Managing Complex Product Development
- Three Approaches

Niclas Adler

AKADEMISK AVHANDLING

Som för avläggande av ekonomie doktorsexamen vid
Handelshögskolan i Stockholm framläggs för offentlig granskning
fredagen den 10 december 1999, kl. 14.15 i sal Torsten
Handelshögskolan, Sveavägen 65.

Managing Complex Product Development
- Three Approaches

STOCKHOLM SCHOOL OF ECONOMICS
EFI, THE ECONOMIC RESEARCH INSTITUTE

EFI Mission
EFI, the Economic Research Institute at the Stockholm School of Economics, is a scientific institution which works independently of economic, political and sectional interests. It conducts theoretical and empirical research in management and economic sciences, including selected related disciplines. The Institute encourages and assists in the publication and distribution of its research findings and is also involved in the doctoral education at the Stockholm School of Economics.
EFI selects its projects based on the need for theoretical or practical development of a research domain, on methodological interests, and on the generality of a problem.

Research Organization
The research activities are organized in nineteen Research Centers within eight Research Areas. Center Directors are professors at the Stockholm School of Economics.

ORGANIZATION AND MANAGEMENT	
Management and Organisation; (A)	Prof Sven-Erik Sjöstrand
Center for Ethics and Economics; (CEE)	Adj Prof Hans de Geer
Public Management; (F)	Prof Nils Brunsson
Information Management; (I)	Prof Mats Lundeberg
Man and Organisation; (PMO)	Acting Prof Jan Löwstedt
Industrial Production; (T)	Prof Christer Karlsson
ECONOMIC PSYCHOLOGY	
Center for Risk Research; (CFR)	Prof Lennart Sjöberg
Economic Psychology; (P)	Prof Lennart Sjöberg
MARKETING	
Center for Information and Communication Research; (CIC)	Adj Prof Bertil Thorngren
Center for Consumer Marketing; (CCM)	Associate Prof Magnus Söderlund
Marketing, Distribution and Industrial Dynamics; (D)	Prof Lars-Gunnar Mattsson
ACCOUNTING, CONTROL AND CORPORATE FINANCE	
Accounting and Managerial Finance; (B)	Prof Lars Östman
Managerial Economics; (C)	Prof Peter Jennergren
FINANCE	
Finance; (FI)	Prof Clas Bergström
ECONOMICS	
Center for Health Economics; (CHE)	Prof Bengt Jönsson
International Economics and Geography; (IEG)	Prof Mats Lundahl
Economics; (S)	Prof Lars Bergman
ECONOMICS STATISTICS	
Economic Statistics; (ES)	Prof Anders Westlund
LAW	
Law; (RV)	Prof Erik Nerep

Chairman of the Board: Prof Sven-Erik Sjöstrand. *Director:* Associate Prof Bo Sellstedt,

Adress
EFI, Box 6501, S-113 83 Stockholm, Sweden • Internet: www.hhs.se/efi/
Telephone: +46(0)8-736 90 00 • Fax: +46(0)8-31 62 70 • E-mail efi@hhs.se

Managing Complex Product Development
- Three Approaches

Niclas Adler

STOCKHOLM SCHOOL OF ECONOMICS
EFI, THE ECONOMIC RESEARCH INSTITUTE

To Pernilla

A Dissertation for the degree of Doctor of Philosophy, Ph.D.
Stockholm School of Economics 1999

ISBN NR 91-7258-524-2

Keywords:

Product Development
Project Management
Organizational Design
Organizational Performance
Organizational Learning
Complexity
Ericsson
Table-tennis Research

Distributed by:
EFI, Stockholm School of Economics
Box 6501, S-113 83 Stockholm, Sweden

PREFACE

This report is a result of a research project carried out at the Economic Research Institute at the Stockholm School of Economics. The research project has been performed within the FENIX research program that has been carried out in co-operation between the Economic Research Institute, Chalmers University of Technology, AstraZeneca, Ericsson, Telia, Volvo and with substantial support from the KK-Foundation.

This volume is submitted as a doctor's thesis at the Stockholm School of Economics. As usual at the Economic Research Institute, the author has been entirely free to conduct and present his research in his own ways as an expression of his own ideas.

The institute is grateful for the financial support that has made this research possible.

Bo Sellstedt	Bengt Stymne
Director of the Economic Research Institute	Professor
at the Stockholm School of Economics	Stockholm School of Economics

PREFACE

Businesses of today are complex, and the purpose of this thesis is not to emphasize once again that it is a complex world out there. The purpose is rather to analyze how new approaches to manage this complexity have been applied to perform complex product development. My aim is not only to provide illustrations and possible ways to correct for dysfunctions in existing approaches but also to provide experience from the application of actual alternatives based on fundamentally different basic assumptions and to put this experience into the perspective of emerging business conditions. I believe this thesis is important for at least two reasons: (1) by introducing and discussing new approaches for managing complex product development based on fundamentally different basic assumptions, to inspire practitioners and academics to reconsider the way in which this increasingly important endeavor is managed and (2) by reflecting upon experience in carrying out the research process, to describe a joint journey for both researchers and practitioners.

ACKNOWLEDGEMENTS

I have great belief in distributed ownership, that is, if many people feel an ownership of something, it can be much better than it otherwise would have been. The research projects the organizational settings and the research environment that made this thesis possible are not a result of my own doggedness alone but of the invaluable efforts of a great number of people. This thesis would not have been what it is today without their continuous enthusiasm, ideas and support. I would first like to thank Flemming Norrgren for his way of making research worthwhile and ability to make things more fun. I would not have completed this work without Flemming. I would also like to thank Bengt Stymne for his constant curiosity and openness for new things and for his patience with a difficult doctoral student. There are many others who have meant a great deal to me in the process of developing as a researcher and in completing my thesis. Peter Docherty and Sven-Åke Hörte who first recruited and introduced me to the research world and later in the process both have given valuable comments to different generations of drafts of this manuscript. Horst Hart for his valuable support in learning me how to perform research in close co-operation with industry and for being one of the most non prestigious senior researcher I ever have met. Sofia Börjesson, Mats Lundqvist and Claes Tunälv have all been both my colleagues and at the same time mentors in different research projects. All three also gave their valuable comments on both articles and different parts of this manuscript.

I wrote this thesis during a period in which I had at least three different work places. An advantage of having a number of different work places is that there are more people who offer their help. My colleagues in the search for new knowledge have been many. I would specially like to thank Arne Filipsson, Hans Karlsson and Lars Marmgren who all has been both practitioners in the organizational settings as well as close colleagues and partners in searching for new knowledge and an increased understanding. I would also like to thank Pär Mattisson for his inspiring work and for reading this manuscript and giving important comments and Bernt Ericsson for both inspiring discussions and energy and for on short notice giving Ericssons comments on the manuscript. I would also like to thank colleagues at FENIX for their patience with me neglecting my duties during the writing process. I wish I had had the time to take advantage of everyone's knowledge. I would also like especially to thank those who, like me, have been "almost done" for a far too long time and who shared my frustration over how long this process of being "almost done" can be. I would like to thank colleagues at PMO for their support and ideas in spite of my long absences, colleagues at CORE for together offering an exciting scientific work environment, and last but not least all the hundreds of people at Ericsson who have dealt patiently with my questions, propositions, models and theories for over five years

Thanks also go to Janet Vesterlund, who worked under considerable time pressure to make the text understandable for more than my Swedish colleagues.

This thesis had not been possible to produce without financing and there I owe my thanks to a number of important contributors. I would first like to name in this context Ericsson, whose continuous financial support was a necessity for my work. I would further like to mention the Program for learning at Swedish Work Environment Fund (AMFO), the INPRO program at the Swedish National Board for Industrial and Technical Development (NUTEK), the support of Center for Research on Organizational Renewal (CORE) by the Council for Working Life Research (RALF).

This thesis had not either been possible to produce without a flexible organizational setting that facilitated the boundary spanning work with different disciplines and universities involved in close cooperation with Ericsson. I would therefor like to thank IMIT with Birgitta Andersson, Ulf Hultquist and Bengt Karlsson for their pleasant way of taking care of everything that must be done so that a research project can be carried out.

Finally, I would like to thank Pernilla for her patience with all our un-rebuilt houses and her boundless enthusiasm for all our ongoing rebuilding projects, which has made it possible for me to complete this thesis.

Thank you all!

