiveness and real competitiveness. The real competitiveness is explained with a value chain, five forces of industry competition and the diamond model. The diamond model explains the competitiveness in a national setting. Innovation is a result of determinants in the industrial diamond, and a dynamic industry cluster consisting of innovative capabilities can sustain long term competitiveness. The creation and upgrading of competitive advantage determine success of firms both in the exports of goods and services and direct foreign investments.

When the studies relating to different countries stimulated by Porter (90) have been prepared, particularly concerning the countries of small open economies, a frequent question has been made. What does Porter say about the emergence of industrial clusters? As pointed out already he does not say very much on the internal evolution. Porter was studying mainly mature successful clusters. He has many examples how the clusters may upgrade or deteriorate in the course of time. When explaining the functions of clusters he lists the favourable preconditions for an emergence of a cluster, Porter (90, pp. 159-165).

Table 7.1 Preconditions of the emergence of a cluster - nine critical success factors of a cluster, Reve and Mathiessen (94, pp. 119-125).

1. Time. Successful clusters demand mostly a long time to develop from the comparative advantages and disadvantages present in an economy.
2. Critical mass. An industry has to be fairly large to carry out the breakthrough to the export market.
3. Entrepreneurs and dedicated people. Many successful clusters contain stories of entrepreneurs and the efforts made in the beginning.
4. Demanding international customers. Demanding customers - either domestic or international - are the key determinant for the development of a cluster.
5. Rivalry and cooperation. Rivalry is the basic factor of a cluster. Successful companies often cooperate, however, with the competitors when mutually beneficial.
6. Advanced suppliers. Internationally competitive subcontractors may be a major source of advantage for companies and allow them to concentrate on the core businesses.
7. Flexible organization and management. Flexibility is needed to exploit the opportunities opened to companies.
8. Continuous knowledge development. The upgrading of factors and innovation may continue without limits. The competitive advantages are lost if the upgrading is ceased.
9. National pride. The development easily gets features from national thinking increasing commitment.

A start for the formation of a cluster reflects the competitive strength. Companies in the industry are established around some particular competitive advantage. Under favourable conditions a group of some firms evolve to a cluster. Too good conditions may be, however, a retarding factor for the evolution of a cluster. There are no easy general solutions.

A cluster may also lose its competitive advantages. The upgrading of factors and the innovation pattern may cease. The market conditions may change, because competitors in another country gained some additional positive determinant. The main reasons for losing the competitive advantages have been collected from Porter (90, pp. 166-173).

Table 7.2 Main reasons for losing the competitive advantages of a cluster, Porter (90, pp. 166-173).

1. Deteriorating factor conditions.
2. Conflicting local needs and global demand.
3. Unsophisticated domestic demand.
4. Technological changes lead to severe disadvantages in factor conditions.
5. Continuous under investments.
6. Inflexibility in operations and management.
7. Domestic competition fades away.

The conditions of the enhancement and deterioration of a cluster in the preceding tables are to a great extent mirror pictures for each other which is only logical. The other observation on the both tables is that most of the critical factors listed related to developing or deteriorating clusters are actually characteristics of an environment of a company. This observation already gives a sign that these lists of preconditions give a good starting point for a determination of the crucial factors of the environment of a company for its development.

7.3 Evolution of an engineering company towards an international significance

As the intention here is to build up a framework from the model of Porter which would be suitable for analysing the preconditions of development of individual companies, the framework is based on the strengths of Porter´s approach. At the same time the criticized points are avoided in the model. The companies discussed here are the engineering companies with particular features. The company level framework has to be built to suit the object industry and companies taking into account the next aspects.

1. The framework to be developed is to be applicable to the engineering companies which in their company development are between the initial and full maturity stages.
2. The framework will be used for the engineering companies which may be - depending on a case - the knowledge-based companies already in the beginning, and later on they may evolve to increasingly more knowledge-based, e.g. specialized companies. A part of engineering companies is not, and never becomes the knowledge-based companies, but work in a standard engineering.
3. The specialized factors and their upgrading is a very important precondition for the development of these companies.
4. The customers in investing industries are extremely demanding due to the vital importance of the successful implementation of the large investment projects for each investing company.
5. In the model of Porter the related and supporting industries are consequences of clusters. In the case of engineering, the investing industries are the clusters and the engineering companies are born only because they were needed by the investors. The existence of the cluster structure is behind and serves as a background.
6. The domestic rivalry in the engineering industry is tough as the entry barrier to the industry is low. The international rivalry in the industry is hard as the nature of the industry favours local companies and the internationalizing companies still try to compete on different national markets.

Small diamond of a company

In the Finnish Porter study, Hernesniemi et al. (94)[2], the alone stars or individual successful companies without a cluster background are discussed in chapter 17. The basic notion in the chapter is that a knowledge-based

[2] The alone stars are discussed in chapter 17 of the book. This treatment is based on the unpublished munuscript of Pekka Lehtonen in ETLA, The Research Institute of the Finnish Economy.

company develops an environment around itself which has the cluster types of characteristics. We call it a small diamond, to make a difference between a diamond around an industrial cluster and a small diamond around a knowledge-based company. The small diamond depics a situation, where a knowledge-based company starts its operation by introducing specialialized knowledge to an emerging company. In the next stage the product is taken to the market. If the new products correspond the real need of the market, they sell well and there is a good demand. Sufficient demand is a precondition for the success, because even a high level knowledge and a product do not develop, if the market does not accept new innovative product. The knowledge-based company retards in the shortage of a demand.

The entrepreneurs are using their contacts and create gradually relationships with the supporting industries and companies. The universities and research institutes are often important contacts for the knowledge-based companies.

The rivalry arises at last in the market, if the question really is about a technological innovation. A market with a good demand pulls companies and suppliers. Rivalry is a precondition for the companies to remain active and innovative in the market.

The small diamond is created around the knowledge-based company through specialized know how, sophisticated demand, supporting network and rivalry until a small diamond is complete.

Table 7.3 The structure of a small diamond around a knowledge-based company.

1. Know how or knowledge component which typically exists first for many science-based or knowledge-based companies.
2. Demand component which also has to be the so called sophisticated demand in case of the engineering company.
3. Supporting network consists of the environment of the own company (if that exists) or the service companies in the cluster or in related clusters.
4. Rivalry which includes the own strategy of the company, the selection of the market and the conduct of other companies.

The structure of a small diamond around a knowledge-based company consists of the four basic determinants of competitive advantage that shape the environment faced by a knowledge-based firm.

Many engineering companies work within standard technologies at the beginning of their activities. Later on some of them may develop into very specialized companies through the experience accumulation, references and innovation. These can be viewed as knowledge-based companies, Kässi (96). In case of the engineering companies the emergence of a small diamond often starts from the demand component, particularly so, if an engineering company starts in a large company as an engineering department or as a department for a particular task. The know how is present from the very start, but it develops to the specialized factor only through an accumulated experience. The structure of rivalry and support of the mother company or the supporting services develop to the small diamond in the course of time. When an engineering company is understood as a knowledge-based company, its development can progress from the starting phases only, if the company is able to form an the environment of the small diamond for its surroundings. The determinants of a small diamond are the sources of a competitive advantage in a knowledge-based company. The competitive advantages in a company may remain sustainable if the the small diamond is complete and allows the continuous upgrading of the firm.

The companies are not similar. Therefore the development for each group of companies should be different. The presence of the small diamond can be seen as a precondition for the development of an engineering company to its mature stage within the strategic group where it aims to. It can mean a national engineering company, a market niche engineering company or a specialized supplier company. Essential in the maturity is that the company reaches a significant position within the group where it aims and it has preconditions to maintain sustainable competitive advantage in its own strategic group.

Eight preconditons for a company development

The list of the preconditions of the emergence of a cluster (Table 7.1) can be adjusted for an individual company to develop to a significant company position in its own strategic group.

Table 7.4 Preconditions for a knowledge-based company to develop to a mature position in its strategic group.

1. Time. The time needed for a knowledge-based company to develop from its initial stages to the maturity can be very long. The reason is that everything is based on knowledge and human capacity. It does not change rapidly.
2. Sufficient resources. The resources are needed among others to start marketing abroad and to expand knowledge base.
3. Entrepreneurs and commitment. New engineering companies have to pass a countless number of hindrances which often can be passed only by the urge of entrepreneurs. The commitment to engineering business is needed also from the owners of engineering companies. The development to maturity does demand many sequential steps.
4. Demanding international customers. The arguments of Porter in this matter are directly applicable to an individual company. The purchase occurs from a company at a time. The demanding customers are the key source of an competitive advantage.
5. Rivalry and cooperation. Applied to a small country this means that the companies compete at least in a domestic market. In international bids they can still cooperate to reach a competitive position in large bids.
6. Advanced subcontractors. It is a very valuable thing for a company if it has competitive subcontractors or partners to be set as bench mark for its own activities.
7. Flexibility and capability of the management.
8. Continuous development of the know how.

The fulfilment of the eight preconditions of Table 7.4 is equivalent to the preconditions of Table 7.3. The items have to be understood in the way that fulfilling the preconditions means a creation of the environment where upgrading and innovation are possible. In the same way as with the clusters a mirror picture can be presented from the reasons which would lead to the losing of competitive advantages. The end result in reaching the mature or a significant position in the strategic group can be a great achievement from the viewpoint of a company. This can mean becoming a specialized supplier company, or a market niche engineering company worldwide, or a national engineering company with a limited foreign business share.

8. TOWARDS A MODEL OF ALTERNATIVE PATHS IN THE ENGINEERING INDUSTRY

The integration of a model of the alternative development paths in an engineering industry is the content of this chapter. The model receives its components mainly from the theoretical parts, which have been reviewed in the previous chapters. The empirical information has led to search for typical distinctive strategic behaviours and development paths in the engineering industry. In addition, in the Finnish engineering industry it is observed that the engineering companies have a few distinctive ways to become started, see e.g. Kässi (96). The started engineering companies develop towards the distinctive strategic groups described in chapter 5. In this chapter the conclusions from the presented theories are made and the evident facts in the engineering industry presented, in order to build up a theoretical basis of the development paths or trajectories of the engineering companies.

Before starting there is a question which has to be answered: Why should there be distinctive paths in the company development which the firms should more probably follow than other random patterns. First there is reason to emphasize that a development of the companies is not deterministic, they have a freedom of choice. But given the technologies, the rules of decisions in the market and other business environment the companies tend to make choices to their own benefit which make them resemble certain prototypes. The strategic maps in the industry, as a known theory, are models of these prototypes. In the same way as the external forces are pushing the companies towards certain prototype strategies at the end of the development, they also are affecting the companies in the course of time. When the forces remain more or less constant the companies find certain choices more profitable than others. And the companies find a few alternatives which they believe to lead to the best outcome for them. This is basically the reason that also the development paths tend to receive certain distinctive patterns as the outcomes, the strategic groups of companies. This does not exclude variations in time or behaviour of companies within development paths which comply with the theory of evolution of an industry.

Practically the task to build the development paths of companies means that the development paths with their characteristics have to be depicted between the groups of distinctive start-ups and of the five distinctive strategic groups[1]. The taxonomy considerations in company development, technology change and strategic development will help to find relevant dimensions to pay attention to important features in the development patterns of the companies in the engineering industry. To get started the distinctive groups of the start-ups of companies, and the strategic groups of company behaviour in a “mature” phase[2] are described.

Table 8.1 Alternative groups of start-ups of engineering companies and strategic groups of engineering companies in a "mature" phase.

Alternative groups of start-ups of engineering companies	Alternative strategic groups of engineering companies in a “mature” phase.
1. Local engineering design companies 2. National engineering companies 3. Manufacturing based engineering companies which can be a. small start-up companies in a garage with an innovation and a very narrow market segment (“Innovative companies in a garage”) or b. manufacturing departments in a large company around which an engineering and a turn key delivery business is developed (“Engineering separated from manufacturing”). 4. Engineering divisions or subsidiaries of large companies with many divisions (probably many industries) which become independent in the market operating units and later subsidiaries.	1. Local engineering companies 2. National engineering companies 3. Global engineering companies 4. Specialized supplier companies 5. Market niche engineering companies 6. In-house engineering service departments

1 In the European study, Idom (92), four distinctive groups were formed. We have included one more strategic group due to the specific conditions in the Finnish market following Kässi (96).

2 The word “mature” refers to a development of a company, not an industry. A company is never mature in the meaning that it does not need to develop, therefore the word has been used in quotation marks “mature”. A company can be “mature” in the meaning that it achieves the definition of a strategic group which probably is also evolving in the course of time.

Multivariate model of companies and industries

As pointed out earlier an industry very seldom is technologically and for other reasons a homogeneous monolithic structure, but appears in closer consideration to be heterogeneous and divided into parts. Within these parts the companies may resemble each other, at least in certain respects.

An effort has been made before to review the theoretical aspects which might be of relevance to build up a tentative model of alternative paths in engineering. Some relevant theories have been found. In the building of industry paths it is appropriate to remember that the companies always are multivariate systems. They have one group of inputs and another group of outputs. The model building, at its best, can solely consist of the most relevant variables and then only give some kind of a picture of the reality. A few variables can completely never cope with the reality, and each output is dependent on a multitude of factors. The adjective tentative is most appropriate to describe the state of knowledge for the time being.

8.1 Alternative modes of start-ups

<u>Local engineering design companies.</u>

Local engineering companies are typically started by entrepreneurs. Local engineers start to supply technical engineering services under their own or a newly established company name. The entry barrier is low in engineering design business. Often the engineers have a very good local personal network within the local decision makers. Their experience background is probably strong for that type of work in which they start as a company. The local engineering companies can also be involved in the project management services, but very seldom in turn key deliveries since the risk taking ability of these companies is inevitably low.

Local companies are limited by size. Their strength is that they really know the local needs and the market. As the persons are known as experts, it is very easy to ask for their services and to trust them. In the local companies a particular feature of an engineering industry is well exemplified, i.e. the nature of the business is personal and local. Technical services are rather bought from well-known companies and people. The speciality of these companies is the locality, the customer industries may represent many industrial branches in the area.

As all the services are not locally available, and as many projects are so large that local companies have not enough resources, larger firms are also needed.

National engineering companies.

The national engineering companies often are very similar to local companies. The national engineering companies can be the start-up companies which have initially more resources than the local engineering companies. Therefore they can take larger projects to carry out. For example if an engineering company receives a design and project management work of a paper factory in its early phase, it can be interpreted to be a national engineering company as the project is of national importance. The company remains a national engineering company even though it grows, starts other domestic design offices or starts some export activities.

The range of products consists of technical design, implementation planning of investments, technical expert services and studies and implementation services of investments. Particularly at the beginning, the services are sold on a time basis. This reduces the risks and eases liquidity of a starting company.

Specialities of national engineering companies become most often from industrial areas which are widely represented within the customer industries in a domestic country. Gradually they may start serving also other customer industries. The national companies develop good working relationships with the national decision makers.

Innovative companies in a garage.

These companies are small start-up companies with entrepreneurial background. They are specialized in a very narrow market segment. The entrepreneurs have a background from the business area in which they continue with their new innovative product organized to a newly established company. At the very beginning, it is clear that the company has to start selling the products to a very wide market and many countries, otherwise the market volume is too small due to the narrow market segment.

The typical feature in these companies is that the product innovation is related to a tangible product, often a capital product. The credibility of the small company is, however, too low to sell the innovation as a design service product. Often the entrepreneurs have made their innovation in a very concrete way: they have built the equipment to prove that the innovation works, instead of making a great amount of technical and scientific tests or experiments. The products are also sold to the customers as turn key deliveries including the innovative features.

The appropriation of the innovation can be made by patents or by building the innovative feature into the equipment constructed. Then the innovation is sold as an embedded part of the equipment or as a related service or technology transfer to the sold equipment. The customer gets the benefit in purchasing the equipment and a small company can charge for the innovation in the equipment price. The functions which the innovative company in a garage has include technical design, manufacturing (or assembling), research and development, marketing and sales, implementation of projects, and possibly after sales.

The key to the competitive feature of the market niche company is, besides the innovation, the small size of the market segment. The larger competitors do not make the effort to enter the small market as the effort would not pay back. The potential small competitors have not resources or competitive innovation to enter the segment. A large market share, even in a narrow worldwide segment, gives the benefit of a cumulative learning and makes the segment defensible for a company.

Engineering companies separated from a manufacturing.

This type of engineering service is started from a manufacturing base. In this case it is started in a large company environment. The large company has a manufacturing unit of a product, an engineering unit is established aside. The engineering unit offers technical design services, project management services and turn key deliveries of the particular product. The marketing and sales of the particular product may be organized by the engineering unit. The manufacturing and the engineering are separate businesses in a large firm, but they work together. The engineering unit may also cooperate with other organizations within the large firm or outside. The organization reflects the need to separate the manufacturing and the engineering from each other in a particular case.

The nature of the product (innovation) as well as the way of doing business resemble the one of a small garage firm. The manufacturing unit may produce some other products, too. The organization of the innovative product to an engineering firm identifies the product with the particular organization and people. The engineering unit may differ by the structure of personnel from the manufacturing.

The establishment of the separate engineering unit (or even separate company) for the particular product is the sign of the emphasis that the mother company sets to the particular product.

Engineering divisions or subsidiaries of large companies.

The large companies used to have major organizations to take care of the investments of the firms. The large firms learned to use engineering consults in Finland only 30 years ago. The organizations were and are in-house engineering firms competing with outside engineering companies. Internally the services of in-house engineering divisions are technical design, planning of investments, implementation of investments, commissioning of plants and other project management services. Practically the in-house engineering division is carrying out the investments of the mother company at its risk. The in-house engineering divisions might have some other functions within the large companies like e.g. an entry to an international market or product development activities.

Gradually many companies, not all, let also the in-house engineering units start the competition in an open market for the projects. Many of these organizations have also been corporated. The engineering subsidiaries supply technical engineering services and turn key deliveries to internal customers and outside customers. These organizations can be large companies. They may have up to hundreds or even one thousand experts. They may have had large project implementations in the domestic and other countries. Their turnover at the beginning of the company life may total from hundreds of millions to a thousand million or more Finnish Markka. However, their experience in operations in the open markets at the beginning is limited, they may have only one important customer, the mother company. The experience in the international operations is also restricted. The technical experience, capacity and potential must be vast in many cases.

In Finland these subsidiaries of large companies are mostly tied to process industrial production companies. The know how of these companies is related to the systems knowledge to build up well operating total entities of industrial plants. This know how includes the process know how in the particular field of technology. Often the availability of the operation and maintenance know how of the process industry within the mother company is the competitive edge to the engineering subsidiary. The mother companies of process industry seldom have own manufacturing units of components for the fields they represent, nor company culture to start equipment or component manufacturing of their own.

8.2 Relevant taxonomies of companies and development paths

Earlier different kinds of taxonomies of companies were discussed. The task is now to build a model for alternative development paths for groups of companies in an engineering industry. Some dimensioning is needed to depict the paths to be developed. Because the engineering companies have to fit to the hypothetical paths to be developed, the assumption is that the same categorization can be used for the development paths as for the technological changes.

The different kinds of taxonomies from the studies of innovation and technology change were sourced, as well from the research of strategic management. The studies of technology led to the hypotheses of basic technological trajectories (i.e. within innovative activities). These do have relevance to the effort in building development paths in engineering 1. by giving the model for the construction of industry paths (instead of technology patterns), 2. by giving components to the construction of "specialized suppliers" due to overlapping the task of this study and 3. by catalysing new thinking concerning an induced engineering group of companies[3].

[3] The engineering companies are to great extent related and supporting companies to the investors. From the viewpoint of technology the investors are carrier branches of technology and engineering companies are induced branches of technology, as pointed out earlier.

Table 8.2 Summary of dimensions for different categorizations of companies.

Dimensions for categorization in technology change and innovation studies	Dimensions for strategic maps	Characterization of basic trajectories composed on the base of innovative activities occurs along the determinants[1].
1. Age of a company 2. Size of a company 3. Rate of diversification (range of products and services) 4. Rate of internationalization (market spread of countries)	1. Range of products 2. Geographic market area 3. Size of companies 4. Distribution of company sizes 5. Fragmentation of markets 6. Rate of internationalization 7. Specialization by customer industries 8. Degree of complexity of projects 9. Ability and willingness to carry risks	1. Source of technology 2. Economic and technological trade-offs within a trajectory 3. Sectors of products 4. Patterns of company behaviour. Strategic issues for the companies.

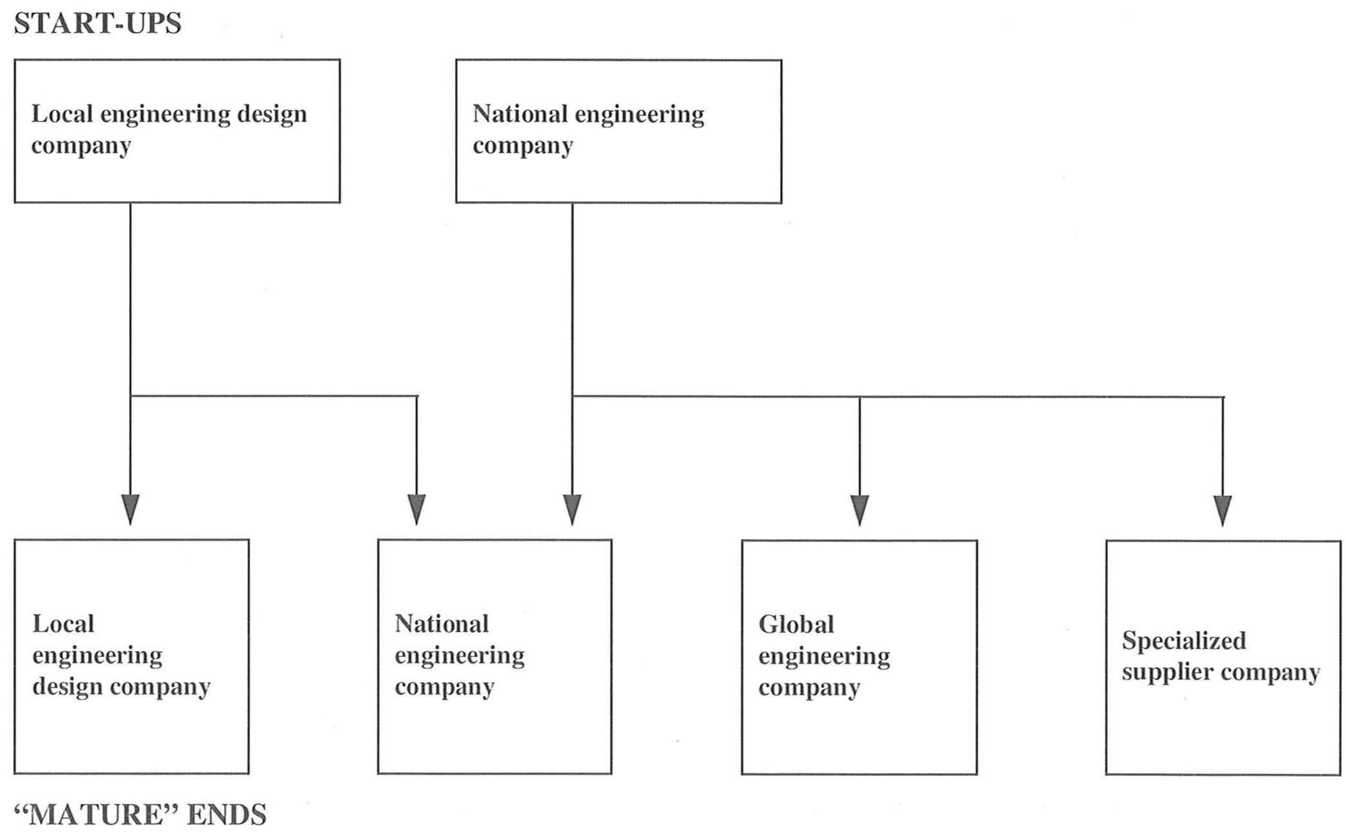
[1] The nature of the determinant is different from the other columns. The determinants are predominantly the decision rules while the other columns present directly dimensions for categories.

8.3 Company development paths in the engineering industry

To help the development of company paths (i.e. company trajectories in an engineering) the discussion in this study is divided to two parts to clarify the presentation. First, the study deals with the companies which started as local engineering design firms, and the companies which started as national engineering firms resulting in different ends of strategic groups, secondly, the families of the innovative companies in a garage, the engineering separated from a manufacturing, and the engineering divisions or subsidiaries of the large companies are discussed and developed in respect to trajectories at an industry level. The discussions and observations are combined at the end.

The selection of paths to be discussed and considered is based on experience. Theoretically there might be also other alternatives, but in practice they do not exist. The paths in which the development is not significant, e.g. when a national engineering company remains a national engineering company, or a local one remains local, will not be discussed. The alternative paths are discussed in an order referring to the figures.

Figure 8.1 Alternative development paths for local and national engineering companies.



A development path from a local to a national engineering company

Start-up (a local engineering company)

- small sized staff, often under 50 people
- local market based on local industrial network
- no foreign trade
- range of services: mostly technical design, expert works, sometimes project management services
- minimum risks
- a local niche is defendable, because the market is too small to interest potential competitors.

Development steps

- growth based on domestic demand
- strengthening of management
- development of management systems
- widening of services by gathering experience. Project management services are included to services of the company.
- a focus or diversification by industries of a company depend on the structure of the domestic industry
- minimum risk approach
- beginning of foreign operations.

An end result (a national engineering company)

- medium sized personnel, over 100 people
- many local offices in domestic country
- export started, 10 to 15 per cent export share of total turnover
- size and infrastructure developed enough to begin internationalization process
- range of services: very wide range of services
- some speciality or technology for which good references attained from domestic market or close geographical areas
- low level of risks
- competitive advantages related to domestic country decision making and to a knowledge of local or national conditions
- technologically a national company follows a lead of investors, and takes a role of intermediator of information and accumulator of experience. The company exploits an incremental learning of technological change in customer industries.

A development path from a national to a global engineering company

Start-up (a national engineering company)

- medium sized personnel, over 100 people
- many local offices in domestic country
- export started, 10 to 15 per cent export share of total turnover
- and infrastructure developed enough to begin internationalization process
- range of services: very wide range of services

- some speciality or technology for which good references attained from domestic market or close geographical areas
- low level of risks
- competitive advantages related to domestic country decision making and to a knowledge of local or national conditions
- technologically a national company follows a lead of investors, and takes a role of intermediator of information and accumulator of experience.

<u>Development steps</u>

- growth of turnover
- expansion of services in specialized field of industries
- expansion of areas of target customers to many industries
- building up an international network of offices and subsidiaries
- building up a management systems for international operations
- a massive accumulation of references all over the world
- ability to assume very special and complex or large international projects
- accumulation of experiences in technological change in customer industries. Technologically a global engineering company behaves normally as a company in an induced branch. But an accumulation of experience sometimes allows to influence strongly on the decision making of the customers.

<u>End result</u> (a global engineering company)

- large sized personnel, over 5000 people
- large turnover coming from diversified industries
- significant offices or subsidiaries abroad
- exports more than 50 per cent
- main activities often in the fields of infrastructure
- industrial customer branches often in chemical, petrochemical, pulp and paper, energy, power plants
- capacity to carry out large projects (large company size, ability to influence on financing possibilities of a customer, ability of taking certain risks in large projects)
- large number of references
- references in large and technically specialized projects
- ability to take advantage of financing by governments and multinational projects.

Some comments are needed on the dimensions relating to building the alternative paths in the engineering industry. These comments relate to development of the local and national engineering companies. Basically the local and national engineering companies are very similar companies. The only difference between them is their size reflecting the size and complexity of projects. The company management has a freedom to decide whether the company grows or remains a small local company.

When a company starts to develop its operations, a natural order would be to expand first the range of services and to widen then the market area. In the case of a small engineering design company this would mean the beginning of offering besides technical design services also implementation planning of investments, consulting and studies, and project management services. The local nature of engineering business is the reason for the expansion of a product range before starting export. The expectation is that the credibility of a technical consultant abroad would require the references on many kinds of tasks as an engineering design company in a domestic country. Engineering design companies do not generally start to offer turn key projects, as the risks are at a higher level in those projects.

Gathering references in a domestic country would, sometimes, reflect to a variation of tasks of a company so that a national engineering company would have a very diversified set of services to offer. When a growing turnover has to be received in one country, various tasks are to be done in different industries. Only after some experience in a foreign market an engineering company may have some perspective to make choices on customer industries and target countries. A company may then form a strategy for further internationalization. When fewer industries are served, a cumulative experience is collected to form a barrier for potential competitors.

The evolution of a national engineering company requires a successful acquisition of knowledge in many areas: a global company has to master more than one industry, it has to be capable to manage large complex international projects, it has to manage its own organization in many countries and cultures. It has to balance its growth and solidity in a fast change.

Technologically the local or national engineering companies are serving investing industries which are the carriers of technology. Most of the time, clearly over 95 per cent of the time, the investing scale intensive industries experience a period of incremental technical changes. The investors gather the experience and improve the efficiency. The learning of the customers also concerns the technical consultants increasing their up-to-date know how on operations of customer industries. The accumulated knowledge of the technical consultant is available for the next customers as improved services.

In a few occurrences, less than 5 per cent of the time, an industry may experience radical technological innovations. The investors take advantage of these major technological changes in a due order. If an experienced technical consultant, an engineering company, occurs to be working with the investor in this kind of a project, it receives an invaluable experience from a new radical innovation. If this happens to a national engineering company, it would probably receive a great competitive advantage over other competitor engineering companies. This would inevitably help the company to grow and expand its international operations to become an international engineering company. This argumentation is in congruence with Lovio´s model of the cumulative and irregular cycles in the evolution of technology. The role of an engineering company could be accomplished successfully as an accumulator, a combiner or a transferrer of technology, even if the source of technology would change. In the cases of scale intensive industries the innovations are coming either from specialized suppliers or from a scale intensive industry itself. This would also explain why some engineering companies are able to move from a level of activities to a larger scale of activities and others are not. This explanation would not leave all the credit to competent management in the first group of companies, only a part of it.

In the terminology of Pavitt a radical innovation or a major technological change could create the technological trajectory in an investing industry. This would mean that new rules to decide on technological and economic trade-offs in an industry might appear.

A development path from a national to a specialized supplier company

Start-up (a national engineering company)

- medium sized personnel, over 100 people
- many local offices in domestic country
- export started, 10 to 15 per cent export share of total turnover
- size and infrastructure developed enough to begin internationalization process
- range of services: very wide range of services
- some speciality or technology for which good references attained from domestic market or close geographic areas
- low level of risks
- competitive advantages related to domestic country decision making and to a knowledge of local conditions
- technologically a national company follows a lead of investors, and takes a role of intermediator of information and accumulator of experience.

Development steps

- growth of turnover
- expansion of services in specialized fields of industries
- expansion of areas of target customers to many industries
- building up an international marketing network
- building up a management systems for international operations
- accumulation of experiences in technological change in customer industries. The cumulative experience gives chances to start developing own technology beginning with the customers of scale intensive production from process innovations and systems innovations, and later on continuing with product innovations for capital goods.
- a conscious strategic decision to take risks in product development instead of international market development
- references all over the world

End result (a specialized supplier company)

- medium to large amount of personnel
- range of products: very specialized according to the sectoral needs
- marketing and sales to the worldwide markets

- area of specialization related to worldwide competitive industries in domestic country
- main activities: process and detailed engineering of industrial plants
- turn key deliveries
- competitive market position: a few suppliers of competitive technologies worldwide
- intense experience in R&D work in the context with the customers of a domestic market, and the worldwide market leaders
- appropriation of technologies by patents and/or rent manufacturing.