Niclas Adler

October 1999, Gothenburg

THESIS SUMMARY

Mastering development of high technology products in order to be successful among powerful global competitors is a complex endeavor. Markets are being deregulated, competition is growing global and the product development of many technically sophisticated durable goods has undergone dramatic changes during the last decade. The day-to-day task of developing a complex product means coping with an almost endless amount of technical, market and organizational interdependencies that most often require mutual adjustment across many types of both technical and organizational boundaries. Complexity increases even further in industries where the pace of technical development, the competition and the customer demands necessitate a flexibility to add new technical solutions or functions during the development process. Hence, implying that new factors and interdependencies arise that must be dealt with dynamically to meet both pre set and emerging targets.

The dominant approach for managing product development are becoming insufficient in many complex and dynamic settings. The competition is growing more and more intense. However, most companies have serious problems in organizing complex product development. Therefore, other means than organizing as financial strength, resources, market strategy or business models constitute the foundation for success. Hence, companies that do find ways to master the complex endeavor can obtain new and important competitive strengths. The basic assumptions on which prevalent theory and the dominant approach has been built is that it is possible and meaningful to *reduce uncertainty by rigorous planning* before execution and that it is possible to *reduce complexity by breaking it down into its pieces* and providing actors with only their own small pieces. In this approach planning should precede action, which in turn should follow the plan. A project's maneuverability is assumed to be synonymous with the project manager's prospects of knowing in great

detail what must be accomplished in the project. If the plan then does not succeed, it is also assumed that the planning process was a failure and that a fine-tuned planning would improve this mismatching of plans with performance. Performance analysis in organizations applying this dominant approach based on planning show that very few complex product development projects meet set or emerging targets.

This thesis reports investigations of two different organizational settings in Ericsson that repeatedly meet or overperform their both set and emerging targets and compete successfully on a highly competitive market. The purpose is to suggest an alternative theoretical foundation and a new conceptualization of managing complex product development that can guide further practical and theoretical development of the emerging approaches. The results reported in this thesis are based on ten different research projects spanning a five-year period in close co-operation with these two high-performing as well as five other organizational settings. The main research method used was labeled *"table tennis research"* as a metaphor for the close and interactive co-operation and the short feedback loops that have been established between the organizational setting(s) and the researcher(s).

The analysis shows that the two high-performing organizational settings have developed new perspectives on and principles and actual models for organizing action. They have moved away from using traditional product and work breakdown structures and minimizing dependencies between the sub-systems. Instead they move toward building up products and increasing dependencies between sub-systems. Their focus is changed in a step-wise manner from parts to wholes. Integration and concern for interdependencies become central issues in the product development process. Dynamic models based on *integration* and *sensemaking* replace linear models based on *planning*. The use of quantitative measures for progress control is replaced by qualitative measures such as actual functionality growth and by soliciting the subjective feelings of different actors. The role of project management also changes from being focused on hierarchical control and project administration to being responsible for developing and supporting mechanisms for co-ordination, integration and sensemaking. The standpoint argued for in the thesis is that these changes together constitute a paradigm shift, where basic assumptions behind the process of managing complex product development are in transition. The approach being abandoned was based on a strong belief in *planning* as a means for reducing uncertainty. A process of deductive optimization was applied for breaking down the total task in order to reduce complexity. The emerging approaches show a strong belief in *integration-driven development* based on a step-wise building up of the product. They aim at continuous effectivization and exhibit a strong belief in *dynamic synchronization*, in the importance of building dependencies and in sensemaking based on action and reflection upon action.

The most important implication stemming from this analysis is that firms having problems in organizing complex product development under today's emerging business conditions are well advised to revisit and reconsider the approach they are applying. Firms that want to build future competitiveness based on knowledge about organizing product development could start experimenting with new and alternative approaches. It is a challenging task for management research to follow and perhaps even to contribute to such experimentation in order to add further experiences to the early examples provided in this thesis. And to develop further the ideas about the meaning of alternative approaches to organizing product development that have been ventured here.

TABLE OF CONTENTS

Table of Figures

INTRODUCTION

Many companies center their attention on the activity that is the title of this thesis, *Managing Complex Product Development,* when they try to improve their competitiveness. Complex product development is no longer a marginal activity – rather, it has replaced production as the single most important internal activity in many companies of today. This thesis is about complex product development in the telecommunications industry and in LM Ericsson. In this industry and this company, complex product development is an increasingly important and basic part in building competitiveness. Markets are being deregulated, new actors are entering the stage of telecommunications, competition is becoming global, the service content is rapidly increasing, new media are being integrated in telecommunications products and services and customers are demanding performance faster, cheaper and with greater content.

The up to now dominant way of managing complex product development has its origins in early pioneering work in the fields of *architecture* and *civil engineering* and later in the *defense industry* in the early 1950s. This dominant method was further and rigorously developed by management researchers and practitioners during the 1970s, 1980s and 1990s. The development aimed at establishing a consistent approach to meet new demands on delivering a great deal of goods and services in a short period of time. Despite the strategic importance of these considerable and continuous contributions, organizations performing complex product development seldom meet set targets on time, at the set cost or with the defined functionality. Even in the best managed companies, initially set targets concerning time, cost and performance are not achieved - on the contrary, only on rare occasions is even a single one of the initial set targets held. Most attempts and suggestions for rectifying the situation have indicated that the early phases of the product development process have not got enough attention and that companies have been unable to make sufficiently rigorous plans and designs before the execution of product development is commenced. Despite the sharpened focus on planning, performance has failed to meet expectations. The larger and the more complex the product development task, the poorer the performance. Since today's most powerful customers do not only expect that the targets initially agreed on are met but also that the targets that emerge during the development process are achieved, the process of managing complex product development faces a successively more difficult challenge.

Can it be that the words *manage* and *complex* in the title of this thesis contains a contradiction? Is it so that the process of complex product development and its activities can not be planned in advance, priorities can not be made in real-time and the activities and processes can not be evaluated afterwards? Is it so that the expectations that set or emerging targets ought to be met are wrong? Is the process of complex product development *unmanageable* and is this thesis thus about *managing the unmanageable*? Or is complex product development *unmanageable* with traditional means but *manageable* with means based on fundamentally different basic assumptions?

This thesis tells that examples have been sought and found where the challenges have been met, i.e. organizations that *do* perform complex product development and *do* repeatedly meet set *and* emerging targets. Targets have been set in accordance with demands made by a customer who forces an intensified focus on speed and content.

The purpose of this thesis is to describe and analyze the specimens found in order to explain how it is possible to perform so well under so challenging circumstances. The purpose is obtained by analyzing the main differences between the dominant and the emerging approaches on *managing the seemingly unmanageable*. Three approaches will be presented and analyzed: the dominant one and two alternative ones applied in high-performing organizational settings. The analysis will demonstrate that actors in the investigated organizations that show high performance have radically changed the way they *perceive* and *manage* complex product development. It will be argued that, taken together, the practice of these settings constitute a paradigm shift in how to manage complex product development. Through their practice they have proven the contradiction has only been apparent. The concepts, means and tools of the dominant paradigm have – so to speak - constructed the contradiction. The actors in the high performing settings have been involved in developing another paradigm that constructs the reality of product development in a different way that removes the contradiction. In addition to describing and analyzing the accomplishment of these actors my contribution in this thesis is an attempt to interpret and conceptualize what they have done.

The thesis contains four main parts. The purpose is for the reader to be able to read one or more parts of the thesis without finding it necessary to read every part. Each part starts with a brief description of the contents and ends with a short summary condensing the main ideas of that part. The appendices at the end of the thesis contain descriptions of the research projects and the organizational settings. For readers interested in managerial implications, chapters 7-10 and selected parts of chapter 11 (pp. 493-498) are recommended, with an emphasis on 10 and parts of 11.

The first part (chapters 1-3) presents the context and the purpose of the thesis. This first part of the thesis will introduce and give the reader a condensed picture of the area of complex product development and its specific characteristics and provide a critical analysis of dominant theories and practice. The shortcomings of complex product development projects will be discussed and analyzed. The first part will also elaborate on the prevalent domain of knowledge regarding the processes of managing uncertainty, managing complexity, managing projects, managing knowledge, innovation and learning, and managing product development. Finally, the purpose of the thesis will be described given the denoted domains of knowledge: *– to suggest an alternative theoretical foundation and a new conceptualization of managing complex product development that can guide further practical and theoretical development of the emerging approaches -*

The second part (chapters 4-6) describes the applied research techniques and methods, the research model and key concepts, and the organizational settings investigated. The second part of the thesis will introduce the applied research design, research principles, and research methods. The specifics of using a research approach called *table tennis research* that aims at building actionable knowledge are explained. A description will be provided of the main building blocks of an integrated research model for how to manage complex product development. Focus will be kept on how this research model has emerged and been applied. Finally, a number of key concepts and the specific contextual characteristics of Ericsson will be introduced.