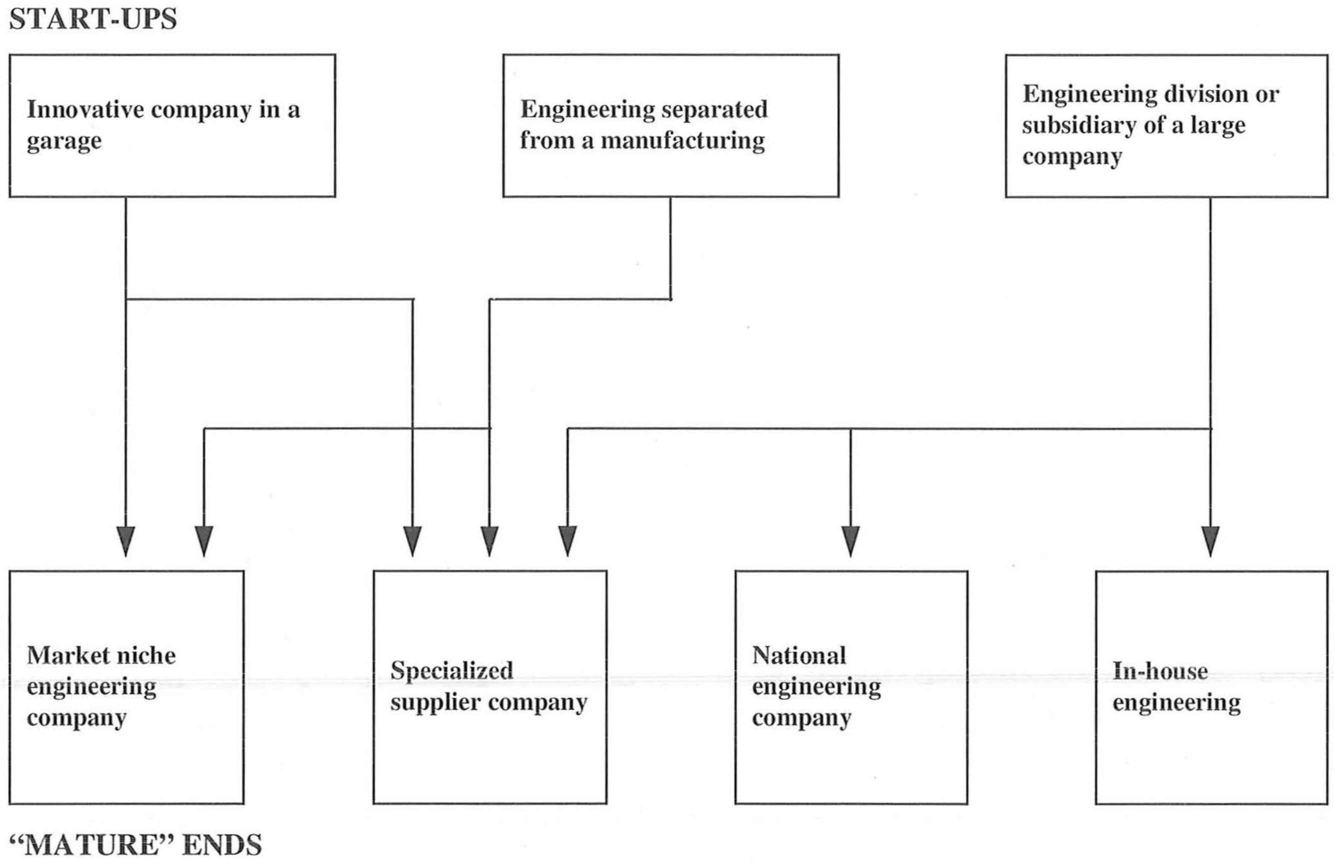
The description of the trajectory from a national engineering company to a specialized supplier company is not a very probable or normal path. Basically the company begins to develope as a national engineering design company and ending to a global engineering company. At some stage the management of a company decides to take rather product development risks instead of internationalization risks. A reason for this decision may also be that the management considers a technological opportunity open to a company.

Why should the management of an engineering company change its way of thinking so radically? Some reasons may be the opportunities that a possible technology change might open a window for an engineering company. An engineering company may be involved with a technology change through an implementation of a radical innovation as explained before. The other possibility is that, at some stage, a cumulative experience in a row of implementations of investments in an industry gives an engineering company such an experience that it cannot avoid exploiting the experience for its own innovations.

Pavitt´s point should be taken up here. His argument has continuously been that the technology is partly company-specific and cumulative. He has collected examples of cases where a row of incremental changes finally led to a radical change. An engineering company accumulating the knowledge in the course of time is in a good position to make innovations, based on a cumulative experience.

The other group of starting companies is more heterogeneous than the group of local and national engineering companies. A common feature within these companies is that they all are from the start project suppliers.

Figure 8.2 Alternative development paths for innovative companies in a garage, engineering companies separated from manufacturing of a large company, and engineering divisions or subsidiaries of a large company.



A development path from an innovative company in a garage to a market niche engineering company

<u>Start-up</u> (An innovative company in a garage)

- small personnel at the beginning
- a company is at the beginning intensely product and technology orientated, otherwise it would not exist

- a very narrow market niche in a very wide geographical area as a target market already at the beginning
- a product is build around one or a few innovations
- export is started from the first projects
- simple organization; one product, wide market
- an entrepreneurial spirit

Development steps

- a first step is to develop the product (rather to a known customer who also finances the first project)
- to sell and build the first reference
- to start marketing and sales according to resources to foreign countries
- to expand carefully the organization only with committed people
- to keep the entrepreneurial management and culture
- technologically a small company is very dependent on the innovation around which the company was established. In this group of companies the basic know how of a company often consists of components from a specialized supplier and information intensive trajectories combining machinery technology with information technology.

End result (a market niche engineering company)

- a number of personnel is small or medium sized amounting from 50 to 200
- selected market and customers: a narrow worldwide market segment. The segment is, however, big enough for a small company.
- technology know how in a very narrow area
- technology and innovativeness is often in the field of equipment technology
- the technology is often sold as an embedded technology in the equipment and as technology transfer in a training programme
- the technology is sold as a part of equipment in turn key deliveries.

A development path from an innovative company in a garage to a specialized supplier company

Start-up (an innovative company in a garage)

- small personnel at the beginning
- a company is at the beginning intensely product and technology orientated, otherwise it would not exist
- a very narrow market niche in a very wide geographic area as a target market already at the beginning
- a product is built around one or a few innovations
- export is started from the first projects
- simple organization; one product, wide market
- an entrepreneurial spirit

Development steps

- first step to develop the product (rather to a known customer who also finances the first project)
- sell and build the first reference
- start marketing and sales according to resources to foreign countries
- expand carefully the organization only with committed people
- keep the entrepreneurial culture as long as possible
- technologically a small company is very dependent on the innovation around which the company was established. The technology base is expanded always when possible. In this group of companies the basic know how of a company often consists of components from a specialized supplier and information intensive trajectories.
- if the company is lucky and the market niche starts to grow rapidly, or the applied technology is applicable in another niche or sector, an innovative company may grow to a market niche engineering company, and later on to a specialized supplier company. The difference between a market niche engineering company and a specialized supplier is in the scale of business, size of resources, size of projects.
- a successful acquisition of additional resources

End result (a specialized supplier company)

- medium to large amount of personnel
- range of products: very specialized according to the sectoral needs

- marketing and sales to the worldwide markets
- area of specialization related to worldwide competitive industries of domestic country
- main activities: process and detailed engineering of industrial plants
- turn key deliveries
- competitive market position: a few suppliers of competitive technologies worldwide
- intense experience in R&D work in context with the customers of a domestic market, and the worldwide market leaders
- appropriation of technologies by patents and/or rent manufacturing, or by own manufacturing.

A development path from an engineering division or subsidiary of a large company to a specialized supplier company

<u>Start-up</u> (an engineering division or a subsidiary of a large company)

- medium or large sized personnel
- a good reference base in own company projects
- range of products: engineering design, services of technical know how, and project management services
- ability and references on turn key projects acquired under the umbrella of a mother company
- R&D work within the mother company research units may support the development of an engineering unit
- technology normally closely bound to the investments of the mother company. Know how generally in systems integration to build well functioning whole plants as the main aim reliable performance and good cost efficiency.

<u>Development steps</u>

- the first step is to develop marketing and sales capabilities for operating in an open market
- to establish project marketing channels to target markets
- to establish own international network with suppliers, customers, and sources of information
- to build up and to secure the commitment of a mother company to engineering business which is totally different from a scale intensive process industry

- to develop a feasible firm-specific technology strategy. The induced technology from an investing (customer) industry, perhaps added with some systems integration and process technology know how, is not sufficient for a specialized supplier.
- to combine the opportunities of engineering and R&D effort within the same large company. The engineering division is very closely tied with the induced technology of the mother company. The problem is to build technologically a bridge from a scale intensive trajectory to a specialized supplier trajectory.

End result (a specialized supplier company)

- see other boxes

A development path from an engineering division separated from a manufacturing of a large company to a specialized supplier company

Start-up (an engineering separated from a manufacturing division of a large company)

- a large company has a manufacturing division which produces equipment or machinery with reasonable potential markets
- an engineering division is established, for one or another reason, aside a manufacturing to take care of design, sales and marketing, project management services, and turn key deliveries of whole plants
- small or medium sized personnel
- a manufacturing company may also have other tasks or products within a large company

Development steps

- to develop marketing abilities
- to acquire capabilities for engineering and turn key deliveries
- a new engineering division has support and commitment of a mother company, and perhaps the resources
- technologically the product base is already at the beginning in a specialized supplier trajectory. Therefore the start is easier in the technological respect than for an engineering division driven by technological thinking of a scale intensive process industry.

- R&D work within the mother company research units may support the development of an engineering unit
- in a minor scale development may lead to a market niche engineering company.

End result (a specialized supplier company)

- see other boxes

The two issues require comments: the starting of export and foreign operations, and the technology change in the different development paths.

The export market is inherent to an innovative company in a garage born in a small country with limited markets. The entrepreneurs do know when they make the innovation that the product will not have market in a small country. Therefore they inevitably think of the possibilities to start the export from the very beginning.

The conventional wisdom of the traditional Finnish companies teaches that the export is started from the neighbouring countries (both geographically and culturally), later on the export target countries are farther away from a domestic country, Luostarinen (79). The traditional wisdom also teaches that the export is started with easy and simple operations, and the variations in operation modes are expanded only in a later stage. The new research results, however, show that small and medium sized companies with sophisticated products may start their export operations in any country in the world. The market pull helps to find customers even in far away staying countries for the innovative products within a narrow niche market, Härkki et al (95). The operation modes have to be selected to suit the product range of the company.

This result is taken as given, and the development paths do not include any specifications on target market selection. This may be true for innovative, specialized products and installations. It is less valid for the "usual" engineering work like engineering design, services for investment planning, planning for investment implementation and project management services. These service products may probably find customers in close countries and markets. The case of a turn key project is in the middle of the extremes. Small innovation based machinery can be delivered to distant countries even as turn key packages, if the importance of an innovative component is dominant in the delivery. But the larger the investment is, the more difficult is the purchase decision. Therefore the large turn key deliveries require well established marketing channels in the target countries, whether close or far away. As the resources are limited for any company, the geographical and cultural distance is a factor in selection to build up the marketing channels to alternative countries.

The innovative companies in a garage and the engineering companies separated from a manufacturing are technologically in a supplier culture (in a contrast to a scale intensive) from the very beginning. They have learned to think in terms of product innovation. They know the risks of product development and turn key deliveries. Somehow, the suppliers of an equipment or a whole plant also find ways to solve the problems of building the first industrial scale references for a new type of equipment or processes. These two types of company families develop towards the specialized suppliers trajectory, they make continuous efforts to improve the performance of their equipment, and try breakthroughs of radical innovations. To their unfortune those radical innovations are rare. But the cumulative technical knowledge may lead them to breakthroughs and close to radical changes.

As the borderline between the market niche engineering companies and the specialized suppliers is not clear, or is related only to the size of companies or projects, an engineering separated from a manufacturing can also end up to a market niche company.

The engineering divisions or subsidiaries of large companies can be large organizations with a concentration of a wide knowledge-base. The technology base is closely related to the investments of mother companies. The mother companies represent a scale intensive industrial companies which aim at the reliable production efficiently and at the low cost operative performance in their investments. A common innovation base of mothers and subsidiaries is in process innovations and systems integration. Another strong feature in the technologies of these companies are the R&D centers maintained by the mother companies. The experience of cumulative gathering of operation and maintenance in the processes of the mother company can be considered as third characteristics and strength.

The opportunities opened by a technological change to engineering divisions or subsidiaries of large companies should be seen in the light of the mentioned strengths. The chanches of the exploitation of technology change through accumulation of incremental changes and experiences, and radical innovations, are best for the engineering subsidiaries of large companies, compared with all the other discussed company groups, i.e. the innovative companies in a garage, the engineering separated from a manufacturing, and the national engineering company. Therefore the probability of a successful development path from an engineering subsidiary to a specialized supplier is the highest, whereas from a national engineering to a specialized supplier it is lowest. The chances to make successful development paths are in the middle of the extremes from an innovative company in a garage to a specialized supplier, and from an engineering separated from a manufacturing to a specialized supplier. The chances of successful development paths of these companies, the innovative and the engineering separated from manufacturing, are better to a market niche engineering company than to a specialized supplier company.

The engineering organizations of large companies were established and maintained when the mother companies were continuously investing. In a non-growing market, the domestic investments remain much lower. When the engineering divisions are corporated, and facing these new market conditions, they meet the questions of the product range and markets. The market wide enough can only be found in foreign countries. If they want to be competitive in a current company size and in foreign open markets, they have to strengthen the product base. This necessarily means own products. As the market conditions push the strategy of a newly established engineering company towards a mode of a specialized supplier company, it may decide to try the change of technological trajectory: from an induced by a scale intensive to a specialized supplier trajectory.

To change both - the market strategy and the trajectory - is difficult. They both seem to be necessary to be competitive in an international market-place. The real commitment of the mother company is needed to make the changes happen. But the alternative is not attractive, because it means to become a national engineering company, and to limit the size of the company to a size suitable to a domestic market. To remain an in-house engineering company is not a stable option, because sooner or later an in-house division turns uncompetitive.

In principle, an engineering division or a subsidiary of a large company could also develop to a global engineering company. This development has not been considered probable for two reasons. It would not solve the problem of a domestic subsidiary. It would also be incompatible with the risk taking model of a engineering subsidiary, which is one of the turn key suppliers, whereas global engineering companies are normally suppliers of engineering services.

The choices in technology acquisition are between the product purchases, the product development and the product licensing. The purchase of technology or products is not an easy matter. Either the available products are not attractive, or they are too attractive and highly priced. The path of product development is long and insecure. The licensing has its limitations. Many companies try all these methods, and combine them a company- specific ways. The appropriation of technologies can be made by patents or other ways so that the ownership of products does not necessarily mean own machinery manufacturing shop.

Another alternative possibility to combine resources of an engineering company which designs and supplies turn key deliveries, and a strong component producer is a strategic alliance. Strong component manufacturers tend to have many potential partners, therefore an alliance to an engineering company is not either an easy way.

Summary

The alternative development paths for engineering companies have been developed from the theory of a firm. The theory of industry has been utilized to understand better the development on a company and industry level. Particularly, the technology studies were exploited due to the technical nature of engineering organizations. The other field of studies exploited were the studies of management and strategy. The theories of industrial evolution utilized so far helped to understand the endogenous evolution of the companies within the development paths, and to some extent the exogeneous development of the paths.

9. CONVENTIONAL APPROACH TO THE ENGINEERING INDUSTRY

9.1 Plan for the treatment of the empirical material

In chapter 9.2 an overview, a short summary, is given of the engineering industry based on the available empirical cases. The continuation of the treatment of the empirical data will be as follows.

The best way to structure the treatment of the empirical material without doubt would be to follow the model of the alternative sectoral patterns. The group of the object companies and the case material is, however, so limited that many paths would receive only a few examples. This would give a too scattered picture of the whole industry. The ability to draw at least some general conclusions from the empirical observations is ensured by first treating the material as a whole, and then adjusting it to the developed industry path model. As already proposed the material falls on the field of the presented model.

In chapter 9.3 the products and services of different kinds of engineering companies are discussed. The evolution of services over time reflects the evolution and sophistication of the industry towards more demanding supply.

In chapter 9.4 the start-ups of the different companies are seen. The organization of the companies was changed many times as a reflection of growth, internationalization and change of role within a large corporation. Especially the roles of the divisions or subsidiaries will be a subject of discussion, as the changes in the roles are explicitly expressed.

Chapter 9.5 discusses various aspects of the evolution of the companies. The points of views to be reviewed will be the target markets of the studied companies, the evolution of internal activities and their reflection in supplied services, the self-sufficiency of the technology in the engineering companies and the relationship of the engineering companies to a manufacturing.

The whole chapter 9 consists of a conventional industry study approach to an engineering. Chapter 10 applies the developed frameworks to the company cases.

9.2 Overview of the industry by case studies

At the beginning, a main categorization within the companies already used during the collection of the case material is presented. The first categorization relates to the scope of responsibility which the engineering companies are willing to take for the investment project.

1. Engineering design companies do technical design, sell expertise and project management services for the different phases of implementation of investments of the customer. The engineering design companies do not take the final responsibility for the technical and financial success of an investment. They can take care of the project management of a project, but they do it at the risk of the investor and, exceptionally, at the risk of the supplier - but not at their own risk.

2. Engineering project companies are organizations that supply projects or parts of projects as turn key deliveries. Engineering project companies take the technical and financial responsibility for the success of the project and carry the relating risk. At some stage at the completion of the implementation the responsibility and the risk are transferred to the customer or the investor.

The engineering design companies of the first category are divided to three groups according to market areas:

- local engineering design companies (D1)
- selectively international companies (D2), i.e. engineering design companies with the main interest in the domestic country and selectively in other object countries
- global engineering companies (D3), which are ready to perform works everywhere in the world.

Engineering project companies of the second category are also divided to three groups:

- small engineering project companies (P1), the personnel of which are generally under 100 and which are active besides in the domestic country also in other selected countries in implementation of investment projects. The projects are small or medium sized deliveries or parts of deliveries on a turn key basis. In these cases of the study, the companies often are divisions or subsidiaries of some large industrial company.
- project supplier companies are medium sized or large project companies (P2) the personnel of which are from 100 to 1000 and which are active in the domestic country and in other selected countries supplying projects on a turn key basis. They have normally emerged from an industrial company carrying out the investment projects of the mother company during a long period of time. Normally, this type of a company mainly uses the components available in the market to integrate the projects.
- component producers are engineering project companies (P3) which actively sell their own products world widely. The turnover mainly consists of the turn key projects in which the own products have an essential part. The companies may have large personnels.

The groups helped to collect the data and material and to categorize it in a meaningful way.

Overview of the engineering industry

Engineering design and planning have existed since industrial activities and investments have been carried out. The in-house engineering departments were minimized or decreased in the Finnish industrial companies in 1950s and 1960s. Until that period the industrial companies tried to carry out everything themselves. At the same time, the same companies started to hire outside engineering consultants to help in their investments. Therefore separate engineering design and project companies started to appear in Finland as late as in 1960s. The appearance of the separate engineering companies was enhanced besides by the foreign models also by the fact that the full fledged engineering departments were very costly to maintain.

Altogether the case material includes 22 companies. In 1993, 14 of them were divisions and subsidiaries bound to the industrial companies.

The evolution of the industrial structure and the age distribution of companies in the material is to be depicted by the amounts of companies:

- in 1965 the cross section picture included 4 companies
- in 1975 the cross section picture included 13 companies
- in 1985 the cross section picture included 17 companies
- in 1993 the cross section picture included 19 companies.

Companies may enter and exit the industry. In addition, the entities may enter the industry and the statistics, when the engineering divisions are collected from small dispersed parts of engineering in a large company. Before 1965 the engineering was only exceptionally organized as a separate whole or a subsidiary. As regards to the age distribution of the units or the engineering companies, the small group of examples show that the Finnish engineering industry is about 20 to 30 years old.

In this study, the company cases in 1993 are grouped according to the categories presented in Tables 9.1 and 9.2.

Table 9.1 Engineering design companies grouped according to the target markets in 1993.

Type of engineering design companies	Engineering company
Local engineering companies (D1)	Alte
Selectively international engineering companies (D2)	Ekono, Projekti-insinöörit, Rintekno
Global engineering companies (D3)	Jaakko Pöyry

Table 9.2 Engineering project companies in 1993 grouped according to the ownership and the project size.

Type of engineering project companies	Engineering company
Small engineering project company (P1)	Finnsugar Engineering, Raisio Engineering, Kemira Engineering, Metra Engineering, Valiotekniikka Engineering, Roxon, Kuusakoski Engineering
Project supplier (P2), often medium sized engineering project company.	Neste Engineering, IVO International, Rautaruukki Engineering
Component producer (P3). The core products in the turn key deliveries mainly own designs.	Partek Engineering, Outokumpu Technology/ Engineering, Kone Wood

Categorization is tentative. The boundary between P1 and P2 is vague.

Change of turnover

The turnover of the engineering in Finland has developed as shown in Table 9.3. All the original data used in chapter 9 is given in appendix 1.

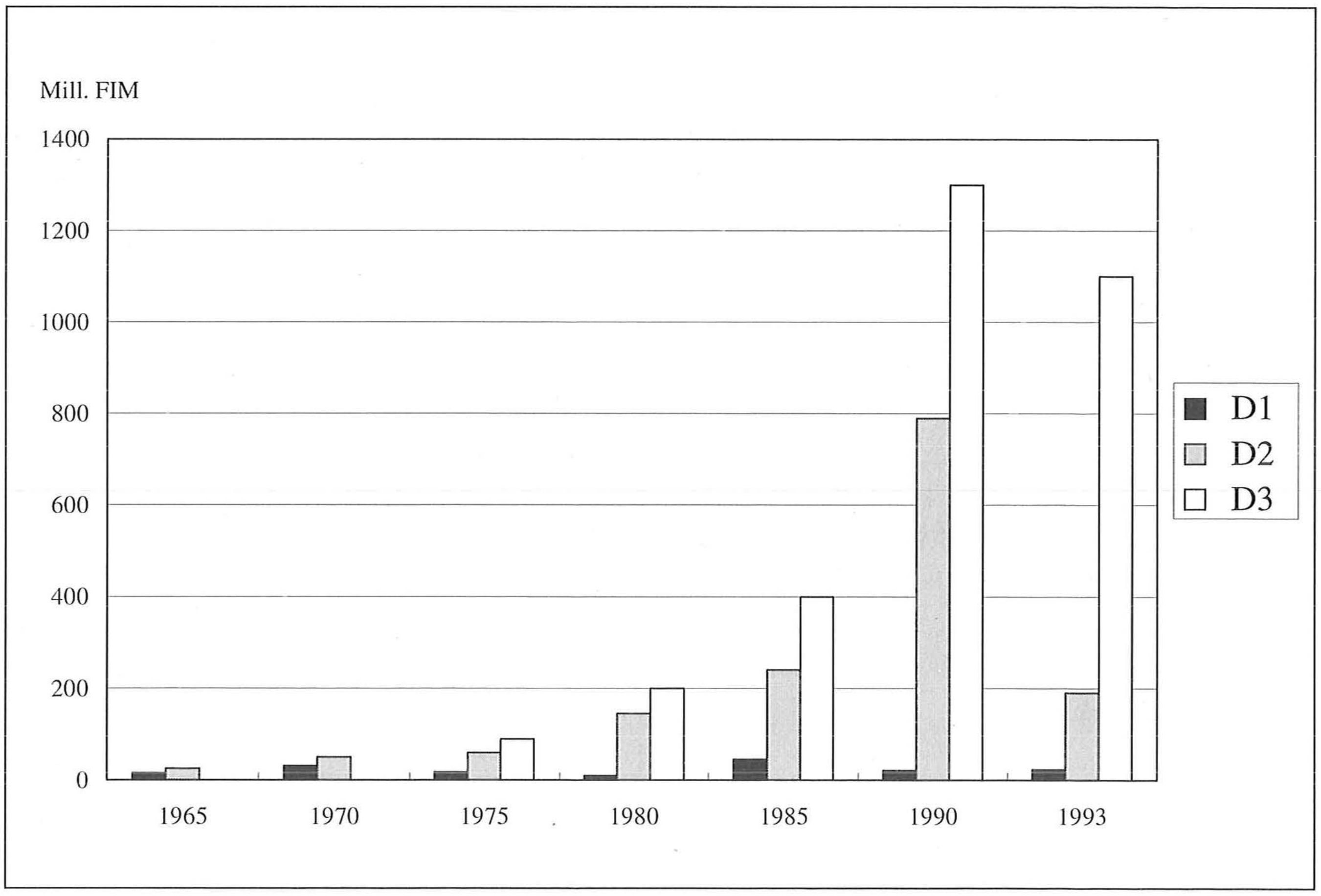
Table 9.3 Turnover of the engineering (engineering design and project companies together) in the companies studied in 1965 - 1993 and the estimated turnover of the whole industry in the same years, million FIM.

	1965	1970	1975	1980	1985	1990	1993
Turnover, in million FIM (studied companies)	147	351	762	1667	2465	5061	5119
Estimated turnover in the whole industry, in million FIM	190	440	950	2080	3080	6330	6400

The turnover figures include the deliveries of the equipment that are invoiced through the engineering project companies. A part of the projects can be directly invoiced between the component supplier and the customer, these deliveries are excluded in the firgures.

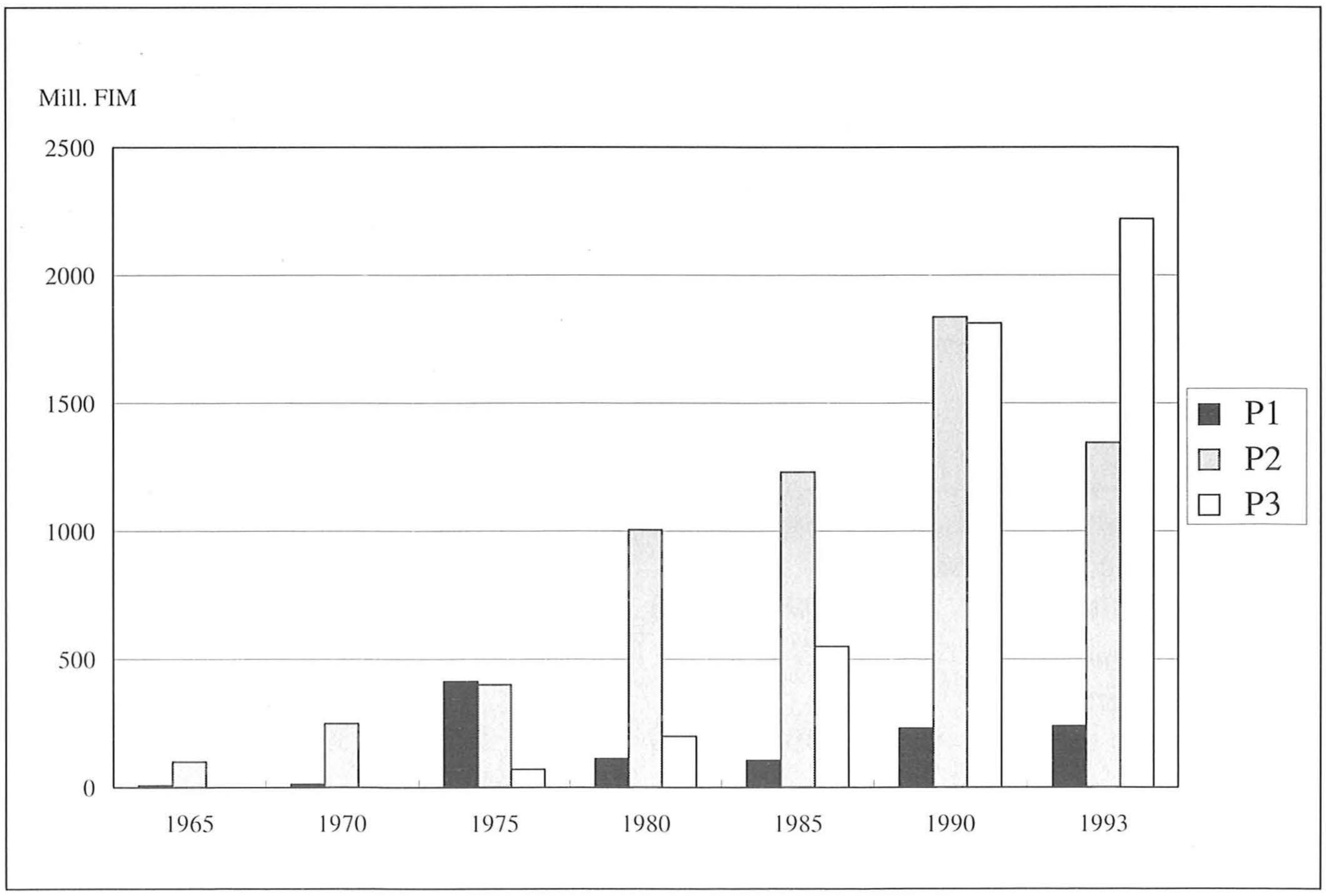
In considering separately the engineering design companies among the enterprices we can see that the turnover of the companies studied passed FIM 2000 million at the highest in 1990. At the beginning of the 1990s the turnover of the engineering design companies decreased significantly. In Figure 9.1. it is evident that the global companies increased their share of the total turnover of the engineering design companies. The selectively international engineering companies were hit worst in terms of the turnover by the depression in the 1990s. The sample is biased and therefore the local engineering design companies are not represented by their share in the study. Therefore their turnover was not affected largely by the depression.

Figure 9.1 The development of the turnover of the engineering design companies studied in 1965 - 1993 grouped into local (D1), selectively international (D2), and global engineering design companies (D3), million FIM.



The turnover of the engineering project companies was at the beginning of the 1990s around FIM 4000 million. The turnover of the project suppliers (P2) decreased about a third from 1990 to 1993, as that of the engineering design companies. The competition for the projects increased in the market as the economic development slowed down. Then the component manufacturers often come to the market to compete with the project suppliers for the turn key projects. But the turnover of the component producers (P3), which export their own components world widely, did not decrease at the beginning of the 1990s. This is partly due to the purchases of the manufacturing companies of Outokumpu Technology which introduced new turnover to the statistics of engineering project companies in the 1990s.

Figure 9.2 The development of the turnover of the engineering project companies studied in 1965 - 1993 grouped into small engineering project (P1), project supplier (P2), and component producer companies (P3), million FIM.



Change of personnel

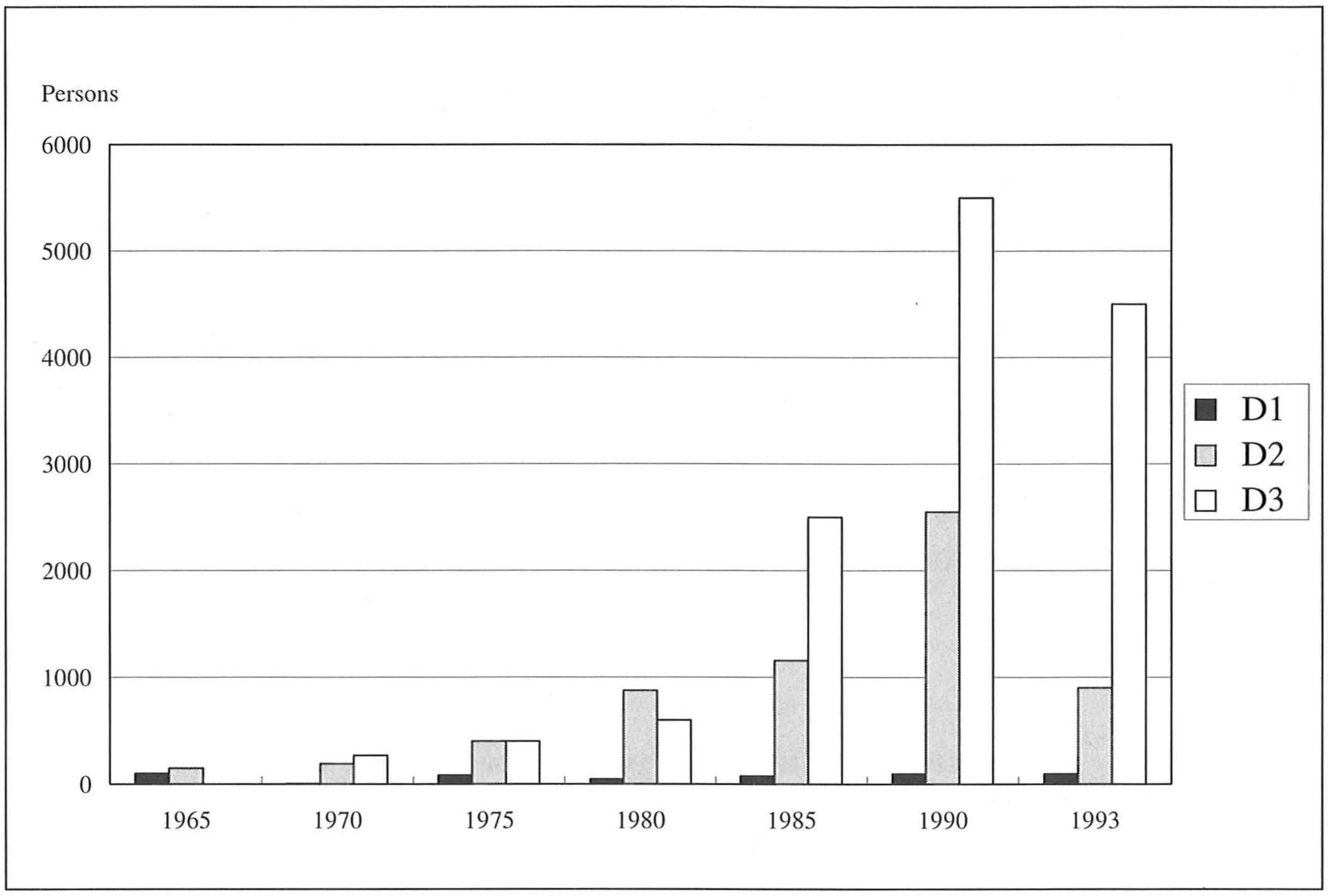
The opportunity of the component producers to compete for the turn key deliveries depends on the industrial field. Own equipment and components may give the component producers good chances in competition for investment projects. Particularly, the component producer whose components represent a significant share of the value of the project has good opportunities to offer. The large engineering project companies or the component producers (P3) have their own core technology in the turn key projects. This helps them to adapt in the competition situations easier than the companies that integrate total factory or plant designs mainly on the basis of technology and equipment available in the market.

The personnel of the engineering companies consist mainly people having different kind and level of engineering education. In the engineering project and design companies also other backgrounds of education are needed, e.g. in economics and law. In the project development and in sales of a project the viewpoint of a customer or an investor is important for the success of the project. The engineering design companies also prepare many kinds of studies for example investment feasibility studies and plans. Their variety of professional skills is also significant. The amount of personnel in the companies studied and the amount estimated in the industry has developed as shown in Table 9.4.

Table 9.4 The amount of the personnel of the engineering (design and project) companies studied and the estimated amount of personnel of the whole industry in 1965 - 1993, persons.

	1965	1970	1975	1980	1985	1990	1993
Amount of personnel, persons (companies studied)	1090	2100	3050	4350	7510	12630	11240
Estimated amount of personnel, persons (in the whole industry)	1360	2630	3810	5430	9390	15790	14050

Figure 9.3 The amount of personnel of the engineering design companies studied in 1965 - 1993 grouped into local (D1), selectively international (D2), and global engineering design companies (D3), persons.

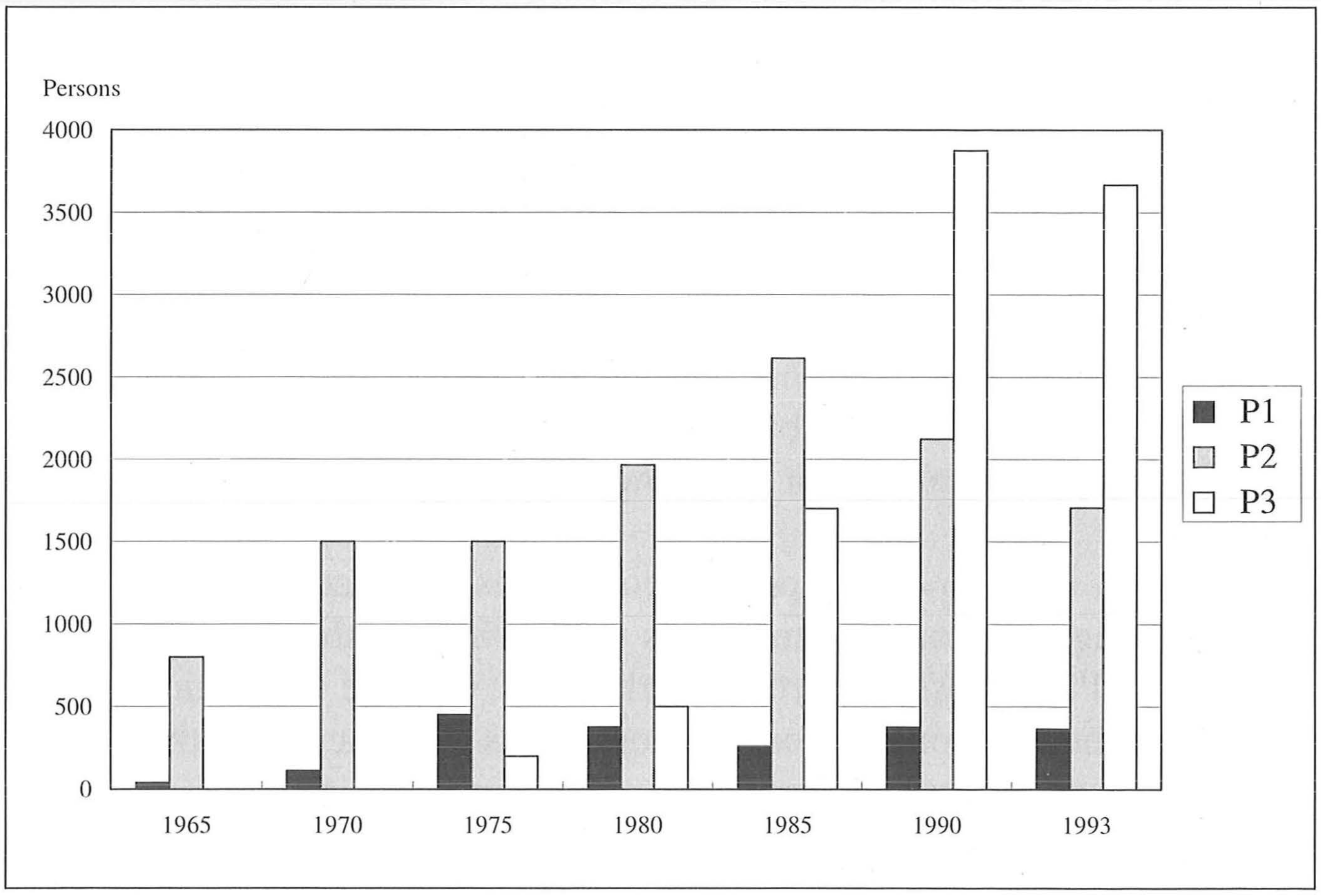


In the engineering design companies the number of personnel was at its highest 8150, at the beginning of the 1990s. The personnel of the global engineering companies studied were 5500 in 1990, and decreased by 20 per cent in 1993. The personnel of the other engineering companies selling to the domestic country and other selected countries fell under a half. In Finland the only engineering design company actually active in the global market is Jaakko Pöyry. During the period from 1990 to 1993 Jaakko Pöyry acquired many business areas from Ekono and Maa ja Vesi. Therefore its personnel did not fall as much as that of others.

In the group of engineering project companies a structural change took place. The biggest group of employers until 1985 was the project supplier companies (P2) whose important market still was the domestic market. After 1985 the component producer companies (P3) increased their number of personnel almost by factor two. Simultaneously the project suppliers had to decrease their personnel. This opposite development of personnel in the engineering project companies compared to the one of the engineering design companies was partly due to the expansion of Outokumpu Technology (Engineering) to the manufacturing of the components in mining and metallurgical industry. The other factor is that some new engineering divisions or subsidiaries started in the industrial large companies in this period. The third factor may relate to own products and technologies which the component manufacturers (P3) mostly have. If our assumption is true, these companies were more competitive compared to the others due to their own products, even in the period of the depression.

The engineering project companies studied employed at most 6400 persons, at the beginning of the 1990s. The personnel dropped to 5700 persons, by the year 1993. The reduction was least in the group of the engineering project companies, particularly the component producers, which strongly base their projects on their own core technology.

Figure 9.4 The development of personnel of the engineering project companies studied in 1965 - 1993 grouped into small engineering project (P1), project supplier (P2), and component producer companies (P3), persons.



Customers of the engineering industry

The local engineering design companies (D1) take part in preparing the investment projects of the domestic industry as suppliers of engineering design work. They serve in general a few industrial branches. All of the invoicing comes from the works to the domestic industry. The examples of the local engineering design companies are so few that it is difficult to comment them more precisely.

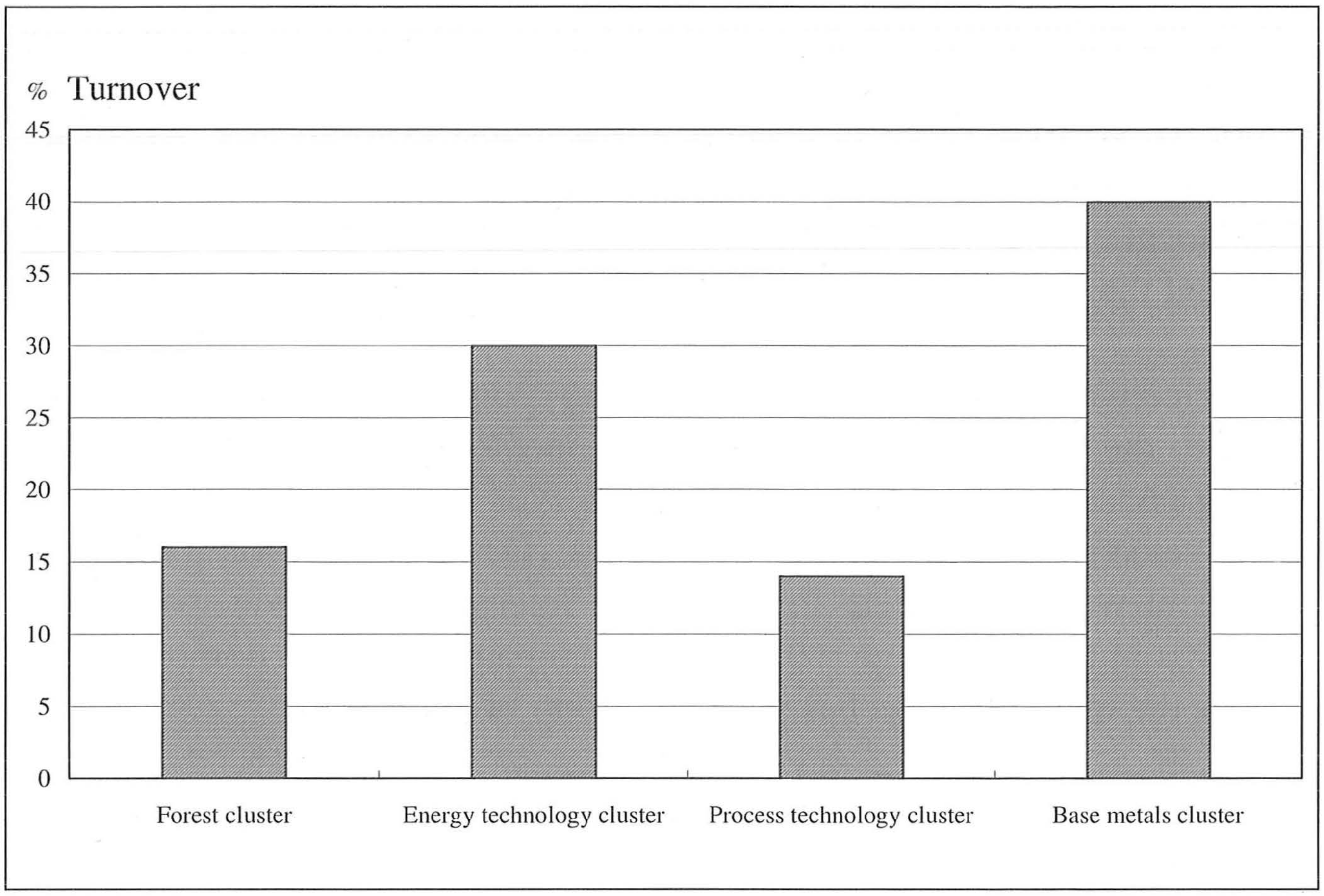
The selectively international engineering company (D2) sells design works to the industry and project management services as a trustee engineering consult of the investor. It often serves many industrial branches. In the selectively international companies (D2) the share of foreign invoicement was 32 per cent in 1993. The internationalization was still in the 1990s at an early stage within these companies and the domestic market was the main business basis for the group of companies.

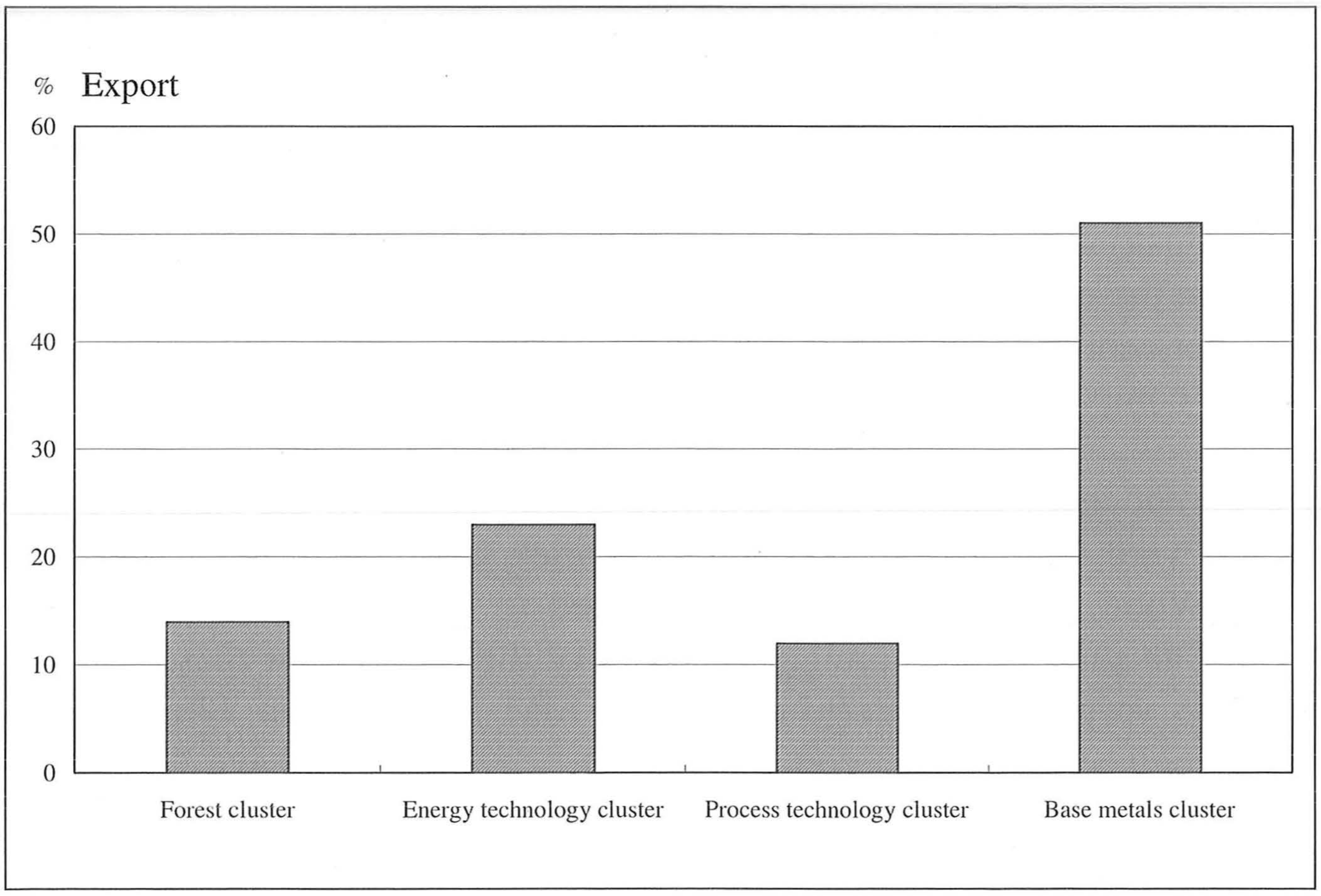
Jaakko Pöyry Companies is the only one of the Finnish engineering design companies to operate really globally. Jaakko Pöyry Companies are formed from about 20 engineering offices located in different countries. 80 per cent of its turnover comes from the tasks given from abroad in 1993. Jaakko Pöyry is the only global engineering design company (D3) in Finland.

In 1993, the total turnover of the engineering project companies studied was FIM 3800 million. The project suppliers (P2) sell mostly projects to one industrial branche, the turnover amounted to FIM 1346 million in 1993. In the engineering project companies studied the domestic turnover is 63 per cent of the whole, and it mostly comes from the deliveries to the mother companies.

The component suppliers (P3) working world widely in the studied companies were Outokumpu Technology, Partek Concrete Engineering and Kone Wood. Kone Wood was transferred to the foreign ownership in 1994. The share of the foreign deliveries of the turnover of these companies was very high, about 90 per cent or FIM 1960 million. Some of the small engineering project companies (P1), see Table 9.2, have very similar turn key projects abroad. They have been categorized to the smaller group only because of the estimated smaller project size.

Figure 9.5 Distribution of turnover and engineering export between the customer industries, percentage shares.





The foreign operations of the Finnish engineering companies can be considered from the point of view of the turnover produced by the foreign business to the companies. In that case the foreign business consists of the individual export projects which are carried out from Finland. The turn key projects also contribute the sales of the local contractors, suppliers or other partners which does not come up in the domestic book-keeping. In the companies studied the turnover was distributed between the customer industries (or clusters) in 1993 as presented in Figure 9.5. The same figure shows the distribution of the exports of the studied engineering companies in 1993.

When considering the distributions of the turnovers and the exports of the companies studied it is important to remember that the total turnover includes both the engineering design and project companies, i.e. the engineering project companies easily dominate the figures. The total turnover of the engineering companies studied was FIM 5281 million and respectively the export FIM 3392 million. The percentage distributions of Figure 9.5 have been calculated based on these numbers. The distribution figures quite clearly show that the engineering industry attains its turnover

Table 9.5 Turnover of the engineering design and project companies and the share of their exports in 1993 by the groups of companies.

	Turnover in 1993 million FIM	Share of an export in 1993 per cent
Local engineering design company (DI)	23	10
Selectively international design company (D2)	190	28
Global engineering design company (D3)	1100	80
Engineering design companies, together	1313	
Small engineering project company (P1)	240	42
Project supplier company (P2)	1346	37
Component supplier (P3)	2220	88
Engineering project companies, together	3806	

mainly from three customer branches, the metallurgical industry, the energy technology and the forest industry. The numbers of the first two customer industries consist more of turn key projects than the forest industry, therefore one has to be careful in reading these figures. This is true with all the numbers and figures in this empirical study as the example companies are quite few. The process industry means here chemical, medicine, construction materials and foodstuff industries.

Table 9.5 presents the turnovers and the shares of exports by the groups of companies. These numbers are for the reader to give a basis for an evaluation of the orders of amounts of volumes which are used for the conclusions. The share of exports in Table 9.5 is the higher, the more international companies are grouped.

9.3 Products and services of companies

The division of the engineering companies into engineering design companies and engineering project companies was introduced in chapter 9.2. The engineering design companies have been further grouped into three different groups according to the scope of the target markets, and the engineering project companies into the groups according to the size and type of the projects. Using more detailed categories the evolution of technical services can be seen over time.

In this study the structure of services of the engineering companies was analysed with the help of the following categorization. This categorization does not relate directly to the previous division. Technical design and implementation planning of investments are basic services of a starting engineering company. Particularly, an engineering design company starts with these services. Later on the range of services expands as the businesses and activities grow, but these services never disappear totally from the supply. Investment planning is related to many kinds of expert services and studies. They can be provided before the actual technical design and also during the technical design and implementation planning of investments. The only definite rule is that all the studies and clarifications have to be ready when the final decisions are to be made.

Table 9.6 The products and services of engineering companies.

1.	Technical design
	- design of integrated plants
	- design of equipment
2.	Implementation planning of investments
	- preliminary design
	- technical design
	- techno-economic design
	- evaluation of alternatives
3.	Consulting and various studies
	- feasibility studies
	- master plans
4.	Implementation services of investments
	- project management
	- training and acceptance
	- turn key deliveries
5.	Sales of technical know how
	- sales of know how of the industry
	- sales of special process know how
6.	Manufacturing and rent manufacturing of investment goods
	- own production of components
	- rent manufacturing of products or special equipment

A particular group of services are the feasibility studies which relate to investment decisions and which also consist of many other aspects than technical matters like financial, juridical and environmental. In a feasibility study the investment is considered in the whole environment in which it is supposed to earn the return on the investor´s capital. Wider scopes are the master plans in which the alternative developments of some geographic area are discussed.

In the implementation phase an engineering design company offers project management services. In addition, an engineering project company offers different, and different scopes of turn key deliveries. The implementation of investment also includes installations, test runs, acceptance, training of personnel and after sales activities.

So far most of the activities presented typically are service products of an engineering design company. An engineering project company offers them even though it emphasizes turn key supplies. The Finnish engineering project companies which often are divisions or subsidiaries of large corporations have sometimes their own technologies, too. They have emerged from a long experience in the investment implementation and from an operation experience in the production plants of the corporation, from the research and development efforts or even from innovations. One way to attain the technologies to the companies or to their engineering divisions is the licencing of a technology.

An engineering company may sell its own technology as a know how or as a process engineering technical knowledge. It may be included in the operation instructions, operation procedures or computer programmes. Mostly it is difficult to charge for the know how. An engineering company has to be very known, international and experienced, and its know how needs to be proved and shown with new references that an engineering company can write a separate invoice for its technology.

Typically, it is difficult to charge technology included in technical design and implementation of design documents. If the technology is valuable the positive results are reflected in the results of the work and in the references. Then an engineering company is selected for the reason that the company is assumed to be competent. Therefore the technology, even though, not patented is an important asset for the company to supply good performances and to sell new projects.

Sometimes an intermediate form between the technical design documents and the patented technology is to construct components or equipment and to embody the technology into them. In this case the customer buys the component and gets the benefit, and pays for the component and for the technology, if the pricing has been correctly made. Because of the seller´s "light weight" or the quality of the technology, the sales of the technology are fairly usual with the help of the equipment. For example in small market niche companies it may the only alternative. Sometimes the tendency not to disclose the core of the technology leads to the sales of the embodied technology in components. An engineering company can sell embodied technology either by using rent manufacturing or integrating manufacturing with its own operations. The flexible manufacturing systems in the machinery production may ease the renting of a manufacturing for own products.

The services of the engineering design companies were analysed in the cross section years in the companies studied using the division of Table 9.6.[1]. The engineering design companies started as technical designers, planners of implementation of investments and as consultants. The shares of implementation planning and of the services of implementations have increased since the year 1965. The works of technical design have lost their importance. The technical design works are made by smaller engineering companies or in foreign projects by local engineering companies.

Table 9.7 Development of distribution of different types of works in the engineering design companies studied in 1965, 1975, 1985 and 1993, per cent of all the items mentioned.

Type of services	1965	1975	1985	1993
Technical design	29	29	19	20
Implementation planning of investments	29	24	37	40
Consulting and various studies	29	35	26	16
Implementation services of investments	0	0	11	12
Sales of technical know how	14	12	7	12
Manufacturing, rent manufacturing	0	0	0	0
Total	100	100	100	100

[1] The companies have been asked what kind of services they have in the range of their products and services. The items mentioned have then been summarized, and the percentage figures are counted of the sums.

In the engineering project companies the four products of services have maintained their importance in all the cross section years. These products of services are the technical design works, the implementation planning of investments, the implementation services of investments and the sales of technical know how. During the three decades the services relating to the planning and implementation of investments have increased their shares. The manufacturing and rent manufacturing have appeared in the picture in engineering project companies.

Table 9.8 Development of distribution of different types of works in the engineering project companies studied in 1965, 1975, 1985 and 1993, per cent of all the items mentioned.

Type of services	1965	1975	1985	1993
Technical design	30	22	17	11
Implementation planning of investments	10	28	34	31
Consulting and various studies	10	6	3	7
Implementation services of investments	20	9	28	28
Sales of technical know how	20	22	11	14
Manufacturing, rent manufacturing	10	13	7	
Total	100	100	100	100

From the viewpoint of evolution in the companies studied the content of know how and technology has increased in the products and services.

9.4 Organizational roles of engineering companies

The engineering companies have been grouped in the previous chapter of this study according to the fact what kind of services they offer to their customers. Because there are clearly two types of ownership backgrounds in the engineering companies in Finland, this can also be used as a yardstick for the categorization. The private ownership, including entrepreneurship background has been already mentioned. The other group of companies has developed from divisions of large Finnish companies or the engineering divisions and they still belong to the regimes of the large companies. The ownership influences on the type of works the engineering company starts with. The privately owned companies usually start with the technical design tasks. The engineering divisions are formed in the large companies in order to take care of the investments of the firm. They learn the role of an engineering project company at the beginning.

The engineering design companies have almost always started as separate independent entrepreneurial companies. Their profile of product range develops wider over time. The independent background of the ownership gives these companies at least two particular features which can be seen even later on in their behaviour. First, they try to avoid risks because the private background does not allow major failures. Secondly the possibilities of private companies to invest in business development and product development are limited. The entrepreneurship gives as a determinant many other features to the behaviour of the engineering design companies.

The engineering divisions of large companies start to serve in the investment projects of the mother company. Some of them remain to this position. The engineering units of large companies which offer their services in an open market may be either profit centers or subsidiaries of the corporations. The engineering divisions have been given different kinds of roles in large companies, e.g. to open the foreign market for the other company units, to commercialize the technical know how of the whole company, to cooperate with the research and development unit of the company for new products and businesses or to maintain the company know how in major capital investments.

The companies are categorized into four separate types. The groups also depict to a certain extent the roles that the different engineering companies take in the market.

1. Independent entrepreneurial companies (C1) which market their services to the companies of different industries. These are mainly engineering design companies, but can also be engineering project companies
2. Separate profit centers in large companies (C2) which market their services to the other units of the company or to the outside companies.
3. Subsidiaries owned wholly or partly by large industrial companies (C3). They market their services mainly to the outside customers but also to the other units or branches of the company.
4. Internal service organizations of the company (C4) which market their services only to the other units of the company.

The evolution of the engineering industry is reflected in the fact that companies are moving from one group to the other due to the changes in the organizations or to the purchases of independent engineering companies by bigger companies. Table 9.9 presents the companies studied and their position in this categorization in the years of cross sections.

The organizations have changed strongly in the engineering companies in the course of time. There are many reasons for the changes. In a young industry the succeeding units have changed their organizations and arrangements as they simply have had to adapt to the growth of turnover and the changes of markets. The other obvious reason for the changes is the internalization and the building up of an international organization. One of these companies is Jaakko Pöyry. The third is the tendency for forming subsidiaries in the Finnish companies in the 1980s. The fourth reason for the changes in Table 9.9 is the changes in the strategic roles of the engineering units of large companies which has also reflected in the organizational positions.

The structural changes are seen in figures presenting the turnover structures and the number of personnel of the companies studied by the categories. In the middle of the 1970s, IVO Engineering withdrew from the international market due to the high internal work load in the Loviisa nuclear and other power projects. This is seen as a large share of internal

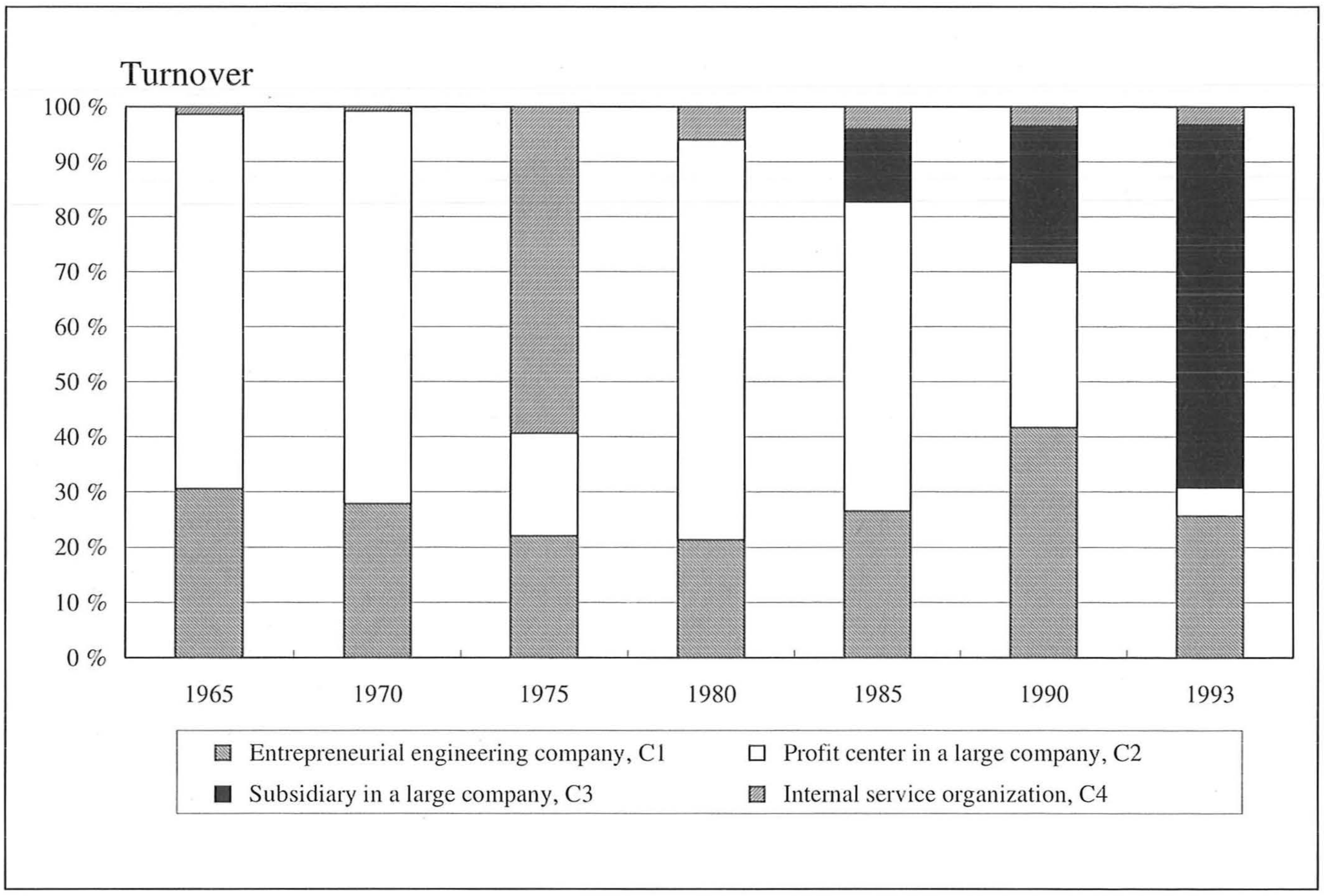
Table 9.9 The positioning of the studied companies into the categories previously presented of the engineering companies in 1965, 1975, 1985, and 1993.