The third part (chapters 7-10) describes and analyzes the different approaches to managing complex product development. One approach is the dominant one and based on *planning. The other* two are emerging and based on *integration-driven development* and *dynamic synchronization.* The application of these three different approaches in three different organizational settings will be extensively described and analyzed in order to explain differences in characteristics and performance. Each approach will be described in the same way. A description and analysis of each approach accomplished by the aid of the research model will follow a brief description of the setting and its context. Then a discussion aiming at integrating the whole picture will be provided and an overview of project performance in the organization will be given. By way of conclusion, differences between approaches are discussed and conditions for dispersion and sustainability of the emerging ways to organize complex product development are analyzed.

The fourth part consists of chapter 11 only. It analyzes the emerging patterns and implications for research and practice. This last chapter of the thesis will recapitulate basic ideas and examine some of the preconditions for the suggested propositions. Also, the results presented in earlier chapters will be critically analyzed and compared to experience from other parallel studies.

The appendices contain a description of the seven organizational settings and the ten research projects on which the thesis is based. The aim is to provide the interested reader with more and broader information as a supplement to the other descriptions.

Part I - Setting the Stage	**Part II - The Act of Identifying Emerging Patterns**	**Part III - The Dominant Approach in Comparison to New Approaches for Managing Complex Product Development**
1. Development of complex products and systems 2. Managing complex product development 3. Purpose and goal of the thesis	4. Research Methodology - a Learning Process based on "table tennis research" 5. The model for investigation – a journey towards new approaches for managing complex product development 6. LM Ericsson - a contextual and historical perspective	7. The approach based on planning 8. The approach based on integration driven development 9. The approach based on dynamic synchronization 10. Results and integrated analysis

Part IV - Critical Revision of Emerging Pattern
11. Theoretical and practical implications

Figure 0.1. The overall structure of the thesis

PART I - SETTING THE STAGE

"From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks more manageable, but we pay a hidden, enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of connection to a larger whole. When we then try to "see the big picture", we try to reassemble the fragments in our minds, to list and organize all the pieces. But, as physicist David Bohm says, the task is futile – similar to trying to reassemble the fragments of a broken mirror to see a true reflection. Thus, after a while we give up trying to see the whole altogether" [Senge 1990, p. 3]

This part of the thesis will give the reader a condensed picture of the area of complex product development, product development performance and provide a critical analysis of dominant theories and practice. It will also introduce the specifics and their change in Ericsson product development. In conclusion, the part will elaborate on the purpose of and research themes in the thesis and their relevance.

The purpose of this part is to sketch out the dominant paradigm on how to manage complex product development, analyze its shortcomings and performance to illustrate the need for renewal and, finally, elaborate on emerging theories based on alternative foundations.

CHAPTER ONE

DEVELOPMENT OF COMPLEX PRODUCTS AND SYSTEMS

This chapter introduces the area of complex product development and the area of managing projects. Many aspects have had to be left out in this introduction. The focus is on introducing the area of research and practice by providing a number of illustrations of the process of managing complex product development and on-going debates within the field. The purpose is not to give a thorough analysis of all the important contributions in the area or a complete review of practices in all industries but rather to give the reader a firm foundation for further discussion.

Towards More Complex Product Development Projects

We generally associate complexity with anything we find difficult to understand. The term *complexity* will be used in this thesis to define what types of product development projects are being analyzed - product development projects that are difficult to understand. System scientists define complexity in a system as dependent on (1) *the number of elements in a system*, (2) *the number of relationships between elements in a system* and (3) *the organization and behavior of the relationships* (Flood&Carson 1993). If a *product development project* is analyzed as a system according to the definition above, it is considered complex if the number of elements that must be taken into account, i.e. organizational sub-units, client demands, technical uncertainties, market strategies etc., is high and/or the number of relationships, i.e. interdependencies between organizational sub-units, client demands, technical uncertainties, market strategies etc., is high and/or considered to be complex, e.g. *non-linear* or when behavior of parts are *unpredictable.* This means that a product development project consisting of many reciprocal interdependent sub-units or teams responsible for more than one customer's need acting in an unpredictable context with many technical uncertainties can be regarded as complex in the language of system science. This simple definition, without further explicit numerous boundaries, of complex product development will be used throughout the thesis. This definition will however, be supplemented by the different types of actors' perception of the complexity that meet them.

To enter the arena of complex product development a stylized case is described below. The purpose is to give the reader a firm notion on what complex product development is about. The stylized case is from one of the analyzed organizational settings that will be further described later on in the thesis.

> *Imagine a product development project, the Helicon project, whose intent is to refine a 20-year-old product solution and make it a competitive alternative on a changing market. The project's direct stakeholders are five foreign customers, three internal customers from different business areas, five other large projects at the company that are dependent on a stable product as input and 14 different internal activities placing their own demands. The stakeholders all have different desires and there are unclear hierarchical relationships with one another. At the same time that the project raises the functionality of the product, Helicon must take consideration to about 60 systems to be delivered around the globe. The product in which the project results must also be forward-compatible to a certain extent, as it sets the limits for the performance of coming products, as these will need to be backward-compatible. Helicon's time plan is set at 15 months – six months shorter than the time used in any other project of its size at the company. To manage the technical requirements within this time frame, Helicon is estimated to need 1.5 million man-hours and over 1000 persons during its most active phases. To have access to such resources and competence in all of the sub-systems and components of the project, 17 geographically separate design centres in 14 different*

countries must participate. This means that the resources that Helicon needs are owned by 40 to 50 different line managers that report to local managers outside the hierarchy of the central project management. Besides these internal resources, Helicon will need participants from a number of local consultancy firms working in the project and will also need to outsource a number of activities to local suppliers.

While there is a detailed plan for the Helicon project as a whole and over what the sub-projects will produce over time, everyone knows that this will be changed. There is uncertainty as to how and where the plan will change and what consequences the changes will have but great agreement that it indeed will change. The contacts between Helicon and the development resources distributed in so many places are primarily local sub-project managers appointed by local line managers. Hence, the running co-operation most often takes place in a hierarchical way, as the complexity of dependencies is so great and the consequences of decisions and priorities cannot be seen on lower system levels with current control models. There is uncertainty as to what activities and actors are critical to what phases and as to what dependencies exist and how great they are. Parallel with Helicon, about ten large product development projects are being run at the company, of which several uses the same development resources. The priority principles are simple – the project that appears to have the most acute need is given priority. At the same time, smaller projects are being carried out on local markets by the local development resources, and these projects are always given priority because they are run at the local organization's own initiative for customers on their own market.

The project manager(s) are being responsible for completing Helicon in time with delivery of the agreed functionality[1] without exceeding budget limits. The senior managers in the organizational setting are being responsible for creating a capacity in the organization as a whole to be able to manage a group of projects like Helicon and others to follow in parallel and effectively. The project manager(s) responsible for managing complex product development projects as Helicon have a reason to ask questions about how to best configurate the product to be developed and how to best organize the project to meet the set targets, while the senior manager(s) responsible for managing organizational settings that perform numbers of Helicon projects have reason to ask questions about how the complex task best are met and how both experiences and results are transferred between actors and projects.

Complex product development possesses a number of characteristics that demarcate managing that activity from managing less complex product development. In many industries and companies, a single or a small team of engineers performs product development over a couple of months often sharing the same workspace and the responsibility for the full task.

> *"The design engineer, the laboratory engineer, and the marketing specialist were appointed to the project with the design group head as project manager and a plan as well as a budget were established. The project plan was worked out by the design group head in cooperation with the three members..." [Karlsson 1994, p. 67]*

---

[1] *Functionality* will be used in the thesis to capture both general product performance and how well the products meet set targets in terms of number and type of functions and also quality and robustness.

The complexity is composed of the number of participants[2], the geographical and cultural disparity, and the inherent technological interdependencies, the number of and difference between customers and the number and characters of the different suppliers and co-operators involved in the project. Managing complex product development requires the orchestration of many complex and interrelated details. Creating an outstanding organization for performing complex product development is analogous to creating an outstanding product. Both require orchestration of detail and are complex and intimidating. This thesis is about how to manage projects such as Helicon where complexity arises from *many reciprocal, interdependent, non-linear* and *asymmetric* sub-systems and relationships in both the *technical, market* and *organizational systems* in which the product development projects act. This thesis is about how to manage organizations that continuously face different views on course of action, new circumstances that change the validity of basic assumptions and unforeseen problems. It is about managing uncertainty and about managing situations we find difficult to understand.

Towards Increased Strategic Importance

Projects like Helicon are not exceptions or rare investments made in some industries once a decade or so - they are large and relatively common, complex product development projects in many of our knowledge intensive firms. This thesis focuses on managing complex product development in the telecommunications industry, where Helicon is a good example.

---

[2] An illustrative example on how the number of participants affects complexity is to draw a chart over a work-groups communication pattern. If the work-group is increased from five to fifteen participants the number of possible communication paths within the organizational system increases from 10 to 94 and if the number of participants exceed 1000, the number of possible communication paths become enormous. If then the different specialist roles, the different cultures and the physical distance are added one get a hint of the full complexity the number of participants can imply.

Product development in the telecommunications industry has peculiar characteristics. A large telephone switch, a base station for transmitting mobile phone calls or a mobile phone are all complex products, comprising a large number of components, functions and process steps. As problems became too complex for a few people to solve, and as growing competition demanded greater depth of expertise, the number of people involved in product development increased significantly. Ultimately, the telecommunication firms faced the classic organizational dilemma: *how to apply specialized expertise and yet achieve an integrated effort*. A project to develop a new switch, mobile phone or base station is complex and takes a very long time to complete; it may involve hundreds or even thousands of people over many months and in many parts of the world. These characteristics make the development of a new product of that kind a fascinating arena in which to study the process of managing complex product development.

In the most recent decades, the telecommunications industry has evolved as one of the most dynamic areas of business. This is due to the changes in the needs and uses of communication as a consequence of the globalization of other industries and markets, calling for the co-ordination of geographically dispersed resources and international business transactions. The telecommunications industry has also undergone tremendous development in its own business owing to the effects of technological changes and the opening up of new markets, e.g. mobile communications and the deregulation of previously closed markets.

Technological leaps and market changes have stimulated rapid product development, such as launching digital stationary and mobile systems that are able to transmit huge amounts of different types of information and offer both end-users and telecom operators an increasing number of functions and services. The electronic revolution reached its greatest momentum in the 1980s and mobile systems has during the 1990s rapidly been spreading throughout the world. As markets are becoming more open, competition is becoming more intense and concentrated, primarily involving a limited number of significant actors who are penetrating an international market rather than doing business that involves only one national telecom operator at a time, i.e. from local suppliers to local customers to global suppliers to global customers. The technical systems offer switching, transmitting and surveillance of information flows that are becoming more complex owing both to greater numbers of technical and organizational dependencies between sub-systems and to greater numbers of technical and organizational dependencies between older generations of systems - *backward compatibility* – and the necessity of keeping open possibilities for fitting with future systems and their development potentials - *forward compatibility.* Added to this complexity, companies must perform product development involving more and more goods and services at an increasing speed, which makes product development more resource demanding and risky (Granstrand&Sjölander 1990, Helgesson 1994, and Bohlin 1995). This forces firms to rethink earlier strategies and to focus more effectively on reusing old elements of products, sharing development between numbers of projects and implementing so called platform development strategies, which in turn adds complexity due to a greater need of co-ordination (Södersved 1991, Clark&Wheelwright 1996, Meyer&Lehnerd 1997, Nobeoka&Cusumano 1997 and Robertson&Ulrich 1998).

Telecommunications faces two-fold prerequisites; many areas are characterized by emerging standards and dominant designs in a technological perspective but are still spreading with respect to market applications and customer perceptions. At the same time new needs are emerging for radical technological leaps to master the next generation of systems. Many companies also struggle to be among the players in the next generation of systems based on more intelligent networks, more services and more media than speech. This next generation of systems further underscores the development sketched above and forces companies to master a competitive situation with many, small and highly flexible customers and shorter life-cycles of product generations together with intense competition from the computer industry. Parallel with this development, most companies also face changes in their own organizations; they now have to co-ordinate dispersed resources over cultural borders and resources in other companies working together in projects.

Even though the technical systems and their components (switches and cellular phones, for example) are getting smaller in a physical sense, they offer an ever-increasing range of capacities, making them larger in an immaterial sense. Increased complexity and growth in immaterial size are dealt with to an extent by designing intelligent hardware components, but specifically through high volumes of software packages. With the technologies at hand today, it is hence necessary for system producers to have large development resources in order to enter or maintain markets, since the development of new systems and redesign of existing products are very design-intensive affairs requiring the efforts of large numbers of engineers. Telecommunication producers are accordingly large companies and the complexity of products and market requirements together with intense competition create needs for continuously elaborating new leverages and mechanisms for enhancing performance.

Mastering these competitive conditions and increasing investments in product development intensify the need for the ability to manage complex product development. One of the most successful telecom companies during the past decade has been Ericsson. Ericsson has faced this challenge and has moved from being a rather small actor with focused resources for product development to being dependent on a global product development organization with a large number of design centers in 23 countries.

> *"Historically, Ericsson developed systems with rather limited human resources. Few people were involved in design, and every one was a highly skilled specialist with broad understanding of the entire telecom structure. We had a 'small company approach' in those days, and I believe it was one of the main reasons for Ericsson's early success. Even the first generation of AXE was built by a relatively small number of engineers, but the complexity has multiplied since then, necessitating a greater number of employees." [Senior Manager at LM Ericsson]*

Today Ericsson is one of the leading supplier of switches, with more than 40 percent of the world market for digital switches for mobile telephony, and one of the three leading suppliers of digital pocket phones with 25 percent of the world market. Ericsson has 95 percent of their sales abroad[3]. For more data on Ericsson and its recent development, chapter 6 is recommended.

The company has been able to maintain its traditional position as a major producer of stationary systems while at the same time establishing itself as one of the two world leaders in mobile systems. In the late 1970s and beginning of the 1980s, Ericsson gained a technological lead in stationary switching through the launching of its electronic switch - *AXE* - a system product that has maintained its competitiveness through a number of revisions. In the 1980s, the company was also an early success in the rapid development of mobile systems. This was achieved by a successful adaptation of AXE technology and coupling it with the use of radio know-how and, later on, drawing on the sophisticated technology in Ericsson´s defense products. As of today, the company's technological lead has been closed but it still is protecting and enlarging its markets. The competitors - at least in stationary switching - are offering similar products, and this has changed their competitive strategy. Even though Ericsson is still investing heavily in the development of new technology, it has successively been giving more attention to market and customer demands. The telecommunications branch is at a stage where companies are focusing more on becoming quicker and more flexible in responding to client needs. The product offered by the major competitors constitutes a *"dominant product design"*, as denoted by Utterback (1994), and the telecom business is in a transitional stage[4] where costs and customer demands in a deregulated market are becoming more important. Hence the companies and their employees must learn how to change their skills and

---

[3] Figures from 1998, Ericssons homepage, www.ericsson.se.

[4] The situation is a bit more scattered than so but this is further developed in chapter two, p. 134ff.

understanding of the new competitive situation. There arises a situation in which it is not sufficient only to make alterations in product characteristics but in which renewal of work practices is both a necessity for and an important tool in creating competitiveness. With mature technological systems and large costs for customer adaptations, work practice effectiveness and efficiency become determinants for profitability. The management of such products as Helicon has a considerable influence on the total costs in the company. The results of a product development project affect the conditions for and the direct costs of other processes in the company such as production, distribution and service - and thus total costs to a greater extent than is reflected in the individual project alone. Individual projects like Helicon also represent more and more actual costs in terms of man-hours. Production costs represent a lesser and lesser part of deliveries of systems in the telecommunications industry while development costs is a dramatically rising portion. (see for example large investigations performed by Calantone *et al.* 1997 or Ogawa&Ketner 1997).

From having been a process that has primarily been evaluated in terms of technical functionality – the number of functions and their performance and quality – the number of errors and the significance of these errors are now the product development process in focus in many companies' efforts toward greater competitiveness. *"Time to market"*, in terms of both the time from the first idea or purchase signal to delivery and delivery precision, is becoming a more and more important, high priority goal in the product development process. A clearer time focus and simultaneous requirements for flexibility and good business further increase the complexity of the product development process. It is more and more important to find ways to both reduce and to manage complexity. Many companies, Ericsson among them, thus wrestle with the question of how to develop and establish a product development organization with the capacity to fulfill all these demands.