	1965	1975	1985	1993
1. Independent engineering company (C1)	Jaakko Pöyry, Ekono, Roxon	Jaakko Pöyry, Ekono, Alte, Rintekno, Projekti-insinöörit	Jaakko Pöyry, Ekono, Alte, Rintekno, Projekti-insinöörit	Jaakko Pöyry, Ekono, Alte, Rintekno, Projekti-insinöörit
2. Profit center of large company (C2)	IVO Engineering	Finnsugar Engineering, Outokumpu Tekninen Vienti, Roxon, Partek Concrete Engineering, Kone Wood	IVO International, Finnsugar Engineering, Raisio Engineering, Kemira Engineering, Wärtsilä (Metra) Engineering, Nokia Engineering, Enson Projektivientiyksikkö	Kuusakoski Engineering, Rautaruukki Engineering, Finnsugar Engineering, Raisio Engineering, Metra Engineering
3. Subsidiary of large company (C3)			Outokumpu Technology/Engineering, Partek Concrete Engineering, Roxon, Kone Wood	Outokumpu Technology, Partek Concrete Engineering, Roxon, Kone Wood, Valiotekniikka Engineering, IVO International
4. Internal service organization of a company (C4)	Raisio Engineering	Neste Engineering, IVO Engineering, Raisio Engineering	Neste Engineering	Neste Engineering, Kemira Engineering

service organizations in the 1970s. The rapidly growing share of subsidiaries in turnover and personnel since the latter part of the 1980s is caused by the increasing maturity of the industry also perhaps by the new school of management thinking.

In the development of the turnover relating to the different categories of companies can be seen, Figure 9.7, that the growth in the independent engineering companies (C1) has been fairly stable since 1965 except the period of the 1990s´ depression. In the last years the turnover of the independent companies fell over 25 per cent. As entrepreneurial companies these firms easily suffer from growth problems due to the shortage of finance.

Figure 9.6 **Structure of turnover and personnel in 1965 - 1993 by the categories in the companies studied, percentage shares.**



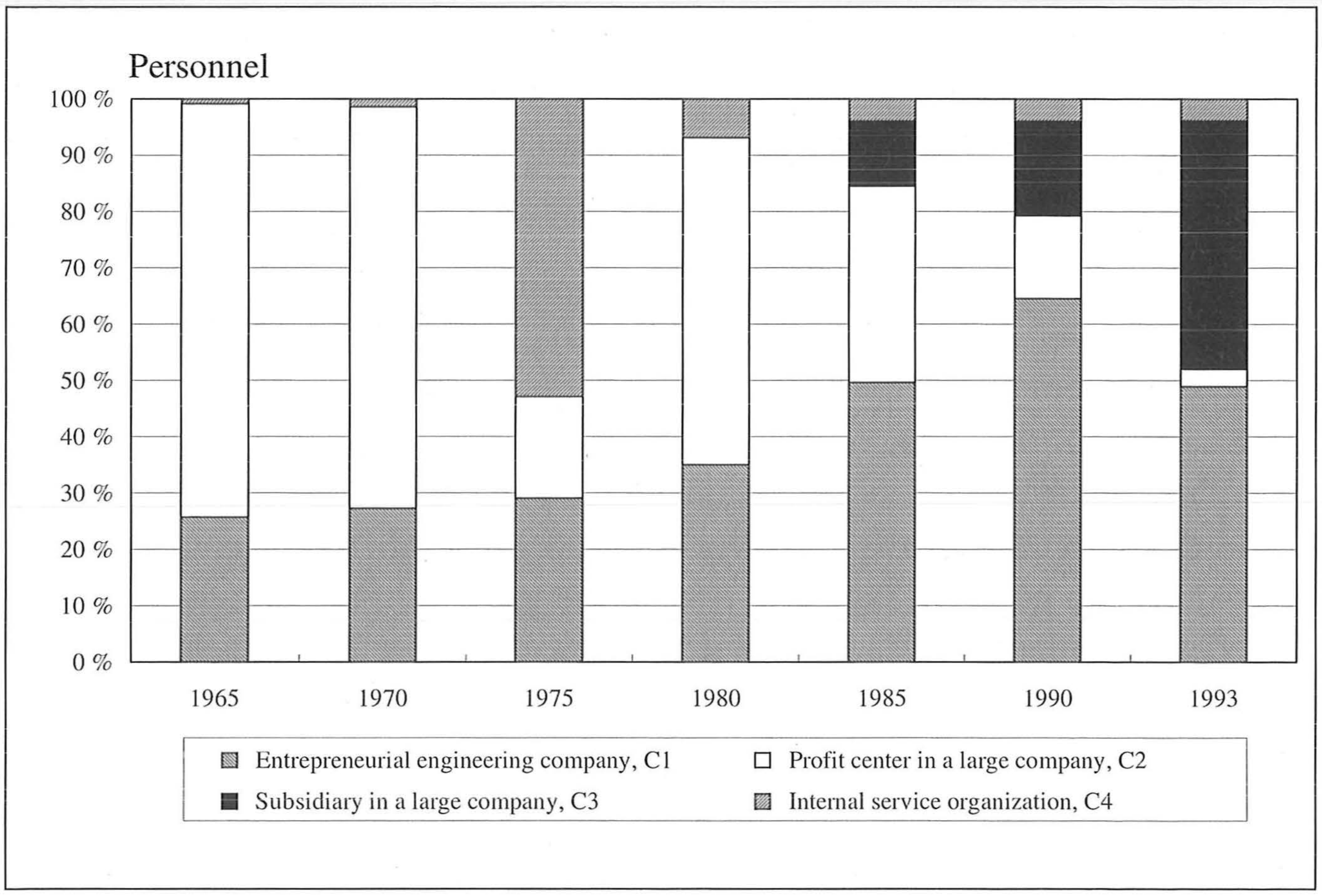
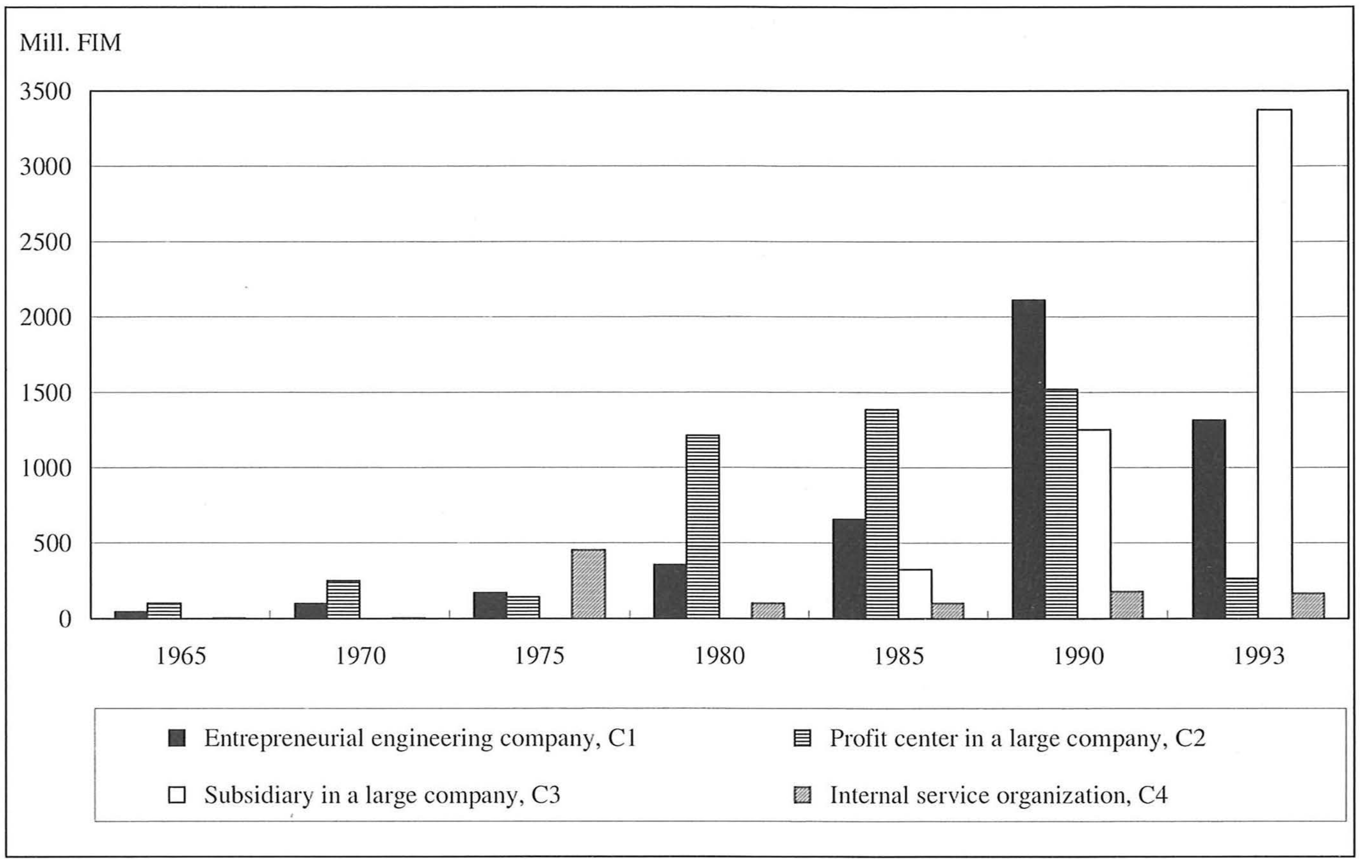


Figure 9.7 Turnover of the engineering companies studied by the categories in 1965 - 1993, million FIM.



The engineering divisions and subsidiaries of the industrial companies (C2 and C3) have grown smoothly after the 1960s and very fast since the 1980s. In the 1980s they are mostly organized as subsidiaries. In Figure 9.7 the two columns in the middle show the turnovers of the profit centers (C2) and the subsidiaries (C3). The fast growth of the subsidiaries of large companies has turned the turnovers of profit centers and internal service organizations to decrease. The explanation is partly, of course, that the most successful units have been organized to subsidiaries. The industrial large companies have had enough resources to finance the growth of the engineering divisions and subsidiaries. The establishing of subsidiaries has made the engineering organizations more independent in their strategies from the mother companies, and given more space for their evolution.

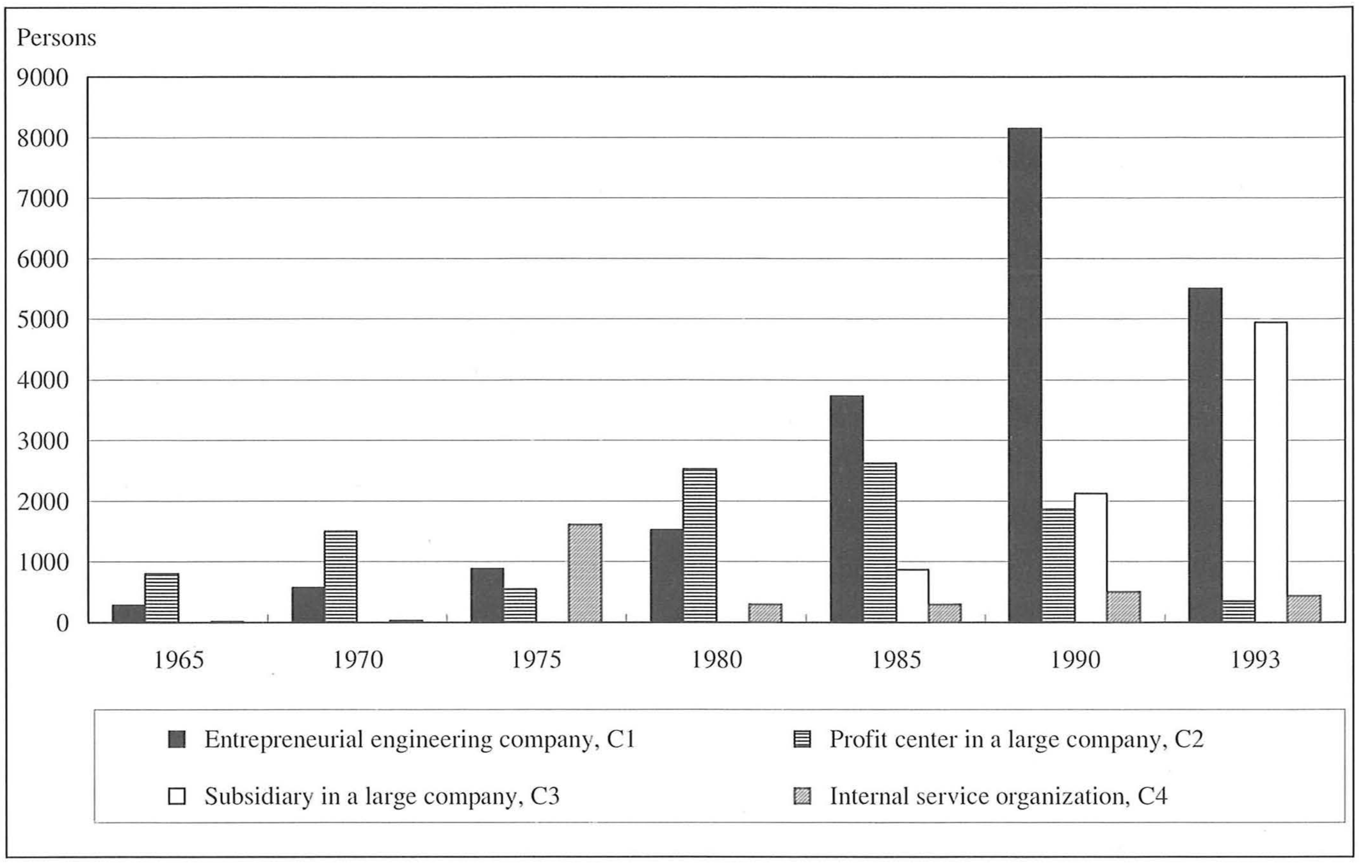
The conclusion of the Figure 9.7 is that the success measured by the turnover and the independence of the organizations shown by forming subsidiaries belong together. The success has many reasons, one of them is the increasing maturity of the engineering business in Finland. For the mother companies it is an easy decision to increase the independence of an engineering division by forming a subsidiary when the business has shown its ability to survive in an open market. An increasing amount of independent decision making from the mother company in the engineering may significantly enhance the possibilities of success, because the engineering products and services are of the type that they are best sold by the experts in the independent roles in their organizations.

The organizational arrangements of engineering units have to find the argumentation in each case from the phase of development and the objectives of the engineering unit and the mother company. There are many obviously different kinds of solutions to which the large companies have come to. Different companies set different objectives for their engineering units.

The development of those engineering companies studied which started as divisions of large companies and produced at the beginning engineering services for the investments of the mother companies may in the initial stage equal to their mother company's development. Many of the engineering project companies studied which started as company divisions are now active in the open market. In the group of the engineering companies studied there is, however, one exception, Kemira Engineering. This company was selling its services and products on a turn key basis in the open market, but decided to withdraw as the interests were conflicting between different divisions within Kemira. The evaluation how to reach the best possible result for the whole company has to take place in companies and the limitations for each engineering company have to be set by the mother companies. In the two other cases studied, the withdrawal of the engineering companies from the market was followed by ceasing the whole business division in the companies.

The development of the number of personnel in the companies studied by the categories in this chapter differs between the independent companies (C1) and the different kinds of the sections of large companies (C1, C2, C3). The services of independent companies are more labour intensive than the products and services of the engineering units of large companies. The amount of personnel in the independent companies fell by 2500 persons at the beginning of the 1990s, whereas the amount of personnel increased in the subsidiary companies (C3) at the same time, see Figure 9.8.

Figure 9.8 Number of the personnel of the engineering companies studied by the categories in 1965 - 1993, persons.



The reason for the labour intensity in independent engineering companies is obvious. These companies are providing engineering services by charging every possible man hour from the customers. The divisions and subsidiaries of large companies market turn key projects and some part of the equipment, not all, is shown in the turnover figures of the engineering units. The explanation for the surprising increase in personnel of the subsidiaries of large companies in the 1990s simply is the purchase of manufacturing operations by Outokumpu Technology at the beginning of the 1990s.

9.5 Evolution of engineering companies

9.5.1 Markets of Finnish engineering companies

In chapter 9.2 the export of the Finnish engineering industry was illustrated. The obvious points appeared from the statistics. The component manufacturers which resemble the international specialized suppliers have a very international market. They exported almost 90 per cent of their turnover. The international emphasis is seen in the exports of the global engineering design companies, the share of export was around 80 per cent. In this chapter the focus is on the selection of foreign target markets of the engineering companies.

When an engineering company starts its activities, it is natural that it finds its first customers in the domestic country or in Scandinavia in the Nordic conditions. This is also seen in the companies studied. The export of engineering occurred only to selected counties besides Finland in 1965. Then 60 per cent of all the companies studied sold only in a domestic market. The companies have been grouped to three groups in terms of export market targets: the purely domestic market, the domestic market and selected foreign target markets, and the very wide international market. The expansion of the target market is seen in the shares of the mentioned market areas.

In 1993 the picture was totally different. Only 12 per cent of the companies studied claim to get their turnover from the domestic country. 53 per cent of them operate in the domestic market and, in addition, the selected target markets. Altogether 35 per cent of the companies claim to market their products and services very widely or globally.

The engineering design companies are very local by nature due to the personal nature of engineering services. The services are rather bought from the known experts and companies. This feature is strongly emphasized in Idom (92) study. This is the reason that in the engineering industry the international companies will never push away the local or national companies. But this is only true to a certain point. When the size and the technological specialization of the project exeed a certain limit, the requirement of a certainty and the avoidance of a risk become more important, and the customer starts to seek for international, experienced and large engineering companies. The engineering design companies are generally small, and the industry is little concentrated, ENR (95a) and ENR (95b).

The engineering project companies can be large, too. For example, if the origin of the company is in a large international multi divisional component producing firm, which started to supply also turn key projects based on the components produced by the company divisions, the question is

Table 9.10 Shares of target markets of the engineering companies studied by categories in 1965 - 1993, in percentage shares. Percentage figures counted from numbers of companies. The groups are the domestic market, the domestic and selected foreign target markets, and the very wide international market.

	1965	1975	1985	1993
Domestic market	60	42	13	12
Domestic and selected target markets.	40	58	38	53
Very international or global market.	0	0	50	35
Together	100	100	100	100

about really big actors in the market. This is an extreme case. But even some specialized component suppliers of the equipment of an industry can be large companies. Clearly the market niche engineering companies are at the other end of the scale.

Such an engineering firm is called a national engineering company which mainly markets its services and products in a domestic country. The company remains a national company even though it would establish a few foreign offices or alternatively buy some foreign engineering companies. In chapter 5, a national engineering company was defined to export up to 15 per cent of its services, and still to remain a national company. Chapter 5 defined the group of global engineering companies a strategic group in an engineering field. They are a group due to the size of the companies, due to the specialization of knowledge in different industries (one is not sufficient) and in transnational complex projects and, of course, due to the high degree of internationalization. Jaakko Pöyry belongs to this strategic group in the field.

The term - multi domestic company - is also used which is not a strategic group of companies in the engineering industry. The multi domestic company is located between the national and global engineering companies. It is born in the process when a national engineering company starts to internationalize. It forms alliances with foreign companies, it may establish its own new engineering subsidiaries in foreign countries, or it may buy subsidiaries wholly or partly. The presence of the engineering company at some stage in many countries is an undeniable fact. In that meaning it alters from a national to an international company. However, the logic of the business measured by the chain of values and presented in chapter 6 may remain the same. If the national engineering units, even though linked together through ownerships or some other arrangements, do business in their domestic markets, their chains of values do not change from the one of national engineering companies. The knowledge base may even remain the same if the interaction between the different national units is limited. We would conclude e.g. Energia Ekono to have been in this stage in the 1980s before its falling. If the different national units start to interact in the markets and really to cooperate with each other utilizing the different cost levels of the countries, the varying competitive advantages of different national companies, and complementing market know how of different companies, they will end up to the new business behaviour. This is most probably reflecting in the chains of values produced by the business areas. At some stage the combinations found and created may lead to such benefits which are difficult to follow and copy. A multi domestic company has then become a global engineering company. It is difficult to define which amount of alterations in the chain of values is needed to become a global actor in the engineering, but principally there exists a definite limit.

The cases of the Finnish engineering companies tell about the problems concerning internationalization in the Finnish businesses. In some cases the engineering division or subsidiary has been seen as a spearhead for the internationalization (Outokumpu Technology), or as an organization which starts marketing the know how of a company abroad (Kuusakoski Engineering), or as an explorer of the markets and competitors (Outokumpu Technology, Rautaruukki Engineering, Raisio Engineering). One role of an engineering division or a subsidiary which has been tried is commercialization of the knowledge of the company (Kemira Engineering, Partek Concrete Engineering). The engineering cases also tell the story of attaining the learning and experience in an internationalization of businesses.

In some companies the technology and projects were sold to very exotic countries without disturbing the main business of the firm (Kemira Engineering). Some companies have attained experience in international businesses by marketing and offering the projects to three or four continents (Valio Engineering, IVO International, Raisio Engineering). Some companies have entered the external markets, withdrawn from there, and again entered the market (Kemira Engineering, Enso Tekninen Vienti, Nokia Engineering, IVO International). Finally, a group of companies were attracted to the export operations by the development aid financing which was earlier more available than today (Nokia Engineering, IVO International, and some construction engineering companies).

Generally in the marketing of projects the competitive advantage requires several necessary items as prerequisites for closing a deal. In this context it is worth while bringing up the necessity to build up the local networks of marketing in the selected target countries. The big turn key projects are so important investment decisions that the local decision making has to be known and it has to be influenced on. This is not possible from the host country of the engineering project company, but it requires to be present with a representative office or a subsidiary. Due to the high costs it is possible to any individual engineering company to select only a limited number of countries to its target markets. This necessity of concentration in marketing is a basic learning in all the marketing courses of export managers arranged by Vientikoulutussäätiö, today FINTRA, since the 1970s.

9.5.2 Evolution of operation modes of engineering companies

The evolution of the companies and thereby the industry can be studied by viewing the evolution of operation modes within engineering design and project companies. The operation modes are related to the products that are offered by the companies.

The operation modes were grouped in the following way:

- to offer detailed engineering design work,
- to offer general engineering design work, including feasibility studies,
- to offer project management as a trustee consult of a customer,
- to offer project management on a seller´s side, and
- to offer turn key deliveries.

The line of distinction between an engineering design company and an engineering project company is somewhere in project management on the customer´s side and the seller´s side. An engineering design company can go down in the list offering the project management services on the seller´s side, but it would never offer the turn key deliveries of plants. An engineering project company would prefer to offer only project management services and turn key projects but also other services depending on the company and conditions.

It is natural that the engineering design companies start with offering detailed engineering design works and general engineering design works including feasibility studies due to the lowest entry barrier into the industry. After having acquired experience and references the engineering design company may also offer project management services. Having delivered project management services the engineering design company may be more competitive also in design works as it can show experience in the implementation phase which often is volatile for many kind of surprises. Normally at this stage the company is ready to offer services abroad and competitive enough to get some works from there.

In the 1970s Rintekno employed 85 people, and its turnover was about FIM 10 million. An important supporting leg was Neste Oy, the investments of which in expansions and refurbishment Rintekno has carried out. The active marketing in Scandinavia, particularly in Sweden, made it a very significant market for the company. In Sweden Rintekno has a subsidiary, too.

Because of the weak result in one year in the second part of the 1970s Rintekno decided to start to offer to its customers besides design work, also project management services. This was partly due to the changes in the market demand. The service package included then design and planning of the plant, project management and implementation of the investment.

Source: Kässi (96)

The case of Rintekno shows that the decision of expanding the range of services was an important decision. Secondly, the point is that Sweden was considered a domestic market. The works were started there before the expansion of product range.

An engineering project company starts its business from a totally different base. It may be an innovative engineering company or an engineering company separated from a manufacturing. For both of these companies there are simply no other possibility to enter the business than to start offering the turn key supplies. If they succeed, it is a starting point for their company development. The divisions or subsidiaries of large companies have their own origin, they are started to take care of the design, planning, and implementation of investments of the mother company. The operations consist at the very beginning of detailed design works, general engineering design works and feasibility studies of the company investments.

Table 9.11 Distribution of operation modes in the engineering companies studied in 1965 - 1993, percentage shares. The percentage shares have been counted from the mentioned operations. A company may often have mentioned several items.

	1965	1975	1985	1993
Detailed engineering design work	57	32	14	15
General engineering design work including feasibility studies	29	24	34	30
Project management as a trustee consult of a customer	14	28	14	15
Project management on a seller´s side	0	16	18	20
Turn key deliveries	0	0	20	20
Together	100	100	100	100

All the investor´s tasks are also given to the engineering division. The final task of the engineering division of the large company is to implement the investment. This work can differ very much depending on the method the mother company decides to carry out the investment.

The mother company could decide to take the responsibility of the investment to itself, i.e. to the own engineering division. This means that the engineering division buys components and subprojects to the investment, and takes care of the integration according to the plans made by itself. Then the engineering represents the investor as an engineering consult. The engineering division may also represent the investor, if the plant is bought from outside as a turn key delivery. The role of the engineering company is then to control the construction work and its accordance with the plans.

The other possible role for an engineering subsidiary would be to act as a turn key supplier. A subsidiary would then sell a turn key project to the investing division of the large mother company.

From this base the newly established engineering subsidiaries are quite particular companies. They may have a long list of references in the domestic and foreign countries, they have provided large projects and complicated solutions for the technical processes. However, they may have a very limited marketing experience at the beginning of their corporate life.

The percentage shares have been counted from all the companies studied. 57 per cent of the companies mention to have produced detailed design work in 1965, and about one third to have made general engineering design work. These two types of activities form in 1993 about 40 per cent of the whole. Project management services were 14 per cent in 1965, and respectively altogether 35 per cent in 1993, in addition the turn key deliveries representing 20 per cent of the whole. The figures are no exact information but they clearly show the direction. The engineering services and the products of engineering companies have become more demanding to the suppliers in the course of time.

9.5.3 Self-sustenance of technologies in engineering companies

Engineering design companies normally work so that they utilize the technology and components available in the market to design whole plants or parts of them. They integrate the whole plants from the components available. The engineering design company may have its own technology in the case that there are patents granted, or some operation experience from the start-ups of the plants. Engineering project companies generally have some of their own technology, at least they have implementation and operation experience from the plants of the other divisions of their mother company.

The engineering companies often do their best to improve their competitiveness, e.g. by acquiring technology. The methods to do this may consist of licencing technologies, alliances between the companies, own research and development efforts (R&D), commercialization of the operation and maintenance know how of the plants, construction or acquisition of own components and application of patents. Engineering design companies normally do not perform actual R&D work because their profitability level does not allow it. Engineering project companies and, particularly, their mother companies work actively in research and development, the results of which are available to the engineering divisions or subsidiaries according to the practice of the company.

Table 9.12 Degree of technological self-sustenance in the engineering companies studied in 1965 - 1993 by categories, percentage shares. Percentage shares counted from the numbers of companies (engineering design and project companies).

	1965	1975	1985	1993
Design based on the available technologies	80	53	33	24
Licenced or acquired technologies	0	20	33	24
Own research and development (R&D), own technology	20	27	33	52
Together	100	100	100	100

All engineering companies studied were asked about the self-sustenance of their technologies at different points of time. The technology self-sustenance was divided to three categories:

- design based on the technologies available in the market,
- licenced or acquired technology, and
- own research and development (R&D), own technology.

In 1965, four of five replied that the engineering activities were based on the technologies available in the market, and one of five that their own technology was used. It should be pointed out that e.g. the own technology of Outokumpu Technology was not yet in the statistics in 1965 as the division was not organized as a separate unit, it came into the data in 1975. In 1993, according to the replies a half of the engineering companies work with their own R&D and own technologies, a fourth of the companies uses licenced or acquired technologies, and a fourth uses technologies available. The answers let understand that the repliers understand the importance of the technologies, but at the same time they tend to give

Table 9.13 Degree of technological self-sustenance in the engineering project companies studied in 1965 - 1993 by categories, percentage shares. Percentage shares counted from the numbers of companies.

	1965	1975	1985	1993
Design based on the available technologies	67	30	8	0
Licenced or acquired technologies	0	30	46	33
Own research and development (R&D), own technology	33	40	46	67
Together	100	100	100	100

the term "own technology" a very liberal interpretation. The tightest meaning of own technology which is the technology patented and products was not at all in the question. The smaller companies or the companies originally related to a manufacturing call all the technologies "their own" which may be embodied in their products, whether patented or not, or original or not. In any case the evolution of the technology base in the course of 30 years is clear from the figures. Table 9.12 included all the companies studied. The picture is even more straightforward if we look at the shares of technological self-sustenance of engineering project companies, Table 9.13.

In 1965, the share of engineering project companies to supply projects based only on the available technologies was 67 per cent, in 1993 there was no such firm any more. Respectively the technological self-sustenance has increased by licencing, technology acquisition, R&D and own technology acquisition.

Origins of the self-sustenance pressures

Engineering design companies desire to express their position towards technology with the word "independent". It means that they are independent of component suppliers and all the other possible external interests. Their task is to design and make integrated plant units from the components available in the market. If a local engineering company is to develop to a national one, or a national to a global one, there is no principal reason, as such, to change the attitude to the technology approach at a company level. If the environment and the market change, there may appear pressures to find new competitive advantages by changing the cost structure, as pointed out in chapter 6. A technology development may be a measure in that effort.

In Finland engineering project companies often are divisions or subsidiaries of large firms. Within the large firm they used to take care of the investments of the mother company. They represent the mother company in the matters of investments. In this role these engineering project companies could also consider themselves as independent, i.e. to decide which technology to choose from the alternatives fulfilling the requirements of the investor. In a large company different kinds of technologies are accumulated

- through operation experience,
- by own R&D work, and
- by building new references.