Product Development Performance and Conditions - an Overview

Performance in complex product development can be viewed from many perspectives, and some often-discussed aspects of these perspectives and a number of performance variables are critically analyzed below. To put performance into a relevant context, some critical aspects of conditions for performing product development efforts are also discussed. Specific attention is given to *manageability*, *support systems*, *resource allocation*, *organizational co-operation* and *set of conceptions*.

Insufficient Manageability of Most Product Development Efforts

Development projects are often defined in the leading project management literature (see Engwall 1995 for a review) as:

> *"...large tasks having a clear purpose with certain given frameworks for time, economy and work investments..."*

An important distinction in development projects is the difference between the project itself – the work task – and the results of the project or the finished product – the object. While the project is the gathering of efforts in a limited time, the finished product is the lasting result at the end of the efforts. Thus, in project management terms, the result is a final goal defined together with the party who has commissioned the project. This final goal is most often beyond the control of the individual development project, and the role of the project is not to question the correctness of the task other than in its performance (Engwall 1995). The project is an agent responsible for ensuring that goals are fulfilled as effectively and resource-effectively as possible without disturbances. This according to Engwall (1995) is usually described in the literature in the following way:

> *" ...the project shall fulfill stipulated demands on function and quality, that it will be performed in an established time plan and maintain an established budget (Barnes 1985, PMI 1986 and Selin 1990 in Engwall 1995, p. 46, translated from Swedish)*

The three central performance dimensions in the above definitions – time, cost and the product's functionality – are at the same time the dimensions that are central in practical discussions of the performance of the product development project. Each performance dimension is emphasized more or less, depending on the project's conditions, goals and situation.

The concept of manageability is used in this thesis to describe the conditions for successfully steering a project toward fulfilling set targets. A number of studies have been done to analyze the performance of a project in terms of time, costs and the product's functionality. Svensson (1990) studied 42 projects in four Swedish industrial companies, compared them with 91 projects in a database and showed obvious deficiencies in fulfilling targets. Figure 1.1 shows the results of this study. Of the projects studied, only a few fulfilled set targets. The average extra time needed was over 50% and the average extra costs were over 110%. As can be seen in the figure, the 91 projects in the POP database exceeded their time limits by 60% and their cost limits by 80%.

	Relative time deviations (RT)		Relative cost deviations (RC)	
	Mean	Standard deviation	Mean	Standard deviation
7 detailed studies in 4 Firms	1,6	0,8	4,2	3,0
15 projects in Firm A	1,6	0,8	2,2	1,1
20 projects in Firm B	1,4	0,4	1,3	0,5
91 projects from POP-database[5]	1,6	1,1	1,8	1,2

Figure 1.1. Project performance (Svensson 1990)

[5] POP-database is a database with information of 140 new products, with a success/failure design. POP stands for *"product idea and project proposal"*.

Svensson (1990) looked for the causes of this and tested one often used in practice: that the performance of the product was better as a result of the excess time and costs. The tests were not able to verify this.

Another study of 109 product development projects among Swedish industrial companies with over 500 employees that examined product development projects shows the same results (Hörte *et al.* 1991). This study was an attempt to investigate the results of introducing *concurrent engineering*[6] in the performance of development projects. Figure 1.2 shows the results of the study. The difference between reaching set targets in parallel projects, partly parallel projects and completely sequential projects is small, and the most striking observation is how great a portion of the projects do not reach set targets.

	Performance targets	***Cost targets***	***Time targets***	***Market targets***
Sequential projects	77% did not meet set targets	81% did not meet set targets	61% did not meet set targets	86% did not meet set targets
Partly parallel projects	75% did not meet set targets	67% did not meet set targets	69% did not meet set targets	81% did not meet set targets
Parallel projects	73% did not meet set targets	69% did not meet set targets	58% did not meet set targets	91% did not meet set targets

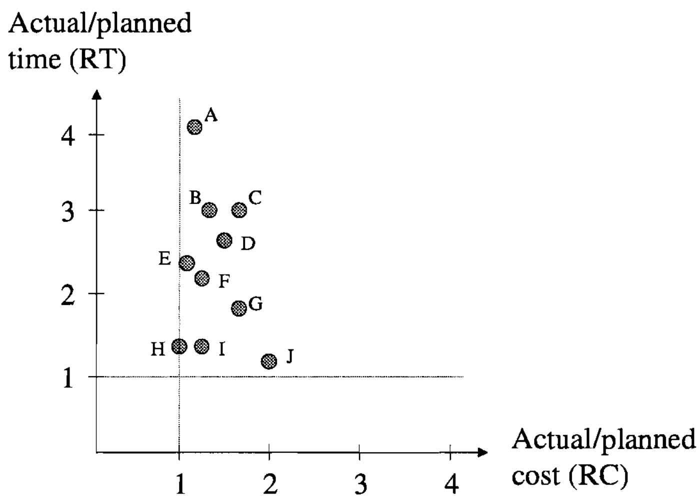
Figure 1.2. Project performance in 109 projects (Hörte et al 1991)

This picture of product development projects that do not achieve set targets is not one of only Swedish phenomena. An international comparison done by Svensson (1990) of eight studies covering 806 projects in a large number of companies and branches shows the same pattern. Figure 1.3 shows the average values for maintaining time and cost limits for different studies. If the projects stick to the established time, they are on or to the left of the vertical line in the figure; if they keep the

---

[6] The concept *concurrent engineering* is used to describe a method for making product development more effective by paralleling activities in product development projects and organizing for co-operation between different functions. This method became popular during the 1980s and is described in e.g. Södersved (1991) and Hartley (1990).

established project budget, they are on or under the horizontal line in the figure.



A) 56 polymer development projects (Villani 1973)

B) 84 development projects in the production of electricity (Norris 1971)

C) 75 pharmaceutical development projects (Mansifield etc 1971)

D) 81 product development projects in the mechanical industry (Fenneberg 1979)

E) 89 development projects in the process industry (Norris 1971)

F) 50 research projects in complex mechanical products (Norris 1971)

G) 79 pharmaceutical development projects (Mansfield etc 1971)

H) 252 chemical and biological product development projects (Norris 1971)

I) 30 "high priority" polymer development projects (Villani 1973)

J) 10 instrument development projects (Thomas 1971)

Figure 1.3. Project performance – an international comparison (from Svensson 1990, p. 33)

Other examples are a study of projects in the American pharmaceuticals industry showing that 80% of the projects carried out did not hold set targets, with an average extra time requirement of 61% and an average extra cost of 78% (Meyer and Lehnerd 1997), Segelod's (1986) research showed great problems in organizations in making project calculations and Morris and Houghes' (1987) studies of 3,000 projects in different branches indicated that they had exceeded their budgets by between 40 and 200%[7].

This is not only a valid description of product development project performance in the past. A number of more recent studies (see for example Gunasekaran 1997, Roy&Riedel 1997, Rusinko 1997, Fox 1998, Souder *et al* 1998 or Verganti 1999) show the same pattern. Projects normally do not meet set or emerging targets.

As the studies above and figures 1.1, 1.2 and 1.3 show, all of the projects studied are characterized by long delays and great extra costs as well as by the fact that important functionality is removed or transferred to future development projects. The y-axis in figure 1.4 describes the product's functionality and the x-axis describes time and cost[8].

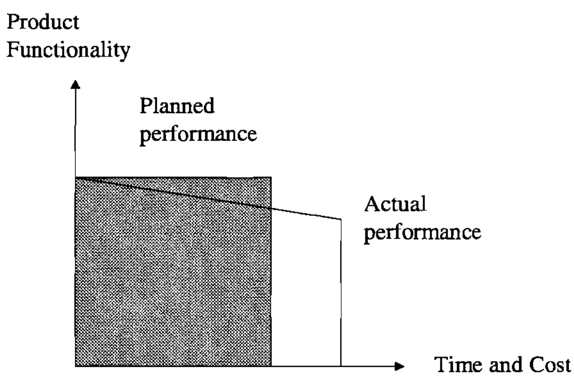


Figure 1.4. Project performance, planned and actual functionality and timing

[7] For a summary of studies of project success and failures se Morris&Hough (1987), pp. 273-280.

[8] Time and cost is both put on the same axis because it follows the same pattern and is often closely linked to each other.

At the start of a project, it is normally agreed that a given functionality will be delivered at a given point in time – this corresponds to the shadowed square in the figure. The actual performance in the normal case is that less than the agreed upon functionality is delivered later than the agreed upon time – this performance is represented by the unfilled, irregular square in the figure.

Ericsson is no exception, but a review of performance in Ericsson´s more complex product development projects[9] gives the following picture (see figure 1.5), which agrees well with the studies by Segelod (1986), Morris&Hough (1987), Svensson (1990), Hörte *et al.* (1991) and Meyer&Lehnerd (1997).

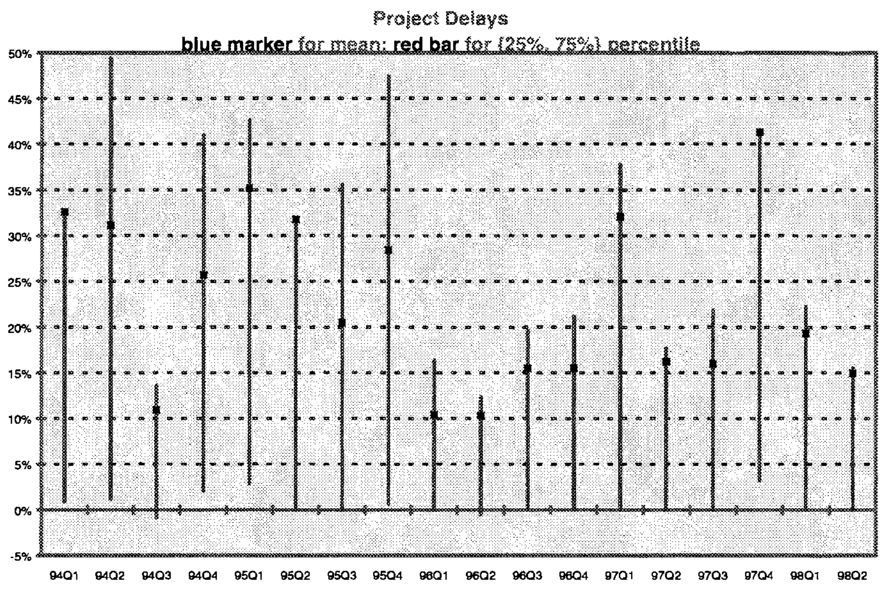


Figure 1.5. Project delays at Ericsson

As figure 1.5 indicates delays has been improved, from about 30% to about 15%, but so has also the demands and the competition, more content

[9] Ericsson systematically put together and analyzes PQT-data over respectively project costs, quality and lead-time.

must continuously be delivered in shorter time. Hence, performance is still insufficient.

This insufficient manageability of product development projects must not be seen as an acceptable situation. Why does the record so consistently show that projects do not normally meet set targets? The frequency of overviews across so many industries suggests that there must be a systematic error in the perceptions of how to manage these complex product development projects. Whether projects meet set targets is not necessarily even the best measure of project success (see for example Ekvall 1998). The project may still be profitable or make an important contribution in another dimension. However, given the above exceptions, systematically not meeting set targets is at minimum indicative that the process of managing complex product development is not sufficient, despite great efforts in companies and among researchers. In intensified competition with increasing demands, i.e. more and more functionality must be delivered in a shorter and shorter time, it is more and more important to find a solution to the problems. In Ericsson, the proportion of external technology is increasing, the globally distributed development is increasing and the lead-time for the most man-hour-intensive phases[10] of development projects has decreased from close to 60 weeks to a bit more than 40 weeks in the last four years (see figure 1.6).

[10] In the PROPS development model, applied by Ericsson this means the process between tool-gate (TG) 2 and toll-gate (TG) 4.

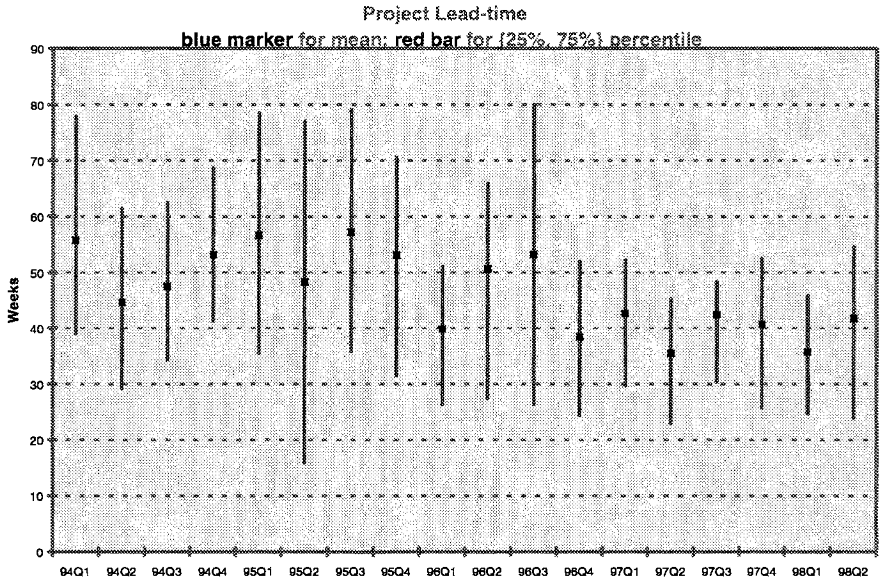


Figure 1.6. Lead-time in complex product development projects at Ericsson over time

Regarding functionality, the number of errors per product has decreased during the same period from an average of nine to five, despite the fact that the average product contains almost 5000 PLEX stmts[11] as compared with 2000 at the beginning of the period, and the fault density has decreased to 20% of its 1993 value (see figure 1.8 and 1.9).

[11] *Ericsson uses Plex stmts* as one quantitative measure of the content in their software products. One plex stmts is one programming code.

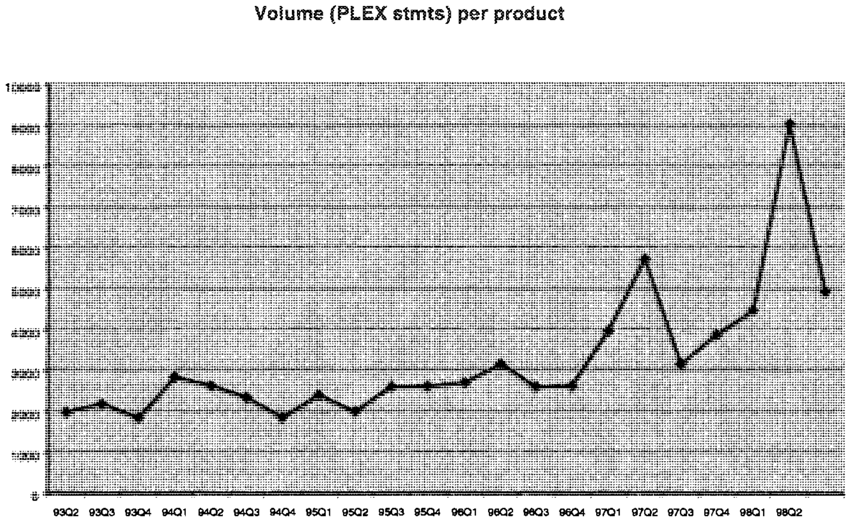


Figure 1.7. Size of the products to be developed at Ericsson over time

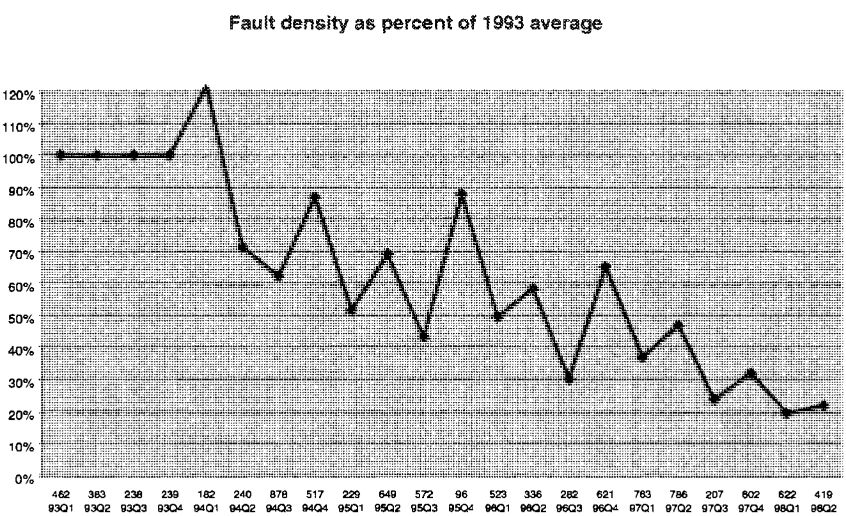


Figure 1.8. Fault density in the products that are being developed at Ericsson over time

This positive development has occurred as a result of a more effective development organization but, at the same time, the problems of meeting set targets, i.e. the manageability of product development efforts, have not been solved.