An engineering project company refers to these facts when it approaches an outside customer and uses them as sales arguments towards a customer. An engineering project company is independent of component suppliers in that it can select what it wants. But it is not independent in the meaning that it has to select one because the company has not own components.

When a subsidiary is formed, it has to meet new conditions. As a corporation it has to survive and serve the customers. If the subsidiary in an open market sets an objective to become a national engineering design company, it can still be technologically independent as before, it does not need own technology, it has to adapt its personnel to correspond to the needs of the current national market. If the subsidiary sets an objective to become a specialized supplier company, it most probably has to acquire some other own technologies by buying, developing or making technology alliances. Only by having own technologies and products it may enter the group of specialized supplier companies.

An innovative engineering company in a garage or an engineering company separated from a manufacturing have the same problem as a subsidiary aiming to become a specialized supplier. To survive in their own strategic groups they need their own technologies. These companies have a tendency to appropriate the technologies by embodying them to the components, in addition to applying patents.

A common reason for the engineering project companies to acquire technologies are the cost structures, as shown in chapters 6. Own technologies may give some space to manoeuvre in the business competition.

A question is made whether there is life outside the strategic groups for a company. The answer is positive. But a company which positions itself outside the groups may have to satisfy with a lower profit level.

Technology change

All the companies, including the engineering companies, generally live the phases of incremental technological change. This means continuous gradual improvement in performance and quality. The companies have to develop all the time their activities to keep up with the competition. In some occasional cases the time is mature to technological revolutions. A radical innovation may then replace the old technological generation. The innovation emerges within those companies which have experience in the industry for a long period. At least the final winners of the change emerge among them.

The radical innovations may appear from individual ideas by some person or a group. More often today the ideas for innovation emerge from a long standing work and cumulative experience. The cumulative experience includes a long row of incremental innovations, and they finally may lead to the radical change although the individual changes may be small.

In Outokumpu the problem was the extensive use of energy in the process of metal production. In the 1940s, the technological idea emerged about a better solution in the process, at the same time there was risk taking ability to build a test unit of a production scale using the process of flash melting. After the success in the first installation and process, the sales of technology started as the metal producers came to Outokumpu to ask, whether the technology should be for sale or for licencing.

Outokumpu Technology emerged from a product, the process of a flash melting. The technology of a flash melting aroused at the very beginning great interest, and many potential customers came to Outokumpu to ask possibilities to buy or to licence the technology. The first licence was sold to Furukawa Co in Japan in 1954. The next sale was made to Masinimport in Romania in 1963. At the beginning the sales of technology was in the interest and the objective of the top management of the company. In 1965 a separate sales department of technology was established. The Research Center of Physics in Outokumpu developed equipment and instruments in the 1960s. Based on that an instrument factory was established in 1972. Products in sales were e.g. anode foundry and vertical casting equipment.

Source: Kässi (96)

In the terminology of this study a radical innovation was made by Outokumpu engineers in the 1940s. The era of fermentation took almost 30 years until the company was assured enough to establish a separate organization to sell the technology and equipment for that. At the same time other processes and equipment were developed by the company so that Outokumpu Technology in the 1980s was a self-sufficient technology supplier in its own industry.

In Outokumpu the actual engineering organization was built only after the product or products existed. This is opposite to the evolution in most other Finnish engineering project companies, where the demand for the investment planning and implementation services was first fulfilled by new organization. The engineering organization learned only gradually a special know how in the industry in the course of implementing many projects.

The radical innovation gave Outokumpu a special opportunity to utilize the technology. First action was to appropriate the technology to its own by patents. Secondly the company got a significant position in the market of metallurgical equipment which was amplified by developing other products to supplement the flash melting process. The whole evolution of Outokumpu (later on the role was given to Outokumpu Technology) to a specialized supplier company world widely started from one single innovation. The most important individual factor to enable the development of Outokumpu Technology was the good level of the basic knowledge in the metallurgy in the 1940s and thereafter. All the other factors and requirements could be built later on.

A cumulative experience in projects or a wide cumulative knowledge (in projects, operations, R&D, etc.) could give the chances to the similar breakthrough phenomena in the forest industry and energy technology. The respective companies would be Jaakko Pöyry and IVO International. This is not to say that these companies are expected to make radical breakthrough innovations, even though it is not excluded. But it is expected that if such innovations in the respective branches of industries appear, these companies have background and resources to take care of utilization of the new technologies. If this would happen in the energy technology and if IVO International was to be an engineering project supplier in these cases, it would have good chances to move towards the core of the specialized suppliers´ group. Jaakko Pöyry could still strengthen its position as a global engineering company. But the times of radical innovations are not foreseen. As hypotheses of the writer, almost as a speculation, the new combustion techniques of solid fuels for IVO International and a closed pulp and paper making process for Jaakko Pöyry could be mentioned as such opportunities. These are innovations which could potentially make the engineering companies mentioned as agents in their own industries in the world market.

The next opportunities towards the similar technological paths could be for Raisio Engineering and Cultor Development. It has been estimated elsewhere that these companies are moving towards the strategic group of specialized suppliers, Kässi (96). Purely in terms of technology they may be in the position to exploit the technological breakthroughs in the case that they are to come. They have sufficient cumulative technological base and potentially resources to exploit a chance when it comes.

If the engineering companies can utilize the change of the technology as discussed before, they are not any more mere servants of the investing companies which transfer and combine information and material flows. They may become active agents of technological change by using the know how that they have succeeded to acquire. By distributing the new technologies which they now also carry they enhance and speed up the evolution in the investing industry.

9.5.4 Manufacturing and engineering

Manufacturing does not belong to the activities of engineering project companies. Engineering project companies can be engaged with a manufacturing operation from two directions:

1. Some engineering project companies may come to manufacturing or rent manufacturing because they want to exploit some strategic option or benefit.

2. In some cases the origin of engineering is in manufacturing. It is then natural that engineering and manufacturing are parallel activities in the same corporations.

The strategic options or benefits that an engineering project company may achieve by entering manufacturing or rent manufacturing can be

- to expand the range of own products in projects,
- to expand the turnover and thereby the space of maneuvering in competition, and
- to exploit some technological innovations through component production.

The Outokumpu Technology studied is an example. At the beginning of the 1990s, it bought manufacturing units, strengthened its product range and expanded its turnover. A few companies have started rent manufacturing or small scale manufacturing for their special techniques among them Finnsugar Development, Raiso Engineering, Rauraruukki Engineering, and IVO International.

Within the companies studied, a group had a clear manufacturing background, including Roxon, Kone Wood, Kuusakoski Engineering, and Partek Concrete Engineering. Roxon and Kone Wood manufacture products and components and sell their products on turn key basis. Kuusakoski Engineering has organized its know how in metals recycling around an engineering unit which consists of small manufacturing operation of special equipment as well. Rautaruukki Engineering has bought some

Table 9.14 Relationship of all the engineering companies studied to manufacturing activities in 1965 - 1993, persentage shares.

	1965	1975	1985	1993
Conventional engineering	100	77	63	39
Own products, “rent manufacturing”	0	0	16	39
Own manufacturing	0	23	21	22
Together	100	100	100	100

products and manufacturing, IVO International has some technology which it has produced as a rent manufacturing operation.

The companies were asked about the following approaches to the manufacturing:

- conventional engineering,
- own products, "rent manufacturing", and
- own manufacturing.

The answers were the following in all the companies studied including engineering design and project companies, Table 9.14. The similar trend is to be read in the replies of the engineering project companies, Table 9.15.

The distribution has totally changed during the last 20 years. In 1975, five of eight (63 per cent of) companies were conventional engineering project deliverers relying on the components available in the market. In 1993, the picture is totally different, the main part of the engineering project companies has at least some examples of own products, in "rent manufacturing", or own manufacturing. It is concluded that this is a reflection of the cost pressures referred to in chapter 6.

Table 9.15 Relationship of the engineering project companies studied to manufacturing activities in 1965 - 1993, persentage shares.

	1965	1975	1985	1993
Conventional engineering	100	63	50	15
Own products, "rent manufacturing"	0	0	21	54
Own manufacturing	0	38	28	31
Together	100	100	100	100

Partek Corporation bought in the 1970s the machinery manufacturing of Toijalan Konepaja and later on a machinery manufacturing in Germany. The produced products are machinery and equipment for producing cement and concrete elements for construction purposes. In the 1980s the engineering activities including planning and marketing of turn key projects were organized into a separate unit from various manufacturing units. This represents a tangible way the engineering company separated from a manufacturing and a machinery shop, as the separated organizations can locate on two sides of the one factory yard. The concrete technology is labelled by the engineering organization, the manufacturing unit may produce some other products, too.

Roxon is a company which can be labelled as a market niche engineering company. It was started in the 1960s. At the beginning it was supplying technology for materials handling as designs, components and as turn key deliveries. Roxon has experienced many changes of owners. It started to grow with the deliveries to the mining industry and with the successful effort to expand internationally. In the late 1980s, the company tried to decrease the share of engineering having a great tendency to fluctuate up and down over time.

In the 1980, in Kemira Engineering there was as a part of its business idea to sell process methods and specialized equipment which were both developed by Kemira to customers. IVO International has decided to market some of its patented power plant technology to the foreign power plants as components which are "rent manufactured" by domestic or foreign manufacturing units[2].

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2 In all the case examples a reference was made to Kässi (96).

10. APPLICATION OF THE DEVELOPED FRAMEWORKS

10.1 Positioning of engineering companies on strategic maps

10.1.1 Engineering companies in the light of strategic groups

In chapter 5 five different strategic groups in the engineering industry were identified. These groups were named

- Global engineering companies
- National engineering design companies
- Local engineering design companies
- Specialized supplier companies
- Market niche engineering companies.

The characteristics of the strategic groups and the base of the competitive advantages are shortly reviewed. The opportunity is used to comment the companies studied in the context of the strategic groups, too.

<u>Global engineering companies</u> are design firms with a few thousand people, and operate internationally. These engineering companies have more than one industrial branch of specialization. The special advantage of the global engineering companies is that they have resources in many countries so that they can take the responsibility for the international projects. The engineering organizations of the company in different countries have created similar internal standards for their procedures. These procedures need not to be created when the project is purchased. This may be a significant competitive advantage compared to the offer made by a consortium composed of many national engineering design companies. The other competitive advantage relates to the fact that in many countries they can locally follow the development of a great amount of projects, and take part in them already in early stages. Therefore they have a benefit compared to the later coming competitors. The international financial institutions are a part of the international project follow-up of the project

development. The global engineering project companies are capable to do project development at an international level.

The base of the competitive advantage:

- A large amount of experts
- An ability to manage large international projects
- References and proved capability to many kinds of projects
- A capability to create and develop projects together with national and international organizations.

As the only Finnish engineering company Jaakko Pöyry belongs to this group. Its base is in the forest industry, but today other strong areas include environmental technology, particularly water engineering, energy technology, and construction. Ekono Group probably tried to develop to this kind of an engineering company in the 1980s, but failed, because of the lack of resources or they were bound to other purposes.

National engineering design companies are medium sized engineering design firms which often have many design offices in their domestic countries. As concerns Finland the national engineering design companies also consider Sweden as their domestic market. National engineering companies either have one industry as a specialization field or not. From the point of view of experience accumulation it would be better to concentrate on one industry, but due to the small market segments in a country this might not always be possible. Often national engineering design companies plan to grow international. It is often a very difficult phase of evolution. Personnel and other resources easily limit growth.

The base of the competitive advantage:

- A good local and national network of persons
- A wide reference base in domestic country in different projects
- A capability to create and develop projects together with national organizations.

Projekti-Insinöörit belongs to this group among the companies studied. It has also made efforts to attain foreign projects. Rintekno is a national, actually Nordic, engineering design company. It also has some selected few products which are offered to wider markets.

Local engineering design companies are small companies, but their engineering know how is normally at a good level. They work in detail design, general design, services for planning and implementation of investment projects, but mainly at a local level and partly at a national level. They get their work through local contacts and with a good service. If the local business develops they grow with the business.

The base of the competitive advantage:

- A knowledge of the local business and people
- A knowledge of the local decision making.

Among the companies studied this group is very weakly represented. Actually only Alte Oy belongs to this group. We have to refrain from many conclusions concerning the group of local engineering companies in this study.

Specialized supplier companies are international technology enterprises. They are also, according to the terminology of this study, engineering project companies. The amount of personnel varies from a hundred to a few thousands. These companies have successfully developed technology and products for some specific industry as a long term effort. They have a clear technology base that they maintain with their own product development. They are international actors widely, often globally. Generally, the competitive advantage is originated from a domestic strong cluster and is therefore sustainable. It is to be noted that the companies, often specialized in this way, serve some basic industries or some infrastructures of an society like traffic, energy generation, or construction. This often makes the competitiveness achieved sustainable as these structures normally do not change fast.

The base of the competitive advantage:

- A selected technology segment has only a few suppliers world widely
- Product development has a central position in the activities of these companies, the specialized suppliers have their own patented products.
- A technology-based competitive advantage.

An example of specialized suppliers is Outokumpu Technology. It markets its products internationally and has its own product range in the basic metal industry and mining. Its present position as a company in its strategic group is an end result of a long and many staged path of a company development. The needs and strategies of the mother company have influenced on the current end result. Outokumpu Technology has also integrated production with its engineering activities, although it clearly started from technologies, design and project engineering. A particular feature mentioned of Outokumpu, later Outokumpu Engineering and now Outokumpu Technology that the innovation of flash melting came first, followed by the sales of licences and finally the organizational arrangements. This is opposite to most of the other cases of subsidiaries of large companies where the order is the investment projects, the organization of an engineering, the gradual accumulation of experience, starting to sell outside the own company market and an internationalization.

IVO International is an example of the latter path of a company development. When it became a large subsidiary it had delivered large projects in the domestic country. However, its turnover was mainly included in the investments of the mother company and the domestic country. The internationalization which was then started has strongly changed the weight point of the turnover on the sales effort abroad. To be competitive abroad IVO International needs to develop own products for its competitive advantage.

Kone Wood and Roxon are examples of the companies which had their own products and components for the specific purposes. In their business operations, the turn key project deliveries were started and this also lead them to carry out design and planning of the installations. They are examples of the companies where the borderline between component manufacturing and engineering project business is very narrow as discussed in chapter 6.

<u>Market niche engineering</u> companies are small specialized firms. Their small size results from the fact that they are young and they have not had time to grow, or from the fact that their market niches are globally so small that the market does not allow then to grow over certain definite volumes. The market niche can be a protection for the companies concerned, because the really big companies do not get interested in the narrow market niche for the sake of the limited volumes. A small market niche company is not brought into an intolerably difficult competition. If

the technology and products of the market niche company are specialized enough, the investors of the segment find world widely the products of the company, even though it cannot establish itself in many different countries. The idea and the logic of the business are very similar to the ones of the specialized supplier companies, the activities are only adjusted to the available resources of the company. For example the technology is sold as embodied into the machinery and equipment, because the resources available do not allow to build up very wide appropriation of the rights. The products are priced based on the benefits they give to the customer, not according to the production costs. The price then hopefully includes the charge for the development of a technology, too.

The base of the competitive advantage:

- The technology is so specialized that small local companies are not able to catch up the lead,
- The market is world widely so narrow that the big companies do not become interested in the product development and the market niche, and
- The niche company retains its leading position by continuous product development and by new references.

The borderline between the specialized supplier companies and the market niche companies is mainly in the scope of the operations. Therefore presenting the examples is not easy. A market niche company of today may rapidly grow in a changing market and become a specialized supplier. Rautaruukki Engineering and Kuusakoski Engineering could belong to this subgroup. In the Finnish market there are other recognizable companies which would belong to this group of companies but are not included in this study.

The strategic groups of the European study, Idom (92), were adopted to this study because they also seemed to describe fairly well the examples of the Finnish engineering companies. The companies seemed to act more or less characteristically in each group, and serve their own customers.

The observed groups of the engineering design companies, the local (D1), selectively international (D2), and global engineering companies (D3) correspond very well to the groups of the local, national, and global

Table 10.1 Examples of the companies studied and their positioning into the strategic groups in the engineering.

Strategic group of companies in the engineering	Examples of the engineering companies studied	Remarks
Global large engineering companies	Jaakko Pöyry Companies	Other companies far away from the same rate of internationalization. Other Finnish companies will not probably become global engineering companies.
Specialized engineering companies*	Outokumpu Technology / Engineering	Outokumpu Technology is a typical company in this group.
	IVO International	The internationalization of IVO International is taking place.
	Kone Wood	
	Roxon	
	Finnsugar Engineering	
	Raisio Engineering	Chemistry of forest industry
	Partek Concrete Engineering	
Market niche engineering companies*	Kuusakoski Engineering	
	Rautaruukki Engineering	
	Valiotekniikka	
	Raisio Engineering	Technology of the food industry
	Metra Engineering	
National engineering companies	Rintekno	Could belong to a Nordic group, too.
	Projekti-insinöörit	
	SLM Yhtiöt in ABB Oy	A role as a national engineering project company
Local engineering companies	Alte	Group was weakly represented

* Note. The difference between the specialized company and the market niche engineering company mainly lies in the scope and size of projects and personnel. The borderline is vague.

companies in the strategic families. The component suppliers (P3) of the engineering project companies are in fact very close to the strategic group of specialized companies or the group of market niche companies. Whether the project suppliers (P2) belong either to the national engineering companies or to the specialised companies, has to be decided case by case. Some of the companies in the study can easiest be defined market niche engineering companies.

10.1.2 Competitive strategies of engineering companies

The strategic competition between the engineering companies and the groups of the companies are discussed in chapters 5 and 6. The strategic groups were given a generic strategy to give strategic direction to the group of the companies. In Table 10.2 most of the companies studied are positioned into the strategic groups and the characterization of the long term strategy and the operative competition is shown for each group.

The key success factors by the strategic groups have been compared with the cases of the engineering firms studied. These factors are qualitative and should be confirmed later on by quantitative methods. Figure 6.1 reflects both operative and long term factors.

10.2 Positioning of engineering companies onto the development paths

A natural way to show up the empirical findings of the study would be to present them divided to the alternative industry paths. This would mean that the companies studied should be located into the paths, and then various data and findings would be presented in the contexts of the paths. Due to the limited number of company cases this is not possible and sensible, because each pattern would include a very few cases. On the other hand, in certain paths there are so few companies in the industry that any statistics on them would not make any sense.

Table 10.2 Examples of the positioning of the engineering companies studied into the strategic groups of the engineering. The characterization of the long term strategy and the operative mode of competition is given for each group.

Strategic group of companies in the engineering. Remarks on generic strategies of Porter (80), and competition mode.	Examples of the engineering companies studied
Global large engineering companies Differentiation or overall cost leadership (in national projects) Design mode	Jaakko Pöyry Companies
Specialized engineering companies* Differentiation or differentiation based focus Project mode	Outokumpu Technology / Engineering IVO International Kone Wood Roxon Finnsugar Engineering Raisio Engineering Partek Concrete Engineering
Market niche engineering companies* Differentiation based focus Project mode	Kuusakoski Engineering Rautaruukki Engineering Valiotekniikka Raisio Engineering Metra Engineering
National engineering companies Overall cost leadership Design mode	Rintekno Projekti-insinöörit SLM Yhtiöt in ABB Oy
Local engineering companies Cost based focus Design mode	Alte

* Note: The difference between the specialized company and the market niche engineering company mainly lies in the scope and size of projects and personnel. The borderline is vague.

10.2.1 Characterization of engineering companies by development paths

The plan to compile this chapter is as follows. The examples of the company cases will be located into the paths first after which the individual paths are studied with the help of the case examples. This captures the development characterizing the development steps of the case companies into development boxes. These boxes are compared to the assumed development steps in the respective development path of chapter 8.

The positioning of the engineering companies into the categories is fairly straightforward. Particularly the end results of the company evolutions, i.e. the strategic groups are easy to recognize.

10.2.2 Industry paths in engineering in the light of examples

The subtitle could also be “Industry paths in engineering in the light of examples: paths and evolution towards them.” The issue of this chapter really is the evolution towards the paths. The assumed evolution steps are presented in chapter 8 relating to each path. In this chapter a comparison is made with the actual evolution steps of the case companies towards the theorized paths. The company case materials are drawn from Kässi (96), and are mainly based on the information from late 1993 and 1994, and checked by the companies in 1994 and 1995. The company cases do not try to disclose the whole story of the company development but only the most relevant parts for the study.

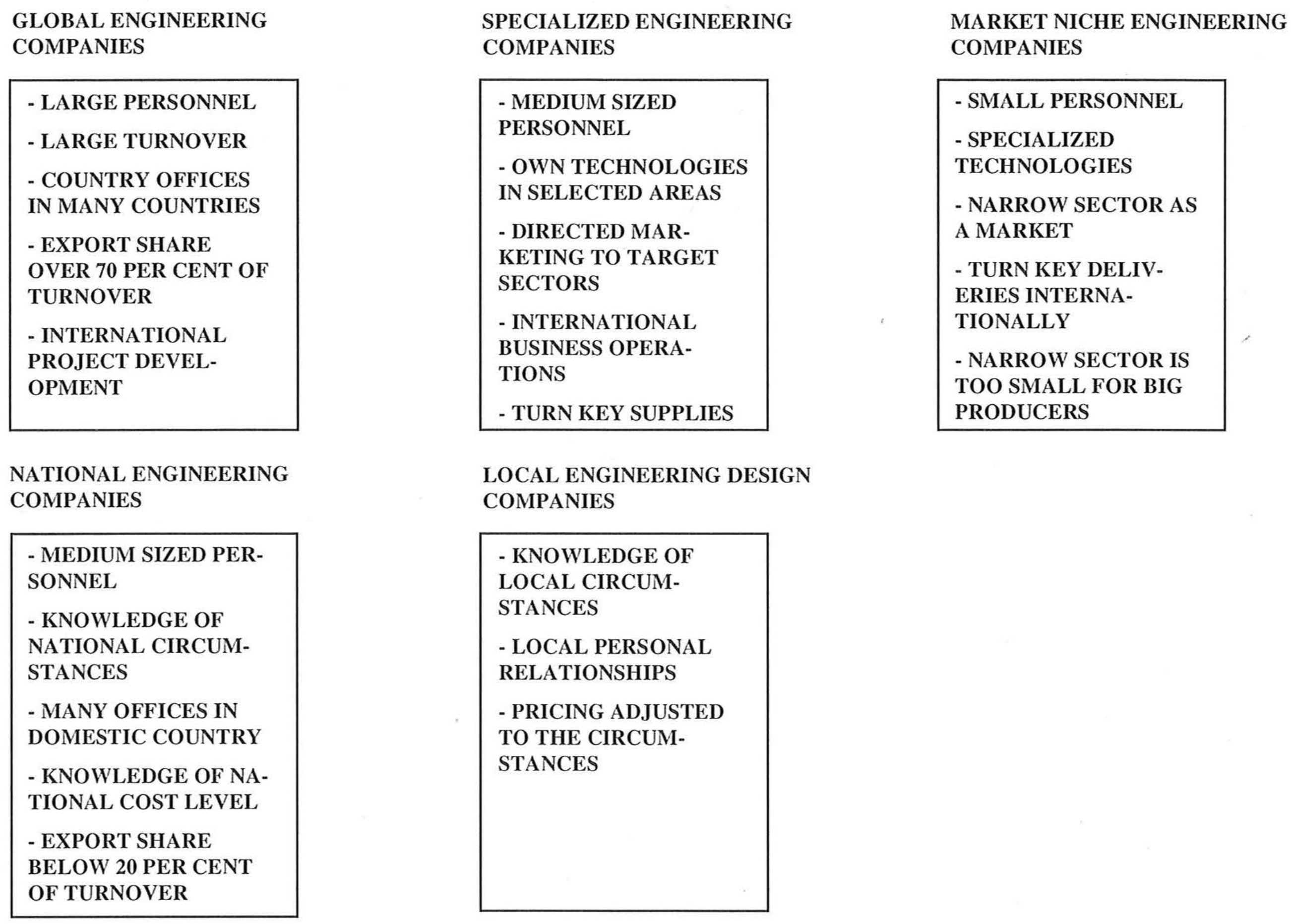
The end results of the evolution, the outcomes of the development are to be described by the strategic groups.

Table 10.3 Alternative paths in the Finnish engineering industry.

Characterization of the pattern	Operative competition mode	Generic competitive strategy	Examples of the case companies
I Local engineering to local engineering company	Design mode	Cost based focus	Alte
II Local engineering to national engineering company	Design mode	Overall cost leadership	SLM Yhtiöt in ABB Oy*
III National engineering to national engineering company	Design mode	Overall cost leadership	Rintekno Projekti-insinöörit
IV National engineering to global engineering company	Design (in national works) or project mode (in transnational projects)	Differentiation or overall cost leadership (in national projects)	Jaakko Pöyry Group
V National engineering to specialized supplier company	Project mode	Differentiation or differentiation based focus	-
VI Innovative engineering in garage to market niche engineering company	Project mode	Differentiation based focus	Kuusakoski Engineering
VII Innovative engineering company in garage to specialized supplier company	Project mode	Differentiation or differentiation based focus	Roxon Kone Wood
VIII Engineering separated from manufacturing to market niche engineering company	Project mode	Differentiation or differentiation based focus	-
IX Engineering separated from manufacturing to specialized supplier company	Project mode	Differentiation or differentiation based focus	Partek Concrete Engineering
X Engineering division or subsidiary to specialized supplier company	Project mode	Differentiation or differentiation based focus	Outokumpu Technology IVO International Raisio Engineering Rautaruukki Engineering** Finnsugar Development
XI Engineering division or subsidiary to national engineering company	Design mode	Cost based focus	-
XII Engineering division or subsidiary to in-house engineering	Project mode	-	Kemira Engineering Neste Engineering

* Note: The company has a characteristics of an assembly company. The strategy seems to limit the company to a domestic market.
** Rautaruukki Engineering could belong to market niche engineering companies which have the similar characteristics as specialized engineering companies.

Figure 10.1 Strategic groups of engineering and their characteristic features.



The evolution of the companies within the alternative paths continues all the time as depicted earlier. A wider case material of the industry would disclose more the dynamic features of these paths.

I Local engineering to a local engineering company

The local engineering design companies serve the needs of the local industries. They know the customers and understand the local circumstances. The products of the local companies are design and project management services. Alte Oy represents well this group of companies.

II Local engineering to a national engineering company

SLM Yhtiöt in ABB Oy

SLM Yhtiöt[1] was started as a one man company which could be described as an electrical repair shop. It expanded to many locations in the home

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1 As concerns SLM Yhtiöt we refer to P. Rouvinen, Energian niukkuudesta teknologian vientiin, ETLA B 93, 1993.

country. The operations included installations, wholesales and retail shops of electrical equipment, and manufacturing of electrical equipment.

The Swedish Asea Ab bought Strömberg Oy in 1985 and Sähkölänteenmäki Oy (the origin of SLM) in 1987. Later Asea and BBC were merged into ABB. SLM Yhtiöt became now responsible for installations and turn key projects of Strömberg and ABB in Finland, in addition the company manages electrification projects and local electrifications in a number of local towns.

In the domestic country, the weight point of the sales is particularly in local areas. The export operations started from the projects to the Soviet Union. Other export countries are, in addition to Russia, Western European countries, Near East, and Far East.

The local projects, the local contacts and the local turnover gives SLM Yhtiöt a nature of a national engineering business. The company belongs to a multinational huge corporation the resources of which are big enough to operate everywhere. However, the tasks given to SLM Yhtiöt seem to be mainly in a domestic country. Another thing is whether SLM Yhtiöt belongs to the field of this study, because the business mainly comprises installation projects of the ABB produced components. The design part is not very significant of turnover, but the project management is large for the turn key contractor.

III National engineering to a national engineering company

National engineering companies are medium sized firms. They often have many working offices in their domestic country. In Finland the national engineering companies consider also the Nordic countries as their domestic market. The national engineering design market is limited. The national engineering design companies either succeed to concentrate to one or a few fields of industry or they serve many industrial fields in their works to get enough volume. Often the national engineering companies have ambitions to grow international. They may export up to 15 per cent of their turnover.

Rintekno Oy

Rintekno Oy was establihed in 1970 when the chemical industry had expanded in Finland in the 1960s, and the supply of the engineering services mainly came from Central Europe to Finland and Scandinavia. The Central European engineering companies had a drawback, they did not know the local circumstances. The need and the niche for the Nordic engineering company were seen in the market to serve the medium sized chemical industry. Rintekno was, for the first ten years, an entrepreneurial engineering company.

The big and important customer for Rintekno has been Neste Oy, the refurbishments and expansion designs of which Rintekno has continuously carried out. The Swedish market was seen as an opportunity already at the beginning. Thanks to an active marketing and a subsidiary in Sweden, Rintekno has made it an important market for the company.

The activities of the company were tried to be directed to the industrial fields of specialities where there would be a deficit of supply of engineering design and a significant market share would be possible to reach. Sweden was a step to this direction and another was concentration on certain special design projects, including biochemical processes, bio technology, medicine production, and petro chemical design and planning works. After a weak year in terms of company profits, Rintekno turned to offer also project management and implementation services in investment projects at the end of the 1970s.

Internationally Rintekno is a small engineering design company, therefore its possibilities in large projects are limited. Instead, the company has concentrated also internationally on refurbishment and modernization projects. The small size of the company gives some flexibility in setting the price level compared to very large competitors. In general, the company has stayed in the market segment where it started 25 years ago.

PI-Yhtiöt

PI Yhtiöt (PI Companies) is an independent engineering company. It sells traditional engineering design and project management services. Its main market is the home country, in addition, the company operates in some other countries. PI-Yhtiöt uses in its designs machinery and components for the plants and systems available in the market.

The idea of PI Yhtiöt was at the beginning to design the project so far that the investor may order the delivery from a supplier as a turn key delivery.

Today, the main customer industries are the construction planning, the design of processes and process equipment in forest and chemical industries, and the basic design of the serial production.

The strategies of PI Yhtiöt is said to be to maintain the quality of the design works, to serve customers in many industries, to build up a domestic network of design offices, to establish foreign engineering offices. PI Yhtiöt has foreign engineering offices in Sweden, Estonia and Hungary. The share of the turnover made in the foreign offices is fairly high, 40 per cent during a couple of years in the 1990s.

IV National engineering to a global engineering company

Jaakko Pöyry Group

After the last acquisitions of companies Jaakko Pöyry Group has many strong active business areas. They are forest industry, construction, city planning, environmental engineering, particularly water planning, and energy.

Jaakko Pöyry Group is an independent engineering design company. Jaakko Pöyry Group takes part in projects as designer, planner, and project manager. It can take a task of the project management even in large projects for the investor, but it seldom takes a responsibility for the projects or parts of them on a basis of turn key delivery. Jaakko Pöyry Group is a global engineering design company with its engineering offices in 22 countries. It belongs to the group of the biggest engineering companies in the world.

The policy of Jaakko Pöyry Group is to remain technologically independent of the component suppliers. Jaakko Pöyry integrates the industrial plants and other units from the components available in the market produced by equipment suppliers. This means that the own know how of Jaakko Pöyry mostly relates to the integration of the wholes and to the knowledge of the systems.

The characteristics of Jaakko Pöyry Group can be described as follows:

- large size, the amount of personnel 5500 people
- large turnover, FIM 1200 million composed of very various works
- large amount of foreign offices in 22 countries

- foreign share of turnover is about 80 per cent
- ability to take large, wide tasks
- very big amount of references, of which still the most important ones relate to the original industry of the company, the forest industry.

An important precondition of the success of Jaakko Pöyry Group is the forest clusters and forest machinery of Finland and Sweden. They were already well developing in the 1950s. The machinery producing clusters started the evolution at the time. It is self-evident and well argued to claim that the engineering companies in the forest industry in Finland are an important relating and supporting industry for the forest and forest machinery industries. An engineering industry in the forest field would not probably have emerged without the forest clusters.

From the company case of Jaakko Pöyry the evolution steps of the company can be summarized into a box. The actual evolution steps can be compared to the expected steps of an assumed evolution from chapter 8 in the path from a national engineering company to a global engineering company.

Evolution steps of Jaakko Pöyry Group since the birth

Start-up

- establishment 1958
- main products at the beginning: factory design and planning, development plans and investment plans
- project management services
- collecting references

In the 1970s

- internationalization by company purchases
- local offices bought to the group
- reorganization

In the 1980s

- becoming a global engineering company
- forest industry, city planning, construction, energy and environmental technologies

- reorganization of the business activities to correspond the needs of international activities

In the 1990s

- purchases of the domestic medium sized companies
- international project development
- cooperation with the international financial institutions in project identification and development.

An assumed development path from a national to a global engineering company

Development steps

- growth of turnover
- expansion of services in specialized field of industries
- expansion of areas of target customers to many industries
- building up an international network of offices and subsidiaries
- building up a management systems for international operations
- a massive accumulation of references all over the world
- ability to assume very special and complex or large international projects
- accumulation of experiences in technological change in customer industries. Technologically a global engineering company behaves normally as a company in an induced branch. But an accumulation of experience sometimes allows to influence strongly on the decision making of the customers.

The comparison between the actual evolution and the supposed evolution paths shows that these two resemble each others. The company cases are to be understood as examples of the developed company paths.

The accumulation of references of Jaakko Pöyry Group in forest industry is very massive. Its role is to be described as a dominant one in some countries. Therefore the experience gathered by Jaakko Pöyry Group approaches the level where the company is able to act as an agent of new technologies in the field. This could happen in the case when the company performs some key tasks in the forest industrial project in which the innovative input is specially high. After having done this task the engineering company may approach a role of a carrier of the new technology, and may even succeed to strengthen its position in the field. Speculatively one could foresee that Jaakko Pöyry might get a role of a technology carrier in the closed paper factory field after the process technology has been adapted in the Finnish forest industry - also more widely in the world market, if it occurs to be in some engineering roles in the first projects.

V National engineering to a specialized supplier company

There is no example of any company to fit this company path.

VI Innovative engineering in a garage to a market niche engineering company

Kuusakoski Engineering

Kuusakoski is originally a metal scrap company. It collects recycled metals and produces recycled aluminium and some other metals at its plant in Heinola. Kuusakoski Engineering supports the main business, as a technical designer, and as a project manager in various kinds of development and investment projects.

Kuusakoski Engineering was established in 1985 to gather all the engineering resources together. At the beginning the task was to support only the activities of the own company. In 1990, the engineering department started to market the services also to the other customers. The target countries for the marketing have been mainly the industrialized countries where the metal scrap is produced, namely the U.S., Far East, and Japan for know how sales.

The engineering department also includes the small machinery shop producing the machinery and the equipment for metals treatment. The activities of the machinery shop belong to an engineering department. The environmental products may become a new product area for Kuusakoski Engineering in the future.

Evolution steps of Kuusakoski Engineering since the year 1985

- establishment in 1985. The mother company is an old and experienced company, established in 1914.
- designing and planning services for the mother company
- project management services for the mother company
- separate machinery shop to produce special machinery for metals treatment
- factory design and implementation services for the foreign projects
- deliveries of the special machineries to the foreign projects
- operation and maintenance services in the foreign units

An assumed development path from an innovative company in a garage to a market niche engineering company

Development steps

- first step is to develop the product (rather to a known customer who also finances the first project)
- to sell and build the first reference
- to start marketing and sales according to resources to foreign countries
- to expand carefully the organization only with committed people
- to keep the entrepreneurial management and culture
- technologically a small company is very dependent on the innovation around which the company was established. In this group of companies the basic know how of a company often consists of components from a specialized supplier and information intensive trajectories combining machinery technology with information technology.

Kuusakoski Engineering has some own technologies for metals and scrap treatment. The own technology is mainly embodied into the machinery produced and sold by Kuusakoski Engineering. The company has sold its technology to Malesia and to the U.S. Kuusakoski has not been able to sell its technology without capital investment. So in these countries, the mother company has become minority investor.

From the company case of Kuusakoski Engineering, the evolution steps of the company can be summarized into a box. The actual evolution steps can be compared to the expected steps of an assumed evolution from chapter 8 in the path from an innovative company in a garage to a market niche engineering company.

The development history of Kuusakoski Engineering as a separate unit is fairly short. It has exploited the long history and experience of the mother company, but the development of the Engineering unit is short.

In Kuusakoski Engineering's case the impact of the information intensive technology is hardly very significant as it may be in some machinery manufacturing companies.

This path could also be discussed with Roxon Oy. Roxon Oy is a selling and marketing engineering company which started as an innovative engineering company. It has grown fast and succeeded to attain a significant market share in some of its segments. The company was positioned, however, to a group of specialized engineering companies due to its large turnover and size of the projects.

VII Innovative engineering company in a garage to a specialized supplier company

Roxon Oy and Kone Wood are located in this category.

Roxon Oy

Roxon originates from the year 1962. It was a typical entrepreneurial company. The products are relating to materials handling, crashing, sealing, transferring, shipping, and homogenizing, and the machinery and equipment relating to them.

The products and their innovative nature have been the strength of Roxon. The owners of the company have changed, including Kone Oy, Partek Oy, Outokumpu Technology and Tampella Oy Tamrock. The owners have realized the potential of good products. They have seen the importance of marketing and the quality of the products. The big owner companies have realized that it is possible to attain a large market share in the world with the products of Roxon. We try to capture the evolution steps into the box.

Evolution steps of Roxon Oy

Establishment

- start-up of the firm as an engineering project company in 1962
- own manufacturing unit for machinery to handle materials in 1965
- products were mainly for the sites of gravel and heaps

In the 1970s

- supplies for the domestic mines
- first efforts to the international markets

- Partek Oy and Kone Oy become owners. Partek resigns.
- reorganization with Kone and cooperation with Kone Wood
- very fast growth in turnover

In the 1980s and the 1990s

- Roxon is sold to Outokumpu Technology
- Outokumpu Technology builds the international organization for transport systems
- customers are power plants, mines, crashing and sealing stations, process industry and harbours
- products are materials and mass handling systems supplied as turn key deliveries
- Tampella Oy Tamrock becomes the new owner of Roxon in 1995

An assumed development path from an innovative company in a garage to a specialized supplier company

Development steps

- first step to develop the product (rather to a known customer who also finances the first project)
- sell and build the first reference
- start marketing and sales according to resources to foreign countries
- expand carefully the organization only with committed people
- keep the entrepreneurial culture as long as possible
- technologically a small company is very dependent on the innovation around which the company was established. The technology base al-

ways is expanded when possible. In this group of companies the basic know how of a company often consists of components from a specialized supplier and information intensive trajectories.

- if the company is lucky and the market niche starts to grow rapidly, or the technology applied is applicable in another niche or sector, an innovative company may grow to a market niche engineering company, and later on to a specialized supplier company. A difference between a market niche engineering company and a specialized supplier is in the scale of business, size of resources, size of projects.
- a successful acquisition of additional resources

The company case is to be understood as an example of the developed company path.

VIII Engineering separated from a manufacturing to a market niche engineering company

There is no self-evident example in the company cases to be discussed within this group.

IX Engineering separated from a manufacturing to a specialized supplier company

Partek Concrete Engineering[2]

Partek Concrete Engineering has its origin in the purchase of the Toijalan konepaja in 1973. The Toijala machinery shop and another one bought from Germany formed the Heavy Machinery Industry in Partek company in the 1970s.

The strategy of Partek was to seek for growth in foreign countries. The solution was to sell whole plants on a turn key basis to foreign markets. The concrete elements were too heavy to be transported long distances, and the direct foreign investments were difficult because of many restrictions in the construction industry. The main markets in the 1970s were Eastern European countries and the Soviet Union.

[2] Could also belong to the market niche engineering companies.

In the 1980s many organizational changes were made. The tasks in the project cycle were organized in two different ways. Nevertheless, the projects were sold all the time. In 1990 the concrete industry was organized to Partek Concrete Oy Ab. The engineering activities were organized by combining the engineering units of Partek and Lohja-Parma engineering to Partek Concrete Engineering in 1992. The new organization is an engineering project company, which designs and sells turn key supplies of concrete element factories. The machinery shop is on the same yard, as a separate production organization, even though owned by the same mother company.

The competitive advantage of Partek Concrete Engineering is the hollow slab technology in which Partek is one of the leading manufacturers of the concrete elements. Partek has used product development resources to develop the technology and the technology is widely used in Finland. Basically the objective of Partek Concrete Engineering is to sell among other things the hollow slab technology embodied into the concrete element factories.

In general, the hollow slab technology, the transferring systems of the concrete are the technologies to be sold on a turn key basis, i.e. including the machinery and equipment. The expectations for the construction industry include large deliveries of factories. The finance is a key element to make the sales.

The reason to divide the engineering and manufacturing to two organizations is the different kind of nature of the functions. This allows the manufacturing unit to produce also other products than only the ones designed and sold by the neighbouring engineering unit.

From the company case of Partek Concrete Engineering the evolution steps of the company can be summarized into a box.

Evolution steps of Partek Concrete Engineering

Start-up

- Partek bought Toijalan konepaja (Toijala machinery shop) in 1972, and later on a machinery manufacturing unit in Germany
- concrete element factories were manufactured and sold to the Soviet Union and other countries of Eastern Europe in the 1970s

In the 1980s

- project deliveries were continued
- own technologies were developed further
- two major reorganizations occurred in the 1980s

In the 1990s

- Partek Concrete Engineering was established combining Partek and Lohja-Parma engineering organizations
- the hollow slab technology, and the transferring systems of the concrete are the main technologies to be sold
- the objective is to sell whole factories on turn key basis
- strengthening of the seller´s finance knowledge
- target markets: the rapidly growing part of the world economy, including St.Petersburg

The development steps can be compared to the hypothesized development path presented in chapter 8. The evolution of the company would be very similar whether the objective is a specialized engineering company or a market niche engineering company. The difference is in the size of the projects and the volume of operations.

An assumed development path from an engineering division separated from a manufacturing of a large company to a specialized supplier company.

Development steps (an engineering separated from a manufacturing)

- to develop marketing abilities
- to acquire capabilities for engineering and turn key deliveries
- a new engineering division has support and commitment of a mother company, and perhaps the resources
- technologically the product base is already at the beginning in a specialised supplier trajectory. Therefore the start is easier in the technological respect than for an engineering division of a scale intensive process industry having a process technology based thinking.
- R&D within the mother company research units may support the development of an engineering unit
- in a minor scale development may lead to a market niche engineering company.

X Engineering division or subsidiary to a specialized supplier company

In this part examples of Outokumpu Technology, IVO International, and Raisio Engineering are used.

Outokumpu Technology

The engineering activity of Outokumpu has developed through many phases from a department of the mother company to a subsidiary developing and supplying technology based machinery, equipment and turn key deliveries.

The technology business of Outokumpu started from the innovation of flash melting technology in the 1940s. The company was committed enough and had the ability to take risk by building a production scale plant on the innovative technology and succeeded in it. The customers from all over the world came to Finland and wanted to buy the licence for flash melting. Outokumpu sold first to Japan and to Romania. Only in the 1960s Outokumpu established a department of metallurgical planning (which later became the technical planning). The turn key deliveries in the 1970s, e.g. to the Soviet Union made Outokumpu a supplier of turn key plants. With respect to the other products, the development in Outokumpu was about similar.

The market of the technology activities of Outokumpu has gradually expanded. The first tests were made at the plants of the company. When the technologies were developed the customers came to buy. At the beginning the customers came from the countries lacking that kind of technology. Later in the 1970s when the company internationalized its activities, it had to make decisions on the preferred countries, and in the 1980s the technology business became global.

The competitive advantage and the base of the Outokumpu Technology have been its own technology. The organization and the engineering business emerged a long time after the technology. Outokumpu mother company continued to use resources to R&D also after the first innovation. In this way, the range of products was expanded from the innovation to the products available for the whole field. Outokumpu was already in the 1940s extremely committed to the development of technologies. In the

1950s and early 1960s this was continued and the top management was also interested in selling the licences of the innovation. The engineering business started to become a business unit and interest grew wider in the company.

In the 1970s, the technology business received more attention as the depletion of the ore deposits in Finland appeared clear. Outokumpu started then to sell systematically its technologies to outside customers expanding its international sales network. In the 1980s Outokumpu also acquired manufacturing activities to produce itself its own technologies as well as the purchased machinery and equipment.

Outokumpu Technology was developed an international specialized supplier company in the true meaning of the strategic group. It is globally active, has its own products and supplies turn key deliveries to different countries. It is a significant company in the industry.

There are two aspects to be referred to in the development of Outokumpu Technology. Outokumpu developed opposite to the other large Finnish engineering companies its technology base and its know how before establishing the engineering organization to sell the technology or other services outside the company. This made the development of Outokumpu Technology different from many other Finnish engineering companies.

Secondly the flash melting technology had behind a technology accumulation and a commitment of the management to technological development. The emergence demanded a purposeful effort and an ability to risk taking. Later on, as the availability of the ore resources in the domestic country changed, the technology division became a vital and equal force within the whole company. One might say that it took a role of the technology carrier in the company. It clearly entered from the culture of the scale intensive industry to the own culture of the specialized company trajectory.

From the company case of Outokumpu Technology the evolution steps of the company can be summarized into a box. The actual evolution steps can be compared to the expected steps of theoretical evolution from chapter 8 in the path from a division or a subsidiary to a specialized supplier company.

Evolution steps of Outokumpu Technology since the 1940s

Emergence in the 1940s

- innovation of flash melting technology in the 1940s
- construction of production scale plant

In the 1950s and 1960s in metallurgical engineering

- sales of the first licence to Furukawa Co. to Japan in 1954
- second licence to Masinimport to Romania in 1963
- separate sales department for technology established in 1965
- technical export department in the late 1960s
- department of a metallurgical planning in the late 1960s
- department of technical export in the late 1960s
- technical export department and metallurgical planning were merged together and named technical export unit in 1978

In the 1960s and 1970 in physics and electronics

- research department / group of physics in 1958 - 1969
- Outokumpu Research Unit for Technology in 1972
- electronics factory in 1972
- Outokumpu Electronics in 1990
- the two roots of Outokumpu Technology worked since the 1960s developing new products for metal manufacturing, mining, instrumentation and measurements

Internationalization

- Outokumpu sold main part of its metals in the world market
- in the 1970s technology branches started to establish sales offices and to build up an international sales network for its products
- in the 1980s Outokumpu wanted to expand the technology based branches
- Outokumpu bought companies and production units relating to its traditional industries, including Rammer and hydraulic hammers, Roxon and its transferring systems, and Galvatec and its technologies for surface treatment of metals

In 1991, all the technology based branches were corporated as Outokumpu Technology Oy. Its products are

- metallurgical and metals treatment plants
- plants and equipment for metals treatment
- plants and metals for metals surface treatment
- components and systems for transferring materials
- hydraulic hammers
- engineering services.

IVO International

IVO International[3] is an engineering project company. It sells turn key projects for power transmission, power plants and other energy systems. IVO International also sells expert services as a secondary business, thus enhancing its own business or the interests of the mother company. The sales of expertise and know how has been dominating in some fields, like in the sales of the nuclear engineering.

IVO International was born from the engineering services of the mother company Imatran Voima Oy. The mother company had all the power plants and energy systems built by its own engineering departments. Since that the main market of the engineering services of IVO International comprised the plants of the mother company and other domestic markets.

In the 1960s IVO Engineering (as the activity of the mother company was called) started to internationalize its operations. It was active in the Soviet Union, Near East, Africa, South America besides the domestic market. Employment aspects were, among others, used as argumentation for the internationalization.

In the 1970s, the management of Imatran Voima Oy decided to cease the engineering marketing outside the company. The whole engineering was employed by the large construction works of power plants in Loviisa and Inkoo. The engineering was overbooked by the works of the own company.

[3] IVO Power Engineering Ltd since 1997.

At the beginning of the 1980s, the company decided again to become international. This time the decision was understood to be final. In 1981 a marketing company IVO Consulting Engineers was established and the name changed to IVO International Oy in 1986. In 1993, all the engineering services of the mother company were transferred to IVO International Oy. The new engineering company employed about 1200 people and its turnover was over FIM 1500 million.

IVO International has always worked as a project supplier. It cooperates with other companies and component suppliers and integrates the whole plants and energy systems on the basis of the components and technologies available in the market. IVO International has gathered an extensive experience in the energy sector. It has also available operation and maintenance know how of the energy systems from the power plants of the mother company IVO Group. IVO Group has some patented technologies, e.g. in nuclear safety technologies and in environmental engineering, besides it has special expertise in various areas.

The characteristics of IVO International can be described as follows:

- the company has a medium sized personnel, about 1100 persons in the domestic country
- business operations are in energy sector and systems, directed to the domestic country and to selected countries. The resources are clearly bigger than the needs for the domestic country.
- as support for the activities are the evolving domestic energy technology cluster and the know how of the own concern
- IVO International has a proved ability to supply and provide turn key projects
- main business of today: turn key supplies, refurbishment projects, investment planning, feasibility studies, and specifications of technical systems.

From the company case of IVO International the evolution steps of the company can be summarized into a box. The actual evolution steps can be compared to the expected steps of theoretical evolution from chapter 8 in the path from a division or a subsidiary to a specialized supplier company.

Evolution steps of IVO International

In the 1940s

- first foreign project supply to the Soviet Union, a hydro power project in Jäniskoski
- IVO´s own projects

Some projects in the home country

- in the 1960s, coal power plant in Naantali
- in the 1970s, nuclear power in Loviisa, coal power in Inkoo
- in the 1980s, bio and peat power plants in Jyväskylä, Joensuu, Haapavesi and others

1. Internationalization

- activities in the Soviet Union, Near East, Africa, South America

2. Internationalization

- main emphasis gradually directed to neighbouring areas, Eastern Europe, Western Europe, South-East Asia, China
- very strong effort to international markets after the year 1993
- own sales companies in the target countries
- purchase of a major subsidiary in Hungary
- at the end of 1995, the personnel of IVO International concern was 1460 people and its turnover FIM 1394 million.

The capacity of IVO International exeeds its own needs and those of the domestic market. The capacity is, however, directed to serve the needs of the domestic market which is to some extent different from the international requirements. The choice of becoming a national engineering company would require to reduce the amount of personnel to a half of the present level in the domestic country, accordingly the objective of the turnover would be much lower than today. This has not been the choice of IVO International, it has made extensive efforts to become international and to increase its sales to foreign target markets.

The first decision made by IVO International is to be an engineering project company. As a project supplier the company tries to have some more space to manoeuvre in competitive situations as pointed out in chapter 6. The cooperation in local projects with the foreign engineering companies, at a lower cost level than in Finland, serves the same objective, as well as the purchase of the engineering design company from Hungary. The technology alliances with the foreign companies and the research and development efforts to improve and develop own products both enhancing the competitiveness of IVO International. They also help the efforts of the company to become an internationally specialized supplier in the selected areas of the energy sector, e.g. in competition with the component suppliers, see chapter 6.

The long and wide cumulative experience, references and all the readiness of the company might give a chance to exploit major technology breakthroughs in the future. The mechanism could be somewhat similar to the one referred in the case of Jaakko Pöyry. Speculatively this could relate e.g. to the technology evolutions of bio, solid or waste fuel energy. The life cycles of the energy sector have been fairly long since the used technologies have to be most proven.

Raisio Engineering

Raisio Engineering belongs to Raisio company. Raisio Engineering is an engineering project company since 1995. The engineering design unit, which served internal design needs, was sold out. The engineering projects relate to the processes and projects of the foodstuff industry. The treatment of potatoes and starch materials is the competitive edge of Raisio company. Besides starch chemistry for foodstuff industry, Raisio Chemicals has developed chemicals for other industries, e.g. paper industry. In this product group the customers are industrial companies in foodstuff and other industries.

The development of paper chemicals belongs to the effort of Raisio company to develop the know how in the field of starch chemistry and of potato treatment. Raisio Chemicals works together with the customers, the machinery suppliers and the suppliers of the paper stuff materials. Valmet Paper Machines is interested in the behaviour of different paper types and chemicals on its paper machines, and possibly ready to take into account the needs for machinery development. The interest of Partek is to find use for its mineral materials in the paper production. The knowledgeable cluster of paper industry in Finland is a good environment to develop paper chemicals.

The other area of strengths is water treatment and water chemicals. There the customers are the municipal water treatment plants, and also in the industries requiring industrial water treatment. Raisio company has used resources to remove the emphasis of its business to other industries than the foodstuff industry.

The use of resources has particularly concerned Raisio Chemicals for industrial and water treatment chemicals. Own processes and products have been developed for industrial purposes and water treatment plants, part of them has been granted patents.

The characteristics of Raisio Engineering are as follows:

- the personnel is relatively small, under 100
- Raisio company has purposefully sought new know how in industrial chemicals and water treatment to replace to some extent the difficult market of the foodstuff industry, even though the development has been continued there, too. A recent example of this is the process of a healthy foodstuff, known widely.
- the new input areas of research and development of the company, industrial chemicals, particularly for forest industry, and water treatment technology, are areas of know how on high level in Finland. It is expected that the cluster environment could be favourable for this development.
- Raisio Engineering has capability for turn key deliveries.

From the company case of Raisio Engineering the evolution steps of the company can be summarized into a box.

Evolution steps of Raisio Engineering

Establishment in the late 1970s

- engineering department was established in the late 1970s as the engineering services were gathered into a same organization
- the new organization was a technical design unit for the company internal needs

- the engineering produced at the beginning both design services and project management and implementation services
- in the 1980s, the engineering was to be a feeler on the market development of environmental technology in the world

In the 1980s

- the products and services were developed in the industrial divisions in Raisio company
- the know how and skills of Raisio Engineering accumulated over time
- in the late 80s and early 90s Raisio Engineering provided services and turn key projects both to internal and external customers
- turn key projects were sold to the Soviet Union in the 1980s. In the 1990s, project export has been made to Hungary, China, India, and Poland. Opportunities are seen for process engineering in the Far East. The target areas of water engineering are the neighbouring areas of Finland, the Baltic regions, Poland, and England.

In the year 1995

- the internal engineering design service unit of the company was sold. The remaining part became a subsidiary. The subsidiary, Raisio Engineering Oy sells turn key solutions and supplies of process and environmental technologies as projects to the outside customers.

The development of Raisio Engineering is promising. The process and product development has its base on the strong industrial and infrastructure clusters of the Finnish industry.

The development steps gathered from Outokumpu Technology, IVO International and Raisio Engineering can be compared to the assumed development path of chapter 8. The company cases are to be understood as examples of the developed company paths.

An assumed development path from an engineering division or subsidiary of a large company to a specialized supplier company

Development steps (for an engineering division or a subsidiary)

- first step is to develop marketing and sales capabilities for operating in an open market

- to establish a project marketing channels to target markets
- to establish own international network with suppliers, customers, and sources of information
- to build up and to secure the commitment of a mother company to engineering business which is totally different from a scale intensive process industry
- to develop a feasible firm-specific technology strategy. The induced technology from an investing (customer) industry, perhaps added to some systems integration and process technology know how, is not sufficient for a specialized supplier.
- to combine the opportunities of engineering and R&D effort within the same large company. The engineering division is very closely tied with the induced technology of the mother company. The issue is to build technologically a bridge from a scale intensive trajectory to a specialized supplier trajectory.

XI Engineering division or subsidiary to a national engineering company

There is no example in the company cases to be discussed within this group.

XII Engineering division or subsidiary to an in-house engineering

Kemira Engineering and Neste Engineering can be categorized to this company path.

The large companies used to have their own organizations to take care of the investments of the firms. The organizations can be in-house engineering firms competing with outside engineering companies. Internally the services of in-house engineering divisions vary and can consist of technical design, planning and implementation of investments, commissioning of plants, and other project management services. Practically the in-house engineering divisions are carrying out the investments of the mother company at its risk. The in-house engineering division may have some other functions within the concern like entry to international market and product development activities.

The in-house engineering department can take the role of a trustee consult who is managing the project for the investor, the mother company. The corporated engineering units often take the role of a turn key supplier as they would do in their sales to outside customers.

The cases when the in-house engineering units start to compete for the projects in an open market have been discussed in the path X. Here the matter concerns those cases where the engineering units are set to serve only internal needs of the company.

In Finland these subsidiaries of large companies are mostly tied with the companies in a process industry. The know how of these companies is related to the systems knowledge to design and build up well operating entities of industrial plants. This know how includes the process know how in the particular field of technology. The availability of the operation and maintenance know how of the process industry within the mother company often is the competitive edge to the engineering subsidiary.

Neste Engineering

The engineering organization was formed inside Neste Oy in the 1960s. The size of the organization was 200 people at the end of the decade. In 1980, the engineering was formed to an independent business unit which reported to the board of Neste Oy.

The reasons for establishing an own engineering organization in Neste Oy were the needs to design, develop, and to implement investment projects within the company. When expanding the needs of the know how, the knowledge also grew in the company. Neste bought a large amount of engineering services outside the company, still having plenty of work for the internal engineering. After the year 1975, Neste Engineering has had a central role in designing the investments of the Neste company. The greatest customers have been the Oil and Chemicals Industries.

The objective of the mother company was to secure the presence of the technical know how and the procurement of the competitive production plants. The engineering had to acquire technical know how and to maintain it.

In the 1980s, the Neste company invested in many new production units in Finland and elsewhere, and the engineering was busy to provide the services needed. As the investments in Neste Oy were reduced down the engineering had to start thinking of sales efforts to outside customers. In the 1990s, the circumstances in Neste concern changed as the Chemicals Industry was merged with the Norwegian Statoil into a common operation in Borealis. The engineering remained in the organization of Neste Oy. As the size of the organization was too large for the needs of the Oil Industry alone, the amount of personnel fell from 400 to 200 people in 1992 - 1994.

In the middle of the 1990s, the position of Neste Engineering has stabilized. The engineering keeps reporting to the board of the company, and supplying mainly engineering services to the Neste industries. The engineering organization has started to operate also in the outside market, e.g. it sells the licences of the MTB process to outside customers. The plans include to start offering engineering and rehabilitation services to the market of the Russian oil refineries and petro chemical plants together with foreign engineering partners. There are indications that Neste Engineering expects to have an opportunity to enter the open market with its engineering services. If this is to happen, Neste Engineering would change the industry path from the in-house engineering pattern to a subsidiary of a large company as referred earlier in this chapter, and start to offer to outside customers.

Kemira Engineering

In the 1970s Kemira made many large investments in domestic factories. The technical services were organizationally in the production group. It was changed to a separate profit center in 1978. The position of the technical group in Kemira was very significant as the technical know how in the plant construction was concentrated in the group. The technical export group made some technical studies for Algerian, Indian and Arabic customers in the early 1980s. The projects were mainly financed by development aid resources.

From 1983 to 1987, Kemira Engineering worked under the head office in the Kemira company. The objective was to combine the technical resources of the technical group and the technical export group. At the time

Kemira strived to become international to secure the growth. Kemira Engineering was supposed to provide services to internal and external customers. The operation was successful in the meaning that the new engineering unit was able to sell projects to many countries like Algeria, Korea, India, Pakistan, and Arabic countries. However, the engineering was not allowed to offer to the main markets of the process industrial divisions of Kemira.

The sales of the engineering services were ceased to outside customers in 1987. Kemira Engineering was merged into the research and development services of Kemira forming an united organization, the Research and Development Unit. The engineering was to be responsible for the design and implementation of the internal investment projects in the Kemira company. The production divisions of Kemira were to be responsible for their own export projects.

The main reasons for the termination of the activities of Kemira Engineering was that it became a threat for Kemira's other production divisions and that the contradictions disturbed the operation of the engineering during its active operations outside.

The base and the objectives of Kemira Engineering are after the year 1987 to maintain the specialized know how in the company, to implement created technologies by the company's own R&D to investment projects, to support the export department of the company. The engineering has been dealing with some international projects with which the mother company has been involved.

11. EMPIRICAL RESULTS OF THE STUDY

11.1 Start-up of engineering companies

In this study five distinctive types of start-ups of engineering companies were identified. Each of them has its own characteristics, and partly therefore the distinctive development path. The development of the companies is possible, not a deterministic future. Many companies also fail, and remain to some intermediate stage for a long time. The distinctive start-ups are shortly presented here.

Local engineering design companies.

Local engineering companies are started typically by entrepreneurs. Local engineers start supplying technical engineering services in the name of their own or a newly established company. The entry barrier is low in engineering design business. Often engineers have a very good local personal network within the local decision makers. Their experience background is probably strong for the type of work they start as a company. The local engineering companies can also be involved in the project management services, but very rarely in turn key deliveries since the risk taking capacity of these companies is inevitably low.

Local companies have a limited size. Their strength is that they really know the local needs and the market. Experts are known and it is very easy to ask for their services and to trust them. In the local companies a particular feature of an engineering industry is well exemplified, i.e. the personal and local nature of the business. Technical services are rather bought from known companies and known people. The speciality of these companies is the locality, the customer industries may represent many industrial branches in the area.

National engineering companies.

The national engineering companies can be start-up companies which have initially more resources than local engineering companies. Therefore they can carry out larger projects. For example if an engineering company receives a design and project management work of a paper factory in its early phase, it can be interpreted to be a national engineering company if the project is large and of national importance. The company remains a national engineering company even though it grows, starts other domestic design offices and starts export activities.

The range of products consists of technical design, implementation planning of investments, technical expert services and studies and implementation services of investments. Particularly in the beginning the services are sold on time basis. This reduces risks, and eases liquidity of a starting company.

The specialities of national engineering companies become most often in industrial areas which are widely represented within the customer industries in a domestic country. The growth strategy of a national engineering company has two options, either to serve only the "strong" customer industry, when the growth potential is limited in a domestic market, or to serve also other industries, when the specialization is retarded as the tasks are in many fields. National companies develop good working relationships with national decision makers.

<u>Innovative companies in a garage.</u>

These companies are small start-up companies with entrepreneurial background. They specialize in a very narrow market segment. The entrepreneurs have often a background in the business area where they continue with their new innovative product organized to a newly established company. At the very beginning it is clear that the company has to start selling the products to a very wide market and many countries, otherwise the market volume is too small due to the narrow market segment.

The typical feature in these companies is that the product innovation is related to a tangible product, often a capital product. The credibility of the small company is, however, too low to sell the innovation as a design service product. Often the entrepreneurs have made their innovation in a very concrete way: they have built the equipment to prove that the innovation works, instead of making a great amount of technical and scientific tests or experiments. The products are also sold to the customers as turn key deliveries including the innovative features.