In summary, despite the enormous attention project management and project analysis have received over the past years, the track record of product development projects is fundamentally poor, particularly for the more complex ones. Complex product development projects seldom meet set targets. In summary, projects most often run over time, run over budget and seldom deliver the functionality agreed upon.

A further illustrative example of the phenomenon is a very recent research project done together with NUTEK[12]. The goal was to identify and analyze 20 projects that fulfilled or exceeded two of three project goals: cost, the product's functionality and time. An inquiry was sent to a large number of successful companies in Swedish industry. All of these companies had difficulties in finding a project that fulfilled these criteria and were close to being completed or were recently completed.

There are different types of tentative explanations for the above situation. Tyebjee (1987) offers three: (1) post-calculation misrepresentation – not all plans are carried out but rather the ones that *"look best"* – the quickest, cheapest and so on, i.e. the ones that are the most difficult to fulfill – are chosen, (2) political misrepresentation – to get a decision to start, plans are made to look better than they are and (3) planning-induced misrepresentation – the planning itself leads to optimism and an over-belief in the controllability of the project. In the explanations Svensson provides, the planning and decision process seems to be the major problem. Is it so that the applied planning process or internally developed decision process provides projects with unrealistic, politically based targets? Do we set up demands on time, cost and functionality that are too

---

[12] *NUTEK* stands for *Swedish National Board for Industrial and Technical Development* and is Sweden's central public authority for industrial policy issues.

difficult? Part of the truth must surely lie here, but not the whole truth. Organizations that perform product development are seldom closed systems that completely define their own prerequisites themselves; these most often emanate from customer demands or strategically decisive positions. Is it the case that product development shall not meet either set or emerging targets? The product development process can perhaps be seen as a learning process in which valuable scientific, technical and need-related information is gained through mistakes. From this perspective, failures and deviations from set targets should be a part of the learning process, and it would then be effective – although not productive – for many development projects to deviate from their plans and for some to fail completely. Perhaps it is also so that it does not matter whether product development projects meet set or emerging targets and that successful product development has to do with something else entirely. (see for example Ekvall 1998). If one makes unique and superior products, perhaps keeping time and cost budgets is not so important. However, much indicates that this is not so. The time of the introduction of a product on the market has again and again been shown to be significant for its dispersion and profitability. Also, reasonably, the predictability of the time point is an important issue in planning other activities. The predictability of the project's resource use also has reasonable significance for a firm's competitive strength, while no studies have shown any significant relationships between increased costs, longer times and commercial success. The significance of the discussion above is of-course dependent on industry and specific business conditions but still, meeting set targets is a vital aspect of competitiveness in all industries and under all business conditions.

The phenomena usually presented (see e.g. Segelod 1986 and Svensson 1990) as causes for deficient performance are: technical *"over-performance"* where resources are focused more than necessary on creating higher technical performance or quality levels than are agreed upon at the cost of time and money, errors in structure, where the support system that normally exists has not existed for the specific responsibility of the particular project; the commissioning party has not understood the difficulties or the marketing side has sold an impossible task, which causes agreed upon time, costs and performance to be unrealistic; a combination of technical and marketing uncertainties and the project could not predict the complexity, which has caused the task to become significantly larger and more difficult than was understood when the goal was set; dependence on critical resources, making it necessary to wait for these on different occasions; the manageability of professionals; decision makers think in the wrong way, which has meant that decisions have been made that have been contra-productive from the perspective of the project; suppliers have not kept their promises, making input arrive far too late. However, there are also causes that are related to the structures of decisionmaking and project choice – in other words, project plans are adapted to what decisionmakers want to see, making them incorrect. While these are all believable explanations for poor performance, they are not force majeur but factors that appear in most complex product development projects and factors that make up the conditions of the project. Segelod (1986) mentions two further explanations: experience is tied to individual persons, and these persons advance to other positions or change organizations, and organizations seldom document and analyze completed projects. Finally, the explanation for ineffectiveness of different kinds can not be ignored – the projects described above have not been executed as successfully as possible given the circumstances. To stay competitive, firms must learn how to master these conditions and perform product development projects that do meet set targets.

In recent years, a number of efforts have been made to attack these manageability problems, most of which has had little or no effect (see reviews by Gunasekaran 1997, Roy&Riedel 1997, Rusinko 1997 or Souder *et al.* 1998). Firms have encountered phenomena such as concurrent engineering, design for manufacturing, design for quality and so forth, but the overall insufficient manageability of product development efforts remains (Hörte *et al.* 1991). Individual actors in the firms working with the projects in question often see projects as toothless three-letter abbreviations that different consultants and/or researchers launch on a regular basis.

Support Systems not Developed for Project-Based Work

Project work has traditionally been carried out in line organizations and, although project-based product development has existed since the 1940s, it has primarily been used for extraordinary efforts such as the development of the atom bomb (Manhattan project 1942) and the development of nuclear missiles (Atlas project 1954) and have only gained wider use in more recent years. This background has left clear traces, and product development in most industries is controlled from a line perspective in spite of the fact that less and less actual development takes place in the line organization. Even in companies in which the dominant portion of process work takes place in different types of projects, support systems such as financial control, personnel functions and incitement and planning systems are developed primarily for the needs of the line organization and not those of projects. It is considerably more difficult for a project manager than for a line manager to gather relevant follow-up and key numbers for his activities.

Illustrative examples are the following statements by experienced project managers

> *"A line manager in our organization responsible for ten engineers or so often has a secretary, specially developed personnel planning systems, budget and follow-up systems and get to go on training programs facilitating their role while a project manager perhaps responsible for hundreds of engineers often has no secretary, has to develop all their support systems himself and is not offered any specially developed training programs. Added to this is that the line manager also has all status, formal authority, the larger room and higher wages" [Project Manager at Ericsson Telecom Systems]*

> *"It's impossible for me to get more than an approximate picture of project status and then I know that the picture is at least a month old" [Project Manager at Ericsson Telecom Systems]*

As these statements indicate, there is great potential in developing a support system for project-based work.

Misuse of Both Key Persons and Many Engineers

The proper use of both key persons and many engineers is imperative for enhancing effective product development. Most product development is project-based and, at the same time, principles for resource allocation are still not developed for this type of work. The specific characteristics of project-based work - further developed below - created by temporary tasks and assignments are not taken into consideration in resource use. The fact that projects often span over a number of functional units and have goals that are different from those of the closest manager and the work group of individual engineers is also neglected. This leads to a situation in which there are both obvious examples of engineers being alienated in relation to the projects and its targets as a result of under-use and of single engineers being clearly exhausted owing to the over-use of certain persons defined as key persons.

Examples are the following statements by experienced project managers and engineers:

> *"The only award for a well-managed, seemingly impossible project is an even more impossible project" [Project manager at Ericsson Radio Systems]*

> *"I was working with code facilitating extra functionality in the Alfa sub-project (a sub-system responsible for building a platform for add-on functionality in fixed switching) for about four months, when I suddenly got the message that this extra functionality wasn't needed anymore in the final product and that it wasn't needed in any on-going project for the moment. So the suggestion was to throw the work away and start helping two colleagues with testing their code. I never really understood why..." [Engineer at Ericsson Telecom Systems]*

"I am responsible for x in the AXE system and that means that everyone working with that part in any project at Ericsson tries to grab me to get help with their specific development and no one sees the total pressure this means" [System Engineer at Ericsson Telecom Systems]

As these statements indicate, there is great potential in developing mechanisms and systems for long-term personnel management in project-based or temporary organizations.

Uncertainties in the Boundary between Line and Project Organizations

In firms performing most product development work in projects and still keeping strong line organizations, a boundary between the two is created which often means many uncertainties for both managers and single engineers. It is difficult for the traditionally dominant line organization to release the historical role it has had and to find a new role adapted to the situation in which much of the process work is run in different types of projects. The line still drives a number of initiatives that would be better handled in projects. At the same time, it is difficult for project organizations to take over the role necessary in order to make it possible for the role of the line to change. Projects tend to focus on their own time-limited task and do not concentrate on issues that concern more than their own project. Individual employees feel great uncertainty in this double leadership situation and in the question of what the different roles consist of.