The key to the competitive feature of the market niche company is the small size of the market segment. The larger competitors do not make the effort to enter the small market as the effort would not pay back. The potential small competitors have not resources nor a competitive innovation to enter the segment. A large market share, even in a narrow worldwide segment, gives the benefit of cumulative learning and makes the segment defensible for a company.

Engineering companies separated from a manufacturing.

This type of engineering service is started from a manufacturing base. In this case it is started in a large company environment. The large company has a manufacturing unit of a product, an engineering unit is established aside. The engineering unit offers technical design services, project management services and turn key deliveries of the particular product. The marketing and sales of the particular product may be organized by the engineering unit. The manufacturing and the engineering are separate business areas in a large firm, but they work together. The engineering unit may cooperate also with other organizations within the large firm or outside it. The organization may reflect the need to separate the manufacturing and the engineering from each other in a particular case.

The nature of the product (innovation) as well the way of doing business resemble that of a small garage firm. The manufacturing unit may have other products, too. The organization of the innovative product to an engineering firm gives the product an identification with the particular organization and people. The engineering unit may have a different structure of personnel from that of manufacturing.

Engineering divisions or subsidiaries of large companies.

The large companies used to have major organizations to take care of the investments of the firms. The organizations were and are in-house engineering firms competing with outside engineering companies. Internally the services of in-house engineering divisions are technical design, planning of investments, implementation of investments, commissioning of plants, and other project management services. Practically taken the in-house engineering divisions are carrying out the investments of the mother company at the risk of the latter. The in-house engineering divisions might have some other functions within the concern like e.g. entry to an international market or product development activities.

Gradually many companies let the in-house engineering units start competing in an open market for the projects, too. Many of these organizations have also been corporated. The engineering subsidiaries supply technical engineering services and turn key deliveries to internal and outside customers. These organizations can be large companies. They may have had large project implementations in domestic and other countries. However, their experience in operations in the open markets is limited at the beginning. They may have only one important customer, the mother company. The technical experience, capacity and potential is often large.

In Finland these subsidiaries of large companies are mostly tied to process industrial production companies. The know how of these companies is related to the systems knowledge to build up well operating total entities of industrial plants. This know how includes the process know how in the particular field of technology. Often the availability of the operation and maintenance know how of the process industry within the mother company is the competitive edge to the engineering subsidiary.

11.2 Development of engineering companies

A relevant question: Why should there be distinctive paths of company development which the firms follow more probably than other random patterns? First, it is clear that a development of companies is not deterministic, the companies have a freedom of choice. But given the technologies, the rules of decision making in the market, and other business environment, the companies tend to make choices to their own benefit which make them resemble certain prototypes. The strategic maps in the particular industry are models of these prototypes. In the same way the external forces push the companies towards certain prototype strategies. They also affect the companies in the course of the time towards certain development paths. When the forces remain more or less constant the companies find certain choices more profitable than others. And the companies find a few alternatives which they believe to result in the best outcomes. This is basically the reason that also the development paths tend to receive distinctive forms as the outcomes, the strategic groups and development paths of companies. This does not exclude variations in time nor the behaviour of companies within development paths.

The strategic groups are presented in Figure 10.1 which represents the cross section picture of the paths. The cases when the engineering companies remain in the strategic group where they are created concern in the first place, local and national engineering companies and, in the second place, subsidiaries of large firms.

Practically the task of building the development paths of companies means that the characteristics of the development paths between the group of distinctive start-ups and of the five distinctive strategic groups have to be depicted. The development paths describe the development over time, and the strategic maps are cross sections at a certain point of time. The taxonomy considerations in company development, technology change, and strategic development help to find relevant dimensions to identify important features in the development patterns of the companies in the engineering industry.

The most important dimensions in the taxonomy of the strategic groups seem to be the size, the specialization (which is in the same dimension as the diversification with the opposite sign) and the internationalization. The same dimension was found as a relevent set of taxonomy of technological change and innovation. Time is also an important dimension for the development paths and, particularly, because the paths also develop in the course of time.

The studies of technology led to the model of basic technological trajectories within innovative activities. These do have relevance to the effort in building the development paths in engineering 1. by giving the model for the construction of industry paths (instead of technology patterns), 2. by giving components to the construction of "specialized suppliers" due to overlapping the task of the study, and 3. by catalysing new thinking concerning induced engineering group of companies. The company life does, however, exist outside the development paths. This happens probably at the cost of profitability of the company.

The engineering companies within a certain development path seldom change the path. This is partly due to the internal reasons, e.g. the reasons relating to the start-up of the company. Partly this is due to the external factors which are behind the emergence of the development paths and the strategic maps. Sometimes, however, changes between the development paths are possible. It may happen because of extraodinary large efforts, changes in the environment or market or good luck. The next table presents the paths which are more propable than many others. For all of them one or more examples are given.

Table 11.1 Alternative development paths in the Finnish engineering industry.

Characterization of the pattern	Operative competition mode	Generic competitive strategy	Examples of the case companies
Local engineering to national engineering company	Design mode	Overall cost leadership	SLM Yhtiöt in ABB Oy*
National engineering to global engineering company	Design (in national works) or project mode (in transnational projects)	Differentiation or overall cost leadership (in national projects)	Jaakko Pöyry Group
Innovative engineering in garage to market niche engineering company	Project mode	Differentiation based focus	Kuusakoski Engineering
Innovative engineering company in garage to specialized supplier company	Project mode	Differentiation or differentiation based focus	Roxon Kone Wood
Engineering separated from manufacturing to specialized supplier company	Project mode	Differentiation or differentiation based focus	Partek Concrete Engineering
Engineering division or subsidiary to specialized supplier company	Project mode	Differentiation or differentiation based focus	Outokumpu Technology IVO International Raisio Engineering Rautaruukki Engineering** Finnsugar Development
Engineering division or subsidiary to in-house engineering	Project mode	-	Kemira Engineering Neste Engineering

* The company has a characteristics of an assembly company. The strategy seems to limit the company to a domestic market.

** Rautaruukki Engineering could belong to market niche engineering companies which have the similar characteristics as specialized engineering companies.

A short characterization of the alternative development paths is presented in Table 11.1. In the table the development paths, the competitive modes and the generic strategics are presented. The positioning of the engineering companies into the categories is presented with the help of examples.

The table does not include the paths in which the engineering company remains in the category where it was established. The included categories have been selected into the table based on the experience. The company examples illustrate the developed models.

11.3 Roles and significance of engineering companies

This research was started by chapter 1 where the industry was preliminarily described by the products and services, and by the roles and tasks the engineering companies include in their activities. In the analysis of chapter 9, the evolution of the structure of products and services could be seen in the Finnish engineering companies. The more demanding types of services have constantly increased their share in the products of the companies towards the 1990s. The evolution of the products and services of the Finnish engineering companies indicate besides the improvered level of the engineering companies, also the increased requirement in the quality of the market demand.

On the background of this development is the change of the pattern of growth of the national product. The growth of the production was driven by large investments until the middle of the 1980s. Since then, the growth is driven increasingly by the innovations, not so that the investments would lose their role, but their role will decrease.

In the growth of production driven by the investments the industry was investing all the time a large share of its resources. The investments as such create new growth and demand to the economy. At the same time new capacity was built, and that allowed to produce more products for the domestic and foreign markets.

In the growth driven by innovations the emphasis is in the improvement of the quality, not in the quantity of growth. The products receive new features and they are produced with more efficient methods. The importance of a knowledge and technology as a production factor is emphasized in this phase.

Concerning the engineering companies, the traditional roles of engineering companies like technical design, technical expertise, investment planning, implementation of investments, project management services of investment, and possibly turn key supplies were asked by the customers during the period of the growth driven by investments. These services will be required also in the future. But the demand will grow for the new types of engineering services like construction of automatic production lines, programming services, re-engineering of production and information flows in a factory, and other knowledge-based, multi desciplinary types of services, see Kässi (96, pp. 24-40).

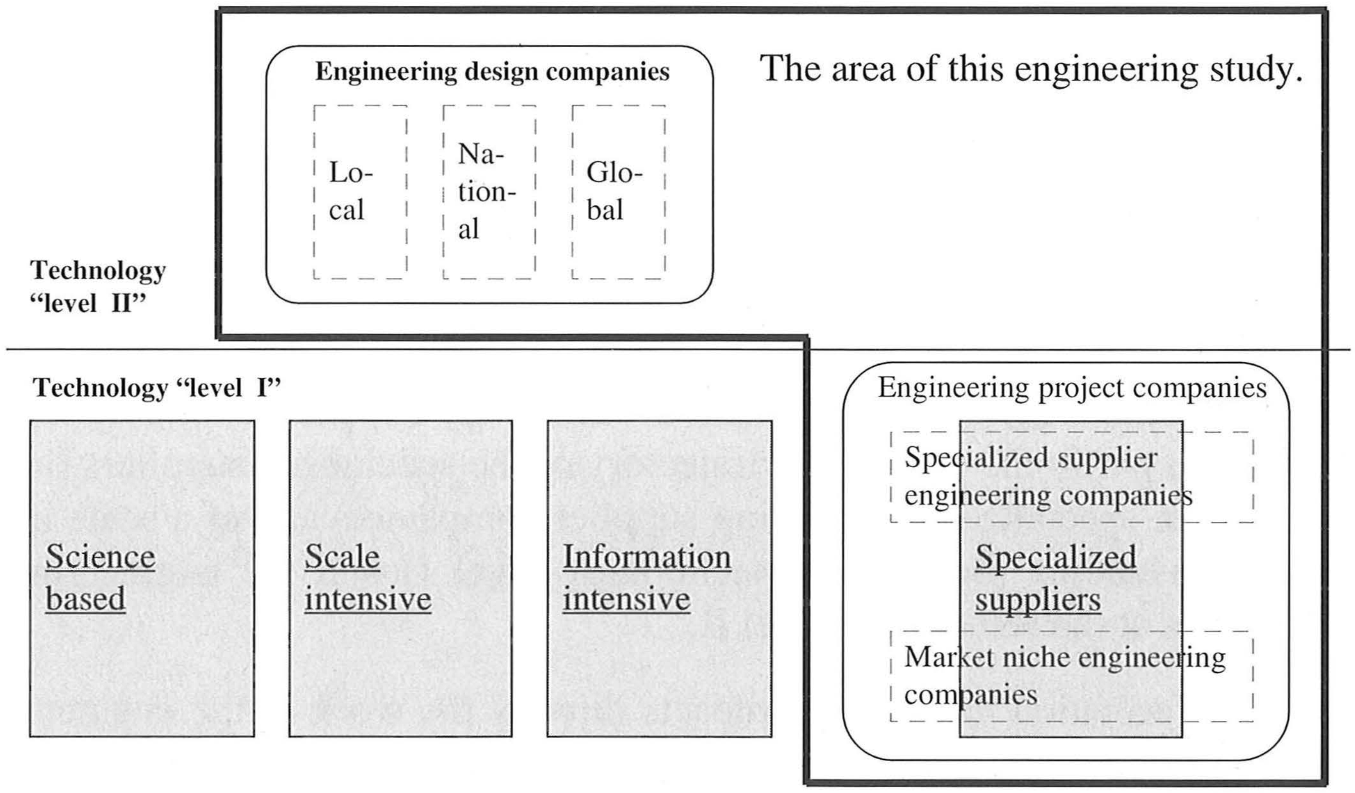
This means that the engineering service industry is going to experience a structural change together with the evolution of the industrial structure. If the key words of the engineering, with respect to the industry, were in the period of the growth driven by investments: investments, technology and development, Kässi (96), they would be in the future technology, evolution, institutional changes, and acting as an agent for evolution, following the ideas of Freeman. This will give new roles for individual engineering companies. The matter is discussed from the point of view of an individual company in chapter 11.6.2.

11.4 Significance of technological evolution

Technology and technological changes are complicated matters in this study, because they have influences on the phenomena via many routes. The main technological aspects are summarized and concluded in Figure 11.1. There are two levels of technology. The first one is the technology carrier level (level I), where e.g. the investors of the industries and the machinery and equipment producers are. Above this level I is the technology level II which includes the related companies such as the engineering design and project supplier companies. The engineering companies at the level II serve the investors and to lesser extent also the machinery and equipment manufacturers. The level II companies are determined to be induced by the level I technologies. The engineering companies serve in the first place the companies in the scale intensive industries.

The four grey quadrangles at the level I are the basic technological trajectories: a science based, a scale intensive, an information based, and a specialized suppliers trajectory. The trajectory determines the technological and economic trade-offs. In each technological trajectory there are own particular rules of decision making, mostly followed by the companies. There are also engineering companies at the technology level I: the strategic groups, the specialized engineering companies and the market niche engineering companies.

Figure 11.1 Evolution of technology trajectories and their impacts on the strategic groups of the engineering companies.



This engineering study consists of five strategic groups, three of them at the technology level II, and two of them at the technology level I. The black thick line in Figure 11.1 depicts the area of this research. This has made the technology matters complicated in the research. The technology level I is a deeper and more profound level. The conclusions on the technological aspects can be summarized as follows.

1. The technological discontinuities caused by the radical innovations, the great accumulation of technological know how, or even changes of technological trajectories, may transfer the engineering companies from the technology level II to the technology level I.

a. The technological changes may transfer the national or global engineering companies to the technology level I, in practice, towards the strategic group of the specialized supplier engineering companies. If this occurs the position of those engineering companies becomes stronger.

b. The technological changes or innovations give also the companies of the technology level I more opportunities to manoeuvre in competitive situations in the market.

2. The basic technological trajectory of information intensive industries is expanding due to the radical innovations made and applied in the information technology. The change of the information technology is so wide that it has been foreseen to start its own new paradigm in the industrial evolution. The paradigm is a wider concept than a trajectory, and it means that a paradigm will impact larger number of industries, if not all, whereas the trajectory would impact a few industries, see e.g. Lovio (89) and Lovio (93) and the references in both of them.

We could depict the change in the information technology in such a way that the quadrangle of the information technology expands so widely that it overlaps partly the technology trajectory of the specialized suppliers (including the specialized engineering supplier companies) and of a scale intensive industries (both at the technology level I) and the engineering companies at the technology level II.

a. The information technology impacts directly the work of the engineering design, for example the productivity may grow rapidly. The technologies will be taken into use in all the countries, therefore we have estimated that it would not directly change very much the competitive situations in the engineering industry between countries.

b. When the information technology trajectory overlaps the technological trajectory of the specialized suppliers, opportunities will be opened for new innovations in the design of capital goods for the investing industries. Also totally new radical innovations may become technologically available and attainable in the market. The innovations are to change effectiveness of production technologies and to increase the productivity of the investing industries radically. The technology improvements are coming to the investing industries, i.e. to the scale intensive industries from the specialized suppliers of technology and machineries, and partly from the production engineering departments. The improvements are implemented by the investments in a production. In the investment projects the engineering companies have their roles and in this way the new opportunities may be opened also for them.

3. The science-based technological trajectory consists the sectors and companies which should have capacity to create radical innovations and later on totally new industries. The conventional engineering services will remain the essential components in the field of industrial services because major investments are always needed and the professional services are then required. If and when the economic growth in the industrialized countries will be predominantly driven by the innovations, not by investments, the new and innovation-based industries will grow faster than the traditional ones. This means that the new types of industries will demand also new types of industrial services. Therefore it is expected that the structure of the service industry will change in the future. The driving forces in this change come from the science-based and innovation intensive trajectories.

In the evolution of industries the emergence of new clusters often reflect some innovative changes in technologies. The technological change is an endogenous factor influencing positively the emergence of a cluster. The eight factors in the infrastructure environment of an engineering company assist the company to develop after the initial stages of the company life.

11.5 Impact on the evolution of clusters

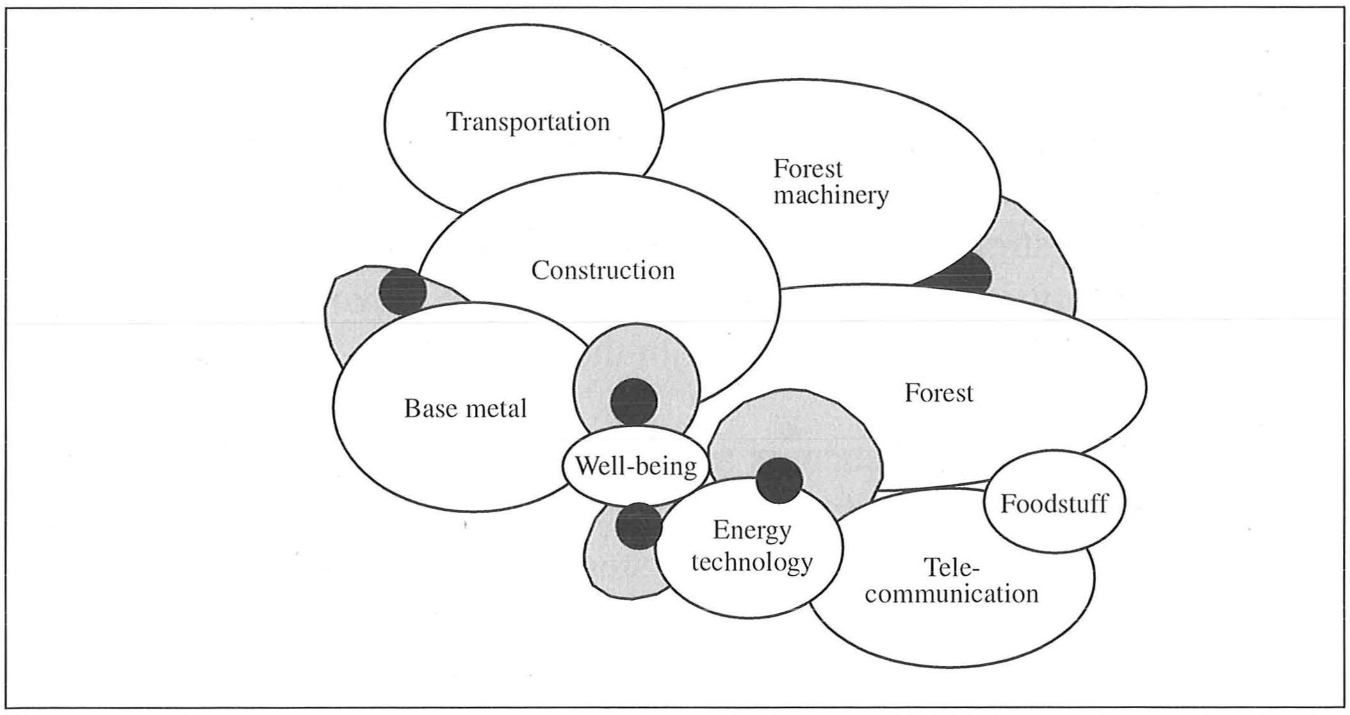
From the empirical material it was clear that the most successful engineering companies in Finland have emerged and developed within the influence of the strong industrial clusters. In the study of engineering companies a question has been, whether the engineering companies could develop an entity including all the engineering companies and have the particular features of industial cluster in the near future.

The potential growth and success areas around the successful engineering companies have been indicated, Kässi (96). If a knowledge-based engineering company which has the infratstucture of the eight preconditions offers its products and services to a rapidly growing market, it may grow very fast. In such a case the engineering company may draw subcontractors, component producers, other engineering design companies and suppliers of services to grow together. This could be a seed for a new cluster.

The finding is that new potential success areas created by engineering operations could be developed in forest industry, in energy technology, and in community technologies including waste treatment and water treatment. In practice this means the companies Pöyry Group, IVO International and a group of construction and engineering companies active in the water treatment technologies. With respect the technologies and the eight preconditions the position of Outokumpu Technology are also good, but the growth expectation of mining and metals technologies is not sufficiently fast. These particular engineering companies have been depicted by the black spots in Figure 11.2. The potential new success areas presented in grey colour are surrounding them.

The new growth to be attained from these fields driven by the engineering companies would require new measures relating to the international project development in these fields. The growth would relate strongly to the present clusters of the industry, but would be initiated by a project development and project purchases. The overall engineering cluster is not, however, expected to emerge as a structure of a cluster due to the fragmented and separate areas of technologies and market segments.

Figure 11.2 Potential success areas of a growth driven by the engineering companies through project sales in period after 2000.



The changes in technology may change the evolution as described in the previous chapter. Technological breakthroughs could, in appropriate circumstances, allow good opportunities for an engineering company to push new technology into exploitation and become an agent of that technology in a wider market than previously.

11.6 Other observations

11.6.1 What can be learned from the failures ?

From the case studies we can learn that the establishment of engineering organization in large Finnish companies was a kind of management mode in the 1970s, see Kässi (96). Sometimes new organizations were established without sufficient consideration, believing the matter easier than it turned out to be.

Employment

One unqualified argument in the establishment of an engineering division to a large company sounds "the engineering over capacity was to be collected together and to be sold in an open market" and it has been mentioned many times. This argument is mentioned in the cases of Enso Gutzeit Oy, Ulkomaan projektit -unit, IVO International during the first internationalization and partly Kemira Engineering. The employment seems not to be a sustainable argument. Engineering units are, however, so small in their importance for the company that their activity is not continued after the first difficulties. The argument of employment loses its importance. In the case of Enso Gutzeit, the company withdrew from the market when the management of the activity left for pension. IVO International withdrew from the market due to the internal tasks. The employment of the engineers is a positive thing but it is not vital reason for the mother company to develop business. Kemira Engineering had not really considered what it does mean to work in an open market in the engineering field.

Role of engineering

When Valio, Hackman and Hankkija started commonly owned Valiotekniikka they had a general impression that by making the marketing more efficient everybody would win. The partners also believed that the engineering activity would not suit the enterprise culture of Valio in which they may have been right. As the activity did not start as fast as expected the component producers, Hackman and Hankkija, withdrew from the company and it remained a 100 per cent subsidiary of Valio. As Valio really wanted to buy efficiently and professionally investment projects and subprojects for its dairies, and not to invest in internationalization of dairy technologies, the engineering operation was minimized.

The development of Valiotekniikka as an engineering project supplier would have demanded the combination of an engineering know how with a process technology for the turn key deliveries. The development of Valiotekniikka to a specialized supplier would have meant an effort to commercialize the process know how of the milk technologies of Valio by the turn key deliveries. In addition, the development of an engineering project company would have required more resources, risk taking, time, and commitment than the policy selected.

Valiotekniikka is to be developed as an engineering design company after 1994. The personnel is 20 per cent of its maximum level of people. The services provided are supposed to be sold to the mother company and the foodstuff industry.

Kemira Engineering's starting and ceasing of an international marketing reflects an inability to see the strategic consequences of starting the engineering project organization, a potential conflict of interests between the operative process divisions and the engineering unit. The business of a project supplier requires the presence of process know how and engineering know how. The customer of the turn key delivery wants to get both. The lack of commitment is also to be suspected in the case of Kemira Engineering. Otherwise it is difficult to understand the international operation for three years time. The engineering was merged to the research and development unit and named Research and Technology unit which serves internal customers.

The engineering activities in Valio and Kemira became to serve mainly or only internal customers. The issues related to the decision are also recognized in other companies. For example in Imatran Voima, where IVO International is to serve, to an increasing extent, external customers, the power and heat production within the mother company has a small unit with technical expertise to buy professionally engineering services either from IVO International or from outside.

Commitment of the mother company

In all of these cases a clear strategy and a defined and accepted role of the engineering organization in a large company are not present. It is often also a sign that the management of the mother company is not committed to the engineering business. Even in the case of Outokumpu Technology the role of the technical and engineering divisions was not quite clear within the own company. But since the 1980s in the case Outokumpu Technology the division has become a vital part of the company and has received all the support it needs from the mother company. The same is true with IVO International since the 1980s.

A clearly lacking commitment comes up with the case of Nokia Engineering in the 1980s. At the beginning, the engineering got the full support from the top management of the company. After the change of the management, the support was not there and the contradictions between the divisions within the company became uncontrollable, resulting in the termination of the activity of Nokia Engineering. In the case of Nokia similar projects have been supplied through different divisions of telecommunication. When the engineering tried to start in the 1980s, the time was perhaps not mature.

Neste Engineering has developed on the basis of the internal investments of the mother company. Likewise engineering has developed as an internal in-house engineering company. When the petrochemical sections of the company were merged with those of the Norwegian Statoil, the personnel of the engineering division was too large for the oil industry of Neste Oy alone. The amount of personnel was decreased significantly. The position of Neste Engineering seems to have stabilized and the engineering continues serving mainly internal customers. Neste Engineering has started to sell some services on a licence outside the company. Neste

Engineering expects possibilities and challenges in entering the engineering market of Russia in cooperation with some western engineering company.

The commitment to develop the in-house engineering companies, like Neste Engineering and the followers of Kemira Engineering, can be discussed with the small diamond model. The point is that the infrastructure of an engineering environment described by the small diamond, or alternatively by the eight preconditions, does not always give the support for the development of the engineering company needed to attain sustainable competitive advantages. It is considered impossible, following an argument of Porter, for an engineering company to develop a small diamond when serving only internal customers in a company. Therefore in the long term the competitive advantage becomes difficult to sustain. The matter has to be decided case by case on consideration of alternatives.

Development of the know how base of an engineering

A point of view to consider the commitment of the mother company to develop an engineering division is to look at the relationship between the engineering and the research and development centers in the same company.

The research and development center is not, by its nature, very competent in commercial aspects, but is more competent in technical and scientific aspects. The engineering division is, or should be, more competent in marketing and other commercial matters. The issue is, how to combine these strengths. The case examples include many kinds of solutions. In some cases the two organizations have been merged together as was done in the case of Outokumpu Technology, Finnsugar Development, and Kemira Research and Technology. Outokumpu Technology is selling both externally and internally, Finnsugar Development is selling mainly internally and Kemira Research and Technology only internally.

Examples of opposite cases where the engineering and research and development are clearly separated from each other are IVO International, Raisio Engineering and Neste Engineering. IVO International and Raisio Engineering sell mainly to outside markets, whereas Neste Engineering sells internally.

Table 11.2 Organization of the engineering and the research and development in the example companies in the context of selling turn key projects outside the company.

	Separate engineering and R&D organization	Engineering and R&D center organized together
Outside marketing or intention to market outside the turn key projects	IVO International Raisio Engineering Neste Engineering	Outokumpu Technology Finnsugar Development
Mainly (only) internal marketing of turn key deliveries	Valiotekniikka	Kemira Research and Technology Center

One aspect of evaluation relates to the right and willingness to sell the technology, developed in the research center, to outside customers. Companies which either sell outside or intend some time to sell outside projects seem to have organised research and development and engineering in separate organizations. However, in a case where an engineering company has really committed itself to a specialized supplier role, like Outokumpu Technology, with the objective to earn by manufacturing components and supplying turn key projects, the two organizations have merged together. In the case of Outokumpu Technology, some sectors of the research were really merged with the engineering, some sectors still exist in a separate organization. While Finnsugar Development does not sell the xylitol technology outside the company, it sells other technologies.

Valiotekniikka of today is partly owned by the Jaakko Pöyry Group, and consequently the research center belongs to Valio's separate organization. Research center tries to commercialize its know how by selling of licences. Kemira Research and Technology Center concentrates on serving the internal customers. In this case a common organization causes no extra risks.

Different arrangements may affect alternative views on the activities of engineering. One view is to see engineering as an engineering design activity and the work is then performed and charged on the basis of time used. The other view is to see the engineering as an engineering project activity. This is often connected to the view that a mere engineering design is not easily competitive for the cost reasons, see chapter 6. If competitiveness is sought from the role of the project supplier, the components are mostly bought from the market and the engineering and R&D are separate organizations. But the ownership of product rights and the component manufacturing seems to lead into a merger of the engineering and R&D organizations.

Maximizing the accumulation of the technical know how within the engineering and the fast commercialization of the knowledge leave open the issue which is an optimal organization, whether a combined engineering and R&D or a separate engineering and R&D. Both have been tried, both have been more or less successful.

Internationalization

Many national engineering design companies have plans to internationalize to reach wider markets and growth potential. Many of them have succeeded, too. Large companies have sometimes given, e.g. Outokumpu, to their engineering divisions spearhead or feeler roles to start the internationalization of the company. The task also includes e.g. the gathering of the information on competition in the market.

The case of Ekono, and dozens of other engineering companies, should tell us that development is not even and smooth. The engineering companies do not generally have a large asset base, therefore they are more volatile than many other companies to the economic fluctuations. The case of Ekono should teach us that the resources were tied to a wrong place at a critical point of time. Even the engineering companies should be prepared for the fluctuation in the environment and markets.

Another issue in the internationalization of an engineering company is related to the local and fragmented nature of the whole business. When engineering design companies buy foreign engineering companies or part of them, or they become partners, the business operations do not necessarily change in either side, not in the buyer´s or the seller´s side. If this is the case the only increase in competitiveness obtained is a better access to the new market.

11.6.2 Factors of the future success

The different roles of engineering companies were constantly referred to in the comments on the development of the actual engineering companies. The following conclusions could be made based on the model discussion and the actual company examples.

1. The conventional tasks of engineering companies are related to the design and implementation of the investment projects. This leads a company directly to the role of a designer and a coordinator, but also very quickly, by necessity, to an intermediatory and accumulator role. This is actually due to the fact that an engineering company always works in cooperation with other companies in an interactive relationship in a network to use a modern terminology. As regards to the engineering companies, these relationships existed already before these words were used in the the context of the economic transactions.

2. The other two conventional tasks that the engineering companies carry out are technical and economic consultation and project development. The content of the expert and consultation is self-evident. The project development is a preparation phase that has to be carried out before the decision for an investment can be made. Normally engineering companies cannot carry the costs of project development on their own. The costs have to be carried by the investor or the special project development companies. The expertise needed for the project development is often in the engineering companies. These tasks give the engineering companies an expert role, and a catalyser role for the investment within a company. From the point of view of the country, the catalyser role might also enhance, project export to other countries if the project development was made abroad.

3. At this point we move from traditional to new tasks and challenges. The technology change has been referred to many times in this study. The tasks of a technology enhancement and innovations, radical or incremental, are not necessarily the tasks of an individual company, although the companies may have an influence on them from the point of view of an industry. Since plenty of engineering resources are in the engineering companies and as the companies work in a network which have many connections to the other companies and organizations, they become accumulators of knowledge and experience and may even become innovators.

With reference to the tasks and roles of points 2. and 3., when the proposition was made that there could be a few engineering driven potential success areas in the Finnish industry in the future, Kässi (96).

4. When evolutionary economics already referred to speaks about the importance of an evolution, a technological change and agents, we also come close to the tasks and roles of the engineering. The tasks of distributing of new technologies and spreading of efficient methods and innovations are obvious to the engineering companies. To perform these tasks the companies take the roles like an agent or an intermediator for a new technology. The roles are not necessarily new, although they could get more weight in the future. The finding is that also the evolutionary economists emphasize the same roles in the evolution of the indusrial structures.

5. Refererence was made to the mechanisms to develop new success areas in an industry. In addition, the opportunities to develop new interdisciplinary clusters into the industry have been dealt with earlier. At the same time it has been admitted that clusters cannot be planned or produced. Preconditions, however, can be developed to increase the probability of success. Engineering companies can be used as agents for new technologies and business areas. They can also be exploited as agents of evolutionary change. The new roles may become for the company the factors for their future success.

The tasks and the roles presented above have been collected to Table 11.3 which is a summary of the discussion.

Table 11.3 The tasks and the roles of engineering companies.

TASKS	ROLES
Design and implementation of investments	Designer Coordinator Intermediatory and accumulator role
Project development Technical and economic consulting works	Expert role Catalyser of the future investments and project export
Technology enhancement Radical and breakthrough innovations	Accumulator of knowledge and experience Innovator
Distribution of new technologies Spreading of efficient methods and innovations	Agent for new technology Intermediator of new technology
Developing new, interdisciplinary success areas between the old clusters Seeds for new clusters	Agent for new technologies and businesses Agent of change

Clearly the engineering companies could have many positive roles in the evolution of industries. It could be worth to consider and evaluate whether expected evolution and technological change in an industry could be enhanced or accelerated by agents like engineering companies. If change is really needed then perhaps some institutional changes could be considered to strengthen the positive roles of engineering. This could happen, e.g. in the area of project development.

12. THEORETICAL RESULTS OF THE STUDY

In this chapter the three theoretical contributions are summarized and shortly reviewed. They are the model of alternative industry paths in the Finnish engineering industry, the eight preconditions of the development of a knowledge-based engineering company, and the model for the emergence of new clusters from an engineering company base.

12.1 Alternative development paths in the Finnish engineering industry

A framework model for the study of alternative paths in the engineering industry has been built. The basis of the model was gathered from existing theoretical approaches including theories of a firm, theories of industrial evolution, as well as a research on technology and innovation and management studies. While all the different parts can be found in the literature, the integration of them to a tentative unified model of development paths for the engineering industry has been carried out in this study.

The model for the internal and external paths was built separately. The same determinants influence partly both the internal and external company paths in the engineering industry. To concretize, we understand the sectoral path to be a curved cylinder in a space created by technological and economic dimensions and it moves from one point of time to another over time. The endogenous evolution occurs within the cylinder, and the exogenous development determines the location of a cylinder. The individual companies live and develop within the development paths, and they seldom change the path in the course of time.

Internal development of companies within alternative paths

To describe the evolution of a company within a path, a theory of the growth of a company, of the endogenous evolution of an industry and a theory of the development of a knowledge-based company were used. The theory of the endogenous evolution of an industry emphasizes the internal evolution in an industry and depicts the structural changes of an industry over time. The approach developed from Porter´s cluster theory underlines the relationship between the engineering company and the environment as a precondition for the development of an engineering company to a mature stage as a company in its strategic group. Together they enrich an understanding of the industry and company evolution.

Theories of the growth of a company teach the initiation of new entrepreneurial firms. They have to pass certain initial phases, and then some phases of growth. The firms experience certain crisis in growth which have to be managed successfully in order to reach the next phase. Only very few companies ever reach the latest phases of growth, some remain for longer periods at an earlier phase, fall down and disappear. The model of the company growth is very valid in the engineering industry as a great part of the companies in the industry are entrepreneurial companies. Most firms in the field are small, and only some companies grow to take big shares of total turnover, personnel and exports.

In the evolution of an industry reference is made to the theory of cumulative and irregular cycles of evolution. Technological change and innovation are the basic driving forces in the evolution of an industry. New or improved technologies grow and substitute old structures and companies with out-of-date technologies. Different kinds and sizes of companies have their important roles in different phases of evolution. In general, large and resourceful companies have important roles in enhancing new technologies. Only they have the resources to launch new major concepts and innovations in the market. The innovative breakthroughs may occur either in small or large companies, but the before runners are seldom the final winners. Radical changes in the industries take time in addition to technological changes they generally require also social and institutional changes.

The cumulative know how and technological knowledge is of importance also in the technological changes. In most cases the final winners are those companies which have a solid base to build on. Occasionally there are technological discontinuities when a part of technological knowledge loses its value. Even then the organizational continuity can compensate for much of the technological loss, partly with the help of supplementary technologies.

The model of the cumulative and irregular cycles of industry evolution is preferred to the simple life cycle model due to the various alternatives it leaves for industrial developments and technology changes. In an industry there are always different kinds of companies. If many cross section analysis are made at different points of time, they will disclose the evolution of the structure in an industry. The shares of types and sizes of companies are changing continuously. At this point the stochastic nature of company evolution has to be underlined. Firms have a freedom of choice and they use it. Even though we do develop patterns of company behaviour in this study they can be true only stochastically within certain ranges in each dimension concerned.

If the theory of an evolution of an industry underlines the internal technological evolution in an industry, the theory of industrial clusters emphasizes the external environment and structures. The preconditions of a cluster to maintain sustainable, competitive advantage are presented by the diamond structure of the cluster environment. The determinants of a diamond can be altered to cope with the description and analysis of an individual knowledge-based company, too. The environment of a knowledge- based company is called a small diamond to differentiate it from a diamond of a cluster.

There is an evidence that a knowledge-based company develops around itself an infrastructure or an environment which can be described by a small diamond. The assumption is that a knowledge-based company after the initial development phases can only reach a mature state in a company development and a sustainable competitive advantage, if it can develop a small diamond around itself. A mature state in the engineering industry would mean that a company attains a significant role in the strategic group which it is aiming at. The objective is different in national or global engineering design companies, in market niche engineering and specialized supplier companies.

The engineering companies are not, at least in the beginning, knowledge-based companies. If they make standard design works in many industrial fields, they remain design companies. With the evolution of an industry and technology an engineering company may become an accumulator of a technology and an agent in the field of technology in a particular industry. Such a role may be given to it, or is accepted by it, if the company works as a division in a large company, or as a specialized supplier company, or even as a large engineering design company. Based on this argument there is reason to believe that for many engineering companies, such as knowledge-based companies, the case of a small diamond is valid. The eight preconditions presented for a knowledge-based company to develop are equivalent to the conditions of the small diamond.

Referring to the development of an engineering company to a mature state, including a small diamond infrastructure and at least a reasonable growth of a volume, the assumption is that at this state of company development it has a chance to utilize the innovative technologies either via a cumulative development or a radical innovation.

External development of alternative paths

The technology is by definition an endogenous factor in the evolutionary theory of industrial development which the companies can influence and so it is understood here. This is in a congruence with the view of technological change which is basically determined by the internal technological causalities but also affected by complicating feedbacks from market and customer needs. The basic trajectories of industries are, however, in most cases exogenous factors from the point of view of an individual company.

Technological and economic aspects form together a techno-economic paradigm which determines the multi dimensional space where the certain industrial branches evolve. Technological trajectories are subspaces of the system which determine technological and economic trade-offs by which the decisions are made in an industry.

The external development of an industry path, i.e. the location of the path over time is developed on the basis of theories on technical change and innovation, and the studies on strategic management. More precisely, the basic technological trajectories of Pavitt gave the idea to build up company paths within engineering[1]. A technological trajectory is normally depicting an evolution of an industry with incremental changes which dominate the evolution most of the time. There are wider and narrower

[1] The same idea was evident already earlier in the interpretation of the empirical observations as noted before. The technological trajectories gave the model actually for building up the paths.

trajectories in terms of the scope of influence. Radical innovations may cause breakthroughs in the development and perhaps changes in the trajectory, and sometimes even in technological system.

The basic technological trajectories applied here were formed with the help of the British innovation statistics. They are, however, so general in nature that they were considered possible to be used as a model for the Finnish industries, too.

Engineering companies mostly serve industries and companies which are in scale intensive industries. A group of engineering companies belong directly to the trajectory of specialized suppliers. The industries of information intensive trajectory very often overlap today the other trajectories.The engineering companies serving scale intensive industries normally follow in terms of technology, investing industries. Specialized suppliers may develop new technologies on their own. The innovations created from merging of the information technology based trajectory with the other trajectories may be a source of many new opportunities.

The strategic groups were found through theoretical and empirical methods. The groups are supposed to be local, national and global engineering design companies, market niche engineering companies and specialized supplier companies. The main dimensions to form the strategic groups are the size of the companies, the rate of internationalization and the rate of specialization. The strategic groups depict the outcomes of the company developments in the engineering industry. The strategic groups form a cross section picture of the evolution in an industry at a point of time. The considerations of the chain of values give additional light to the tendencies in the strategic directions of different types of companies in an industry.

The strategic groups depicted by strategic maps in an industry are merged into the trajectories, and the point of view of business activities is brought into them. At the same time, the cross section picture of the strategic map locates the industry paths into a space describing a strategic behaviour of the group of companies within the particular path.

The behaviour of the strategic group of companies is an external aspect of the group in the meaning that it gives a guidance to locate the group on a strategic map. Therefore the theory of strategic groups belongs to the development of external company paths. At the same time, the strategy of a company includes highly internal aspects of a company behaviour. This is reflected even in the self-explanatory names of the generic strategies of Porter which are to be connected with the strategic groups in the engineering industry.

A tentative model of alternative paths in the engineering industry

The models of internal and external developments paths in an engineering industry have to be combined into one whole. The cross section picture of mature engineering companies, i.e. the locations of the industry paths in an engineering industry, was attained from an European empirical and theoretical study and the types of start-ups of engineering companies from an available empirical Finnish case data. This phase of a model building gives a cause to write about the model of development paths of an engineering industry.

As the end results of company developments have been listed, there is reason to point out the alternative start-ups of groups of companies in an engineering industry. This list is based on empirical observations from the Finnish case material and is local, national engineering design companies, innovative engineering companies starting in a garage, engineering companies separated from a manufacturing and an engineering division or subsidiary of a large company.

At this stage a tangible picture of a theory building can be given. As a limited number of types of company start-ups and a small number of mature outcomes of the same company developments are known, both groups of development stages are at two points of the time axis, the task in forming the industry paths for the engineering industry becomes like building the cylinders between the start and the end points in time.

Time is taken as a dimension to an industry path as it helps to describe the evolution. A technological trajectory also includes the time dimension, but a company pattern does not necessarily have it. Time is a complicated matter in the context of industry paths. Actually at no point of time do all the companies find themselves in initial phases of their company development and even at the point of time of "mature outcomes" there are some companies in the initial stages within an industry. However, if and when our examples of engineering companies include individual companies with a definite point of start-up and a point of maturity in a company life, we can speak of relative time as a dimension with respect to a company life cycle. An absolute or a real time dimension can be used, of course, if an industry is studied with numerous cross section observations.

The studies of technological change and innovation are strongly behind both the endogenous and exogenous evolutions of industry paths. The technology is a driving force in an evolutionary theory of an industry and therefore an important determinant for the internal development within industry paths. On the other hand, the technological basic trajectories constructed on the basis of innovation statistics are external factors at least from the point of view of individual companies. Therefore the model of external development of industry paths also has a technological base.

The internal and external development patterns are not in contradiction with each other. The described characteristics of company evolution can be included in the model of the industry paths. The paths developed can be presented in a table form. Table 11.1 gives names and descriptions for the paths. The references of the table include many behavioural aspects of the paths.

The industry paths presented in Table 11.1 are characterized mainly according to strategic groups which determine the paths. The so called outcomes of the company evolutions are by no means absolute ends. They also develop in the course of time and, of course, the industry paths evolve in time, too.

12.2 Eight preconditions for the knowledge-based engineering company development

In the Finnish Porter study, Hernesniemi et al. (95)[2], the lonely stars or individual successful companies without a cluster background were dis-

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[2] The alone stars were discussed in chapter 17 of the book. This treatment is based on the unpublished manuscript of Pekka Lehtonen in ETLA, The Research Institute of the Finnish Economy.

cussed in one chapter. The basic notion in the chapter is that a knowledge-based company develops around itself an environment which has the cluster types of characteristics. We call it a small diamond to make a distinction between a diamond around an industrial cluster and a small diamond around a knowledge-based company.

Many engineering companies are working within standard technologies at the beginning of their lives. Later on some of them may develop towards very specialized companies through experience accumulation, references and innovation. Then they can be viewed as knowledge-based companies, Kässi (96). In the case of engineering companies the emergence of a small diamond often starts from the demand component, particularly, if an engineering company starts in a large company as an engineering department or as a department for a particular task. The know how is present from the very beginning, but it develops into specialized factor of a knowledge only through accumulated experience. The structure of rivalry and support of the mother company or supporting services develop into a small diamond in the course of time. When an engineering company is understood as a knowledge-based company we see that its development can proceed only from the starting phases, if the company is able to create an environment of a small diamond. The determinants of a small diamond form the sources of a competitive advantage in a knowledge-based company. The competitive advantages in a company may remain sustainable, if the small diamond is complete and allows the continuous upgrading of the firm.

Companies are not similar. Therefore the development for each group of companies is different. The presence of a small diamond can be seen as a precondition for the development of an engineering company to a mature stage within the strategic group where it aims to be. It can be a national engineering company, a market niche engineering company, or a specialized supplier company. Essential in the maturity is that the company reaches a significant position within the group where it aims to be and has the preconditions to maintain a sustainable competitive advantage in its own strategic group.

The list of preconditions of the emergence of a cluster can be adjusted for an individual company to develop to a significant company position in its own strategic group. This list can be used as a check list for the company environment of a knowledge-based engineering company.

Table 12.1 Preconditions for the knowledge-based company to develop to a mature position in its strategic group.

1. Time. The time needed for a knowledge-based company to develop from its initial stages to maturity can be very long. The reason is that everything is based on knowledge and human capacity. These do not change rapidly.
2. Sufficient resources. Resources are needed among other things to start marketing abroad and to expand knowledge base.
3. Entrepreneurs and commitment. New engineering companies have to overcome a countless number of hindrances which often can be overcome only by the urge of entrepreneurs. The commitment to engineering business is needed also from the owners of engineering companies. The development to maturity demands many sequential steps.
4. Demanding international customers. The arguments of Porter on this matter are directly applicable to an individual company. The sale occurs from a company at a time. The demanding customers are the key source for competitive advantage.
5. Rivalry and cooperation. Applied to a small country this means that the companies compete at least in a domestic market. In international biddings they can still cooperate to reach a competitive position.
6. Advanced subcontractors. It is a very valuable thing for a company if it has competitive subcontractors or partners to be set as bench mark for its own activities.
7. Flexibility and capability of the management.
8. Continuous development of the know how.

The fulfilment of the eight preconditions of Table 12.1 is equivalent to fulfilling the preconditions of a small diamond. The items have to be understood in the way that fulfilling the preconditions means the creation of an environment where upgrading and innovation are possible. In the same way as with the cluster, a mirror picture can be presented from the reasons which would lead to the loss of competitive advantage. The outcome in reaching a mature or a significant position in the strategic group can be a great achievement for a company. This could lead to a specialized supplier company, or a market niche engineering company worldwide, or a national engineering company with limited foreign business share.

12.3 Emergence of a new cluster from an engineering company base

As observed before, investing companies generally lead the development in technology development and industrial evolution. They make the investment decisions, they take the risks and try to avoid risks as far as possible. The normal role of an engineering company is to give advise in investments and to propose alternatives.

There are a few cases where this role may change. First, an engineering division or subsidiary may be given the responsibility to coordinate the development efforts of the firm as well as its investments. In this situation the engineering company is "forced" to take the responsibility for the investments. If the engineering company is a mature company in an internationally significant position, it may have the possibility to affect strongly the evolution of the investing company.

Second, a mature engineering company may be able to gather sufficiently large experience to acquire a position to give advice for the investing companies. If the credibility of an engineering firm is good enough, it is easily obeyed because of the expertise even though the decisions would be made by the investor.

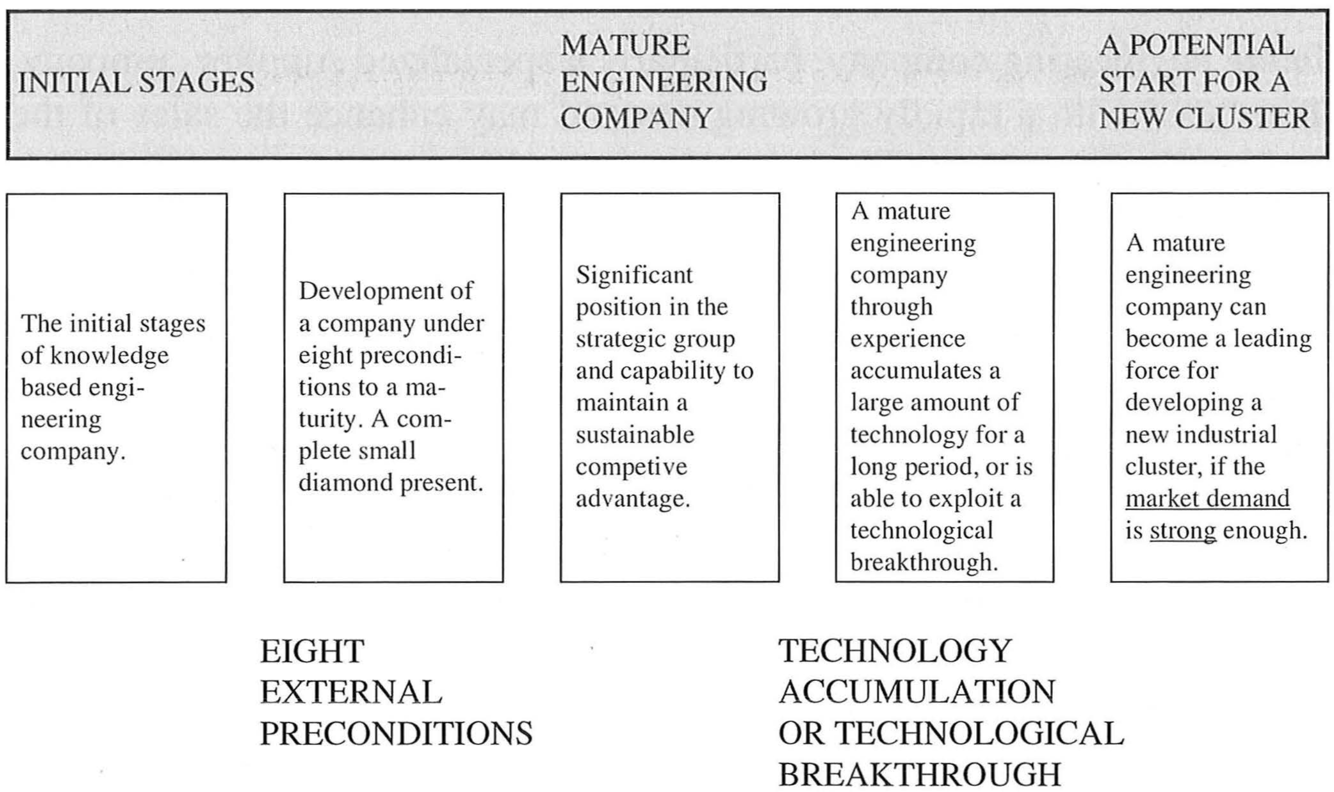
Mature engineering company, particularly a specialized supplier company, when faced with a rapidly growing demand may enhance the sales of the neighbouring companies like subcontractors, design companies, and component manufacturers. This may create the seed of a new cluster.

Technology change may enhance the evolution of a new cluster significantly, too. With reference to chapter 4.4 it should be pointed out that the sources of technology in scale intensive industries are production engineering of the companies, specialized equipment suppliers, and own product and process development. Normally the scale intensive companies emphasize cost effective production and continuous improvement of productivity during periods of incremental technological improvement. However, sometimes technological discontinuity occurs due to cumulative technology development or radical innovation. If any engineering company gets a chance to implement this new technology and the project is successful, the engineering company may get a competitive advantage to exploit in subsequent projects.

Similar kind of breakthrough may occur in the group of specialized supplier companies. If such a company is involved when a technological trajectory takes a new route, it may get a major technological advantage over its competitors. In this company group the source of technology is basically the same as in the group of scale intensive industries.

Our notion is that a mature engineering company may get a very crucial role in the rare cases when it can take the lead for a new dominant technology. In this situation an engineering company may have such an extraordinary competitive advantage that it may exploit its position by using other subcontracting engineering companies or component suppliers in its deliveries. If this happens it could even lead to a core of a new cluster. Generally a breakthrough in the technology is needed for an engineering company to take a lead in the development. In addition, significant market pull is needed to enhance a cluster.

Figure 12.1 Schematic presentation of the development of an engineering company to a mature company and to a leading force in a creation of a new cluster.



13. PRACTICAL CONCLUSIONS

13.1 Considerations for management

The companies were selected to allow large and resourceful companies to have a good representation in the material. Large engineering companies are those companies which can influence the evolution of industrial clusters in a short and medium term perspective. Small engineering companies have their important role in the evolution of the industry itself and to serve the scale intensive industries, too.

The following conclusions are presented for the consideration of the management to be taken into account in company strategies in the industry.

1. In high cost level countries like Finland competition pressures are driving the engineering design companies due to cost structures to become engineering project companies, or to specialize in sourcing internationally, or both. The engineering project companies have pressures to acquire own products or product rights. If specialization is deep enough, the engineering project companies resemble the characteristics of the specialized supplier companies. When the traditional component producers take advantage of the time of offering turn key deliveries around the components produced by themselves, the two company types approach each other from two opposite directions. This will increase competition in the field of turn key supplies and may have other consequences, too.

2. From the obvious observation that an engineering company works in interactive relationships and in the networks, the conclusion has been made that the accumulation of a know how and an experience is the faster, the more the company has the contacts in the projects. There is, however, one precondition which has to be fulfilled: the engineering company has to know and understand its strong points. Otherwise it gives away its strengths without getting anything back from its contacts and partnerships. This is true with the other companies, too. Only in the interactive contacts the various positive roles of an engineering company may advance the accumulation of a know how.

3. The eight determinants developed are the preconditions for an engineering company to become a mature company in its own strategic group. The eight determinants and the growth of demand could give an engineering company good development possibilities. The company would even enhance the birth of a new cluster into the industry, develop projects for itself and the neighbouring companies.

Active interaction with the other companies and the environment enhances the accumulation of technological knowledge in an engineering company. The evolution of the Finnish industry towards growth driven by innovations will increase the demand of highly specialized services with a sophisticated technology content. Technological innovations, particularly major ones, could stimulate the development of companies. Especially the mature engineering companies could consider adaptation new and active roles with respect to technology. In successful cases the new operation modes could open new roads for company developments, too.

In the evolution of industries the emergence of new industries often reflects innovative changes in the technologies. The technology is an endogenous factor influenced positively by the eight factors in the infrastructure environment of an engineering company.

The management of the engineering companies should follow changes in technology. Each industry has its own view on technology. Principally the eras of changes are also the eras of opportunities - also in the engineering industry.

13.2 Considerations for industrial policies

1. The many roles of engineering companies should be repeated here from the viewpoint of industrial policy making. The opportunity to strengthen project development activity by Finnish engineering companies might give a potential for a significant increase in the supplies of turn key delivery projects abroad in the medium term future. This should be considered as a separate measure.

Opportunities have been identified in three industrial branches to increase project export from Finland with the help of engineering companies. This could be done in the projects of forest industry, in energy technology, and in community technology including the waste management technologies and water treatment technologies. These technologies were identified to have strong enough engineering companies to carry out the needed project development, each of them working in the clusters of Finnish component producers, too. In these fields the expected demand in the world market is estimated to grow rapidly.

The key to success is to increase the project development efforts abroad in these technology areas. The assets of engineering companies do not allow to carry out project development to a larger extent, but potential investors, the machinery producers, and possible other parties could have interest in enhancing the development in the area. The developed projects could be seen in the medium term as an increase in the project export from Finland. The volume of the project export could equal 10 to 200 times the invested project development costs.

2. Technological change is also to be followed at a level of industrial policies. Technology changes are at least weak signals for possibilities of structural changes in the industry and of rapid growth rates in certain fields. This is an aspect to be considered both by the management and the policy makers.

The expansion the information technology is expected to bring many kinds of changes into the structures of the industries. This has been pointed out also in this study. The exact direction of evolution cannot be known. One vision of the evolution was presented in the discussion referred to already in this study, Räsänen (89) and Lovio (89a and 89b). The writers expect new types of companies and industrial structures to displace the dominant old manufacturing based companies. These new structures were expected to become stronger. The activities of old production companies were seen to decrease, whereas the new types of companies were expected to expand and to become more meaningful.

The internal structures of companies were seen to change, too. Räsänen (89) wrote about a "hamburger structure". The dominant companies would be the holding companies dealing with the management of strategic resources e.g. product development, trading house activities, business development, and finance. The manufacturing activities, possibly as corporated units, would be under this level. At the top of the core holding company would be the service structures such as advertising agencies, consulting etc.

If technology or research and product development and business development were considered to be the core of the firm, the issue of the relationship between engineering and research and development would be a crucial one for the holding company. The creation of new products and innovation should be secured, as well as the commercialization of the new products. Both organizations would be necessary to maintain the technology rersource of the holding company.

Independent engineering companies are also needed, even if the companies begin to resemble the layer structure. The demand for technical consulting remains for both levels of the core company.

Appendix 1. Products and services of engineering companies

TABLE	1965						1975						1985						1993					
Products and services of engineering	D1	D2	D3	P1	P2	P3	D1	D2	D3	P1	P2	P3	D1	D2	D3	P1	P2	P3	D1	D2	D3	P1	P2	P3
Technical design	1	1	0	2	1	0	2	2	1	4	1	2	2	2	1	5	4	3	1	3	1	5	2	3
- design of equipment				1			1			4		2	1			2	1	1	1			1		1
- design of integrated plants	1	1		1	1		1	2	1		1		1	2	1	3	3	2		3	1	4	2	2
Implementation planning of investments	0	2	0	0	1	0	0	2	2	6	2	2	1	6	4	10	9	7	1	7	4	16	10	6
- preliminary design		1						2	1	1	1		1	2	1	3	3	2	1	2	1	6	3	2
- technical design		1			1				1	2	1	2		3	1	5	3	2		3	1	6	3	2
- tekno-economic design										2				1	1	2	2	2		1	1	2	2	1
- evaluation of alternatives										1					1		1	1		1	1	2	2	1
Consulting and various studies	1	1	0	0	1	0	2	2	2	1	1	0	2	3	2	2	2	2	0	2	2	2	1	3
- feasibility studies	1	1			1		2	2	1	1	1		1	3	1	2	2	1		2	1	2	1	2
- master plans									1				1		1			1			1			1
Implementation services of investments	0	0	0	0	2	0	0	0	0	0	3	0	1	1	1	4	7	9	0	2	1	10	6	8
- project management					1						1		1	1	1	2	2	3		2	1	5	2	3
- training and acceptance											1						2	3				1	2	2
- turn key deliveries					1						1					2	3	3				4	2	3
Sales of technical know how	1	0	0	1	1	0	2	0	0	5	0	2	1	1	0	4	2	2	1	1	1	6	3	3
- sales of know how of the industry	1			1	1		2			2		1	1	1		2		1	1	1	1	3	2	2
- sales of special process know how										3		1				2	2	1				3	1	1
Manufact. and rent manaufact. of investment goods	0	0	0	1	0	0	0	0	0	2	0	2	0	0	0	2	1	2	0	0	0	3	2	3
- own production of componenets										2		2				1	1	2				2	1	2
- rent manufacturing of products or equipment				1												1						1	1	1

TABLES / Total sales and personnel		Sales	1993	1990	1985	1980	1975	1970	1965		Personnel	1993	1990	1985	1980	1975	1970	1965
FIM million	**D1**		23	21	45	10	18	31	15	**D1**	persons	98	95	75	45	85	-	100
	D2		190	790	240	145	60	50	25	**D2**		900	2550	1159	876	400	190	150
	D3		1100	1300	400	200	90			**D3**		4500	5500	2500	600	400	270	
	P1		240	230	105	112	412	13	7	**P1**		364	376	260	375	450	110	40
	P2		1346	1837	1230	1005	400	250	100	**P2**		1706	2122	2615	1965	1500	1500	800
	P3		2220	1813	550	200	70			**P3**		3668	3876	1700	500	200		

Appendix 1. Responses of engineering companies

TABLES	1965			1975			1985			1993		
Engineering vs. manufacturing	a	b	c	a	b	c	a	b	c	a	b	c
Alte				1			1			1		
EKONO	1			1			1			1		
RINTEKNO				1			1			1		
PI-YHTIÖT				1			1			1		
JAAKKO PÖYRY GROUP	1			1			1			1		
ROXON	1					1			1			1
KONE ENGINEERING DIVISION						1			1			1
KEMIRA								1		1		
VALIOTEKNIIKKA											1	
METRA ENGINEERING							1			1		
FINNSUGAR	1			1			1				1	
RAISIO ENGINEERING				1			1				1	
KUUSAKOSKI ENGINEERING												1
ENSO							1					
NOKIA ENGINEERING							1	1				
IVO INTERNATIONAL	1			1			1	1			1	
IVO Engineering / International												
NESTE ENGINEERING				1			1				1	
OUTOKUMPU TECHNOLOGY				1			1		1		1	
OUTOKUMPU ENGINEERING												
RAUTARUUKKI ENGINEERING											1	1
PARTEK ENGINEERING						1			1		1	

a = conventional engineering
b = own products, rent manufacturing
c = own manufacturing

TABLES	1965			1975			1985			1993		
Geographic market	d	e	f	d	e	f	d	e	f	d	e	f
Alte				1				1		1		
EKONO	1				1			1			1	
RINTEKNO				1				1			1	
PI-YHTIÖT					1			1			1	
JAAKKO PÖYRY GROUP		1			1				1			1
ROXON	1				1				1			1
KONE ENGINEERING DIVISION					1				1			1
KEMIRA									1	1		
VALIOTEKNIIKKA											1	
METRA ENGINEERING								1			1	
FINNSUGAR	1				1			1			1	
RAISIO ENGINEERING				1			1				1	
KUUSAKOSKI ENGINEERING												1
ENSO									1			
NOKIA ENGINEERING									1			
IVO INTERNATIONAL		1		1				1				1
IVO Engineering / International												
NESTE ENGINEERING				1			1				1	
OUTOKUMPU TECHNOLOGY					1				1			1
OUTOKUMPU ENGINEERING												
RAUTARUUKKI ENGINEERING											1	
PARTEK ENGINEERING					1				1			1

d = domestic market
e = domestic market and selected markets
f = global market

TABLES	1965			1975			1985			1993		
Technological self-sustenance	g	h	i	g	h	i	g	h	i	g	h	i
Alte				1			1			1		
EKONO	1			1			1			1		
RINTEKNO				1			1			1		
PI-YHTIÖT				1			1			1		
JAAKKO PÖYRY GROUP	1			1			1			1		1
ROXON			1			1			1			1
KONE ENGINEERING DIVISION						1			1			1
KEMIRA									1			
VALIOTEKNIIKKA											1	1
METRA ENGINEERING								1			1	
FINNSUGAR	1					1			1			1
RAISIO ENGINEERING				1				1				1
KUUSAKOSKI ENGINEERING												1
ENSO							1					
NOKIA ENGINEERING								1				
IVO INTERNATIONAL	1			1	1			1			1	1
IVO Engineering / International												
NESTE ENGINEERING				1	1		1	1			1	1
OUTOKUMPU TECHNOLOGY						1			1			1
OUTOKUMPU ENGINEERING												
RAUTARUUKKI ENGINEERING											1	1
PARTEK ENGINEERING					1			1	1		1	1

g = design (based on others' components)
h = lisenced, "acquired technology"
i = own R&D, own technology

TABLES	1965		1975		1985		1993	
Operation modes of companies	design	proj.	design	proj.	design	proj.	design	proj.
	eng.	eng.	eng.	eng.	eng.	eng.	eng.	eng.
- detail engineering	2	2	5	3	4	2	5	2
- general engineering, feasibility studies	1	1	1	5	4	11	3	11
- project management as a trustee of a customer		1	3	4	4	2	4	3
- project management				4		8		9
- turn key deliveries						9		9

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