Examples are the following statements by experienced project managers and line managers:

"Frankly speaking, I never see my lads anymore. We meet in department meetings, early development discussions and sometimes bump into each other in the corridor but I honestly know very little about what they do and how they do it" [Line manager responsible for 40 engineers in a project-based organization]

"I am responsible for the work that is being performed, but I can't choose my own staff, I can't reward them, I can't even buy a cake to have with coffee without asking my line manager" [Project manager responsible for a 100 million dollar project in a line dominated organization]

Missing Set of Conceptions

A project is a project is a project – there is no set of conceptions or established practice for making use of differences in complex product development projects, such as proximity to business, type of customer, complexity, uncertainty and priority or in the questions of creating new businesses, improving existing businesses, improving existing costs or creating an area in which to act. There are great differences between different types of projects and project families, however, in terms of targets, purpose, size, customers, suppliers, partners etc. Product development projects are mentioned and considered in many contexts as a homogeneous group and unit of analysis, independent of whether it is a simple upgrading of a limited functionality that involves only a few geographically gathered individuals or a new development of a complex industrial system involving people from different entities in terms of both geography and culture. Differences in branches are treated to a certain extent, but there are many examples of greater intra-organizational spreading than inter-organizational spreading.

Wheelwright and Clark (1992) elaborate on the distinctive dimensions of *rate of product change* and *rate of process change*, from new to add-ons and enhancements, and define four types of product development projects: (1) *research and advanced development*, (2) *breakthrough or radical project*, (3) *platform or next generation project* and (4) *derivate project*. Other attempts to differentiate between development projects are Iansitis' (1995) distinction between projects having a primarily *system focus* and projects having a primarily *element focus*, Uenos' (1995) distinction between *product-oriented development* and *technology-oriented development* and Shenhar *et al.*'s (1995) distinctions between projects based on *high or low initial technical uncertainty* and those based on a *hierarchical ladder of systems and subsystems.* A common thread in their distinctions is the uncertainty and system perspective. These attempts have not made any significant impact on dominant models for managing complex product development. As regards dominant principles for *managing* complex product development, both state-of-the art and state-of-practice consider projects as a homogeneous entity. In the cases in which this set of conceptions has been developed (e.g. Archibald 1976, p. 26ff and Chada 1981, pp. 8-9), no consideration has been taken to its consequences, that is, what differences and similarities exist and how they should be handled.

Examples are the following statements by experienced project managers and line managers:

> *"In our company we tend to call everything a project. It doesn't matter if it is an assignment for one person during a week to update the search system at our internal library or if it is an assignment for several hundreds over years to renew our product platform to meet the demands of the next century. I think that this reduces the significance of the concept project" [Line manager at a Swedish telecommunications operator]*

As this statement indicates, much work must be done to develop a concept apparatus suitable for project-based work.

Towards Project-based Organizations

According to Engwall (1995), the word project is often said to stem from the Latin expression *"projec' tum"*, which Hellquist (1980, p. 787 in Engwall 1995, p. 41) translates to *"that which is thrown forth" [translated from Swedish].* The concept was imported to English from the Latin in the latter part of the 14^{th} century, and Engwall (1995) states that the first documented use in Swedish was in 1538. Dictionaries describe its meaning as *"suggestion"*, *"plan"* or *"draft"* but also as *"impulse"*, *"idea"*, *"dream"* and *"castle in the air"*. Until the 1960s, the concept of project was used according to Engwall (1995) in primarily three ways: (1) in a technical context for draft, (2) in an administrative context for formal proposals for laws, regulations, agreements or texts and (3) in more everyday contexts for large, complicated, advanced and sometimes wild ideas or suggestions for businesses. During the 1970s, a large number of new project expressions came into use, such as research project, pilot project and project group, and the meaning of the concept takes on the form that can be recognized in diverse project management literature:

> *"Activity, investigation, larger work task with certain, given frameworks as regards time, economy and work effort and with a given purpose" [Engwall 1995, p. 43, translated from Swedish]*

This development of the concept followed a strong increase in project work forms in several contexts. Many industrial companies redefine significant parts of their activities from traditional line work to activity development projects, effectiveness projects, investigative projects and product development projects. This increase in the use of what is called a project probably follows from the possibilities of the project work form for a strong focus in which the use of temporary groupings of energy would allow the achievement of extraordinary efforts and great flexibility. Organizational characteristics are becoming more and more important competitive factors in many branches, and some companies today operate the dominant portion of their process work in different types of projects. During the 1990s, a growing concern with studying project work on its own merits can be seen to be evolving. Buchanan&Boddy (1992) uses the term *project-based organizations*, Midler (1995) discusses the *"projectification"* of car manufacturers, Lundin (1995) and Packendorff (1995) discuss the notion of *temporary organizations* as a further development of project-oriented organizations, Engwall (1995) elaborates on *"the hunt for the successful project"* and Hatchuel&Weil (1999) introduces *design-oriented organizations*. In a study by Clark&Fujimoto (1991) of complex product development in the auto industry, the emergence of different, more pronounced project structures yields the insight that projects are more than a number of solitary and episodic orderings of activities.

This projectification of work life has been developed and grown very strong in organizations devoted to product development. An important explanation for this popularity is the applicability by representing a work method developed for individual efforts in a complex problem – a new solution to a problem, the future orientation – a completely new product, the transcending of boundaries – several technologies and organizational units and that represents a change from permanence and stability to speed and flexibility in the values of company management. Ericsson is one of the companies that began to apply project organization to their development work early on and now operates the greater part of its product development in different types of projects.

In summary, the evident shortcomings in the set of conceptions to better understand the complex endeavor of managing complex product development have acted as inspiration for the main purpose for this thesis, to suggest an alternative theoretical foundation that can guide further theoretical development. In addition the lack of sufficient performance in product development projects have acted as inspiration for suggesting a new conceptualization that can guide further practical development.

CHAPTER TWO

MANAGING COMPLEX PRODUCT DEVELOPMENT

This chapter will recapitulate and analyze the current domain of knowledge regarding the processes of managing uncertainty, managing complexity, managing projects, managing knowledge, innovation and learning, and managing product development. It will be argued that product development efforts in the telecommunications industry have reached a state of complexity and difficulty where today's *dominant perspectives, principles and models for organizing* in managing product development are becoming less sufficient. Hence, where *emerging perspectives, principles and models for organizing* – based on alternative theoretical foundations – provide better explanations for and predictors of performance.

Furthermore, some of the assumptions underlying the prevalent and dominant paradigm for managing complex product development will be contrasted with the new building blocks of the emerging paradigms. This will provide a broader perspective on the empirical evidence cited in subsequent chapters describing new perspectives and principles for managing and organizing complex product development. To shed light on these processes, we will take a closer look at both *state-of-science* and *state-of-art*. These discussions will offer a background for more detailed analysis of the empirical findings. It has not been possible to deal with all of the related aspects, and thus the primary focus here is on three main schools of thought which support the predominant perceptions in the area of managing complex product development. The three are; the school of project management, the school of organizational theory and the school of management of technology.

Managing Complex Product Development Projects – Dominant Theories and Practices

The concept of *dominant theories and practices* is used in this dissertation to describe the ideas, perspectives and schools of thought which are most common and prevalent today in business applications as well as in the public arenas of debate and theoretical analysis. As is always the case, considerable differences do exist among various individuals and groups. But sufficient patterns can be found in a number of important and recurring fundamental themes and assumptions to validate the idea that certain individuals and groups collectively make up and represent *dominant practices*. The purpose of this section is not to offer a complete analysis of the field of knowledge today, but is based upon a survey of three different sets of literature. Inspired by a literature review performed by Engwall (1995) I use three principal criteria for selecting relevant contributions and contributors. The three criterias are: (1) the contributions/contributors are most often cited by key representatives of industrial development environments and researchers in the field of management and organization of product development; (2) the contributions/contributors clearly state that they deal with this field of inquiry; and (3) the contributions/contributors are well known and represent, in my opinion, the main lines of reasoning in the on-going debate. I use as guides in this process three overviews performed in recent dissertations by three colleagues[13]: Engwall (1995), Blomberg (1995) and Lundqvist (1996). This means that a number of quotes from other authors than the three above will be ones they have selected as important to illustrate the field of knowledge. Hence, even if I have read and used that specific author's contribution in other parts of the thesis the quote will be referred to as Engwall, Blomberg or Lundqvist uses it. While this survey does not attempt to cover all questions or contributions to the discussion,

[13] These three thesises provides the reader with broad over-views and by having a fair picture of respectively set of literature this over-view will be based partly on their analysis of each set of literature to contribute in making our research additive.

it does strive to paint a representative picture of both practice and theory within the field. The main concern at this point is to identify the primary areas – the critical and essential elements – in the process of laying cornerstones for a framework in which complex product development may be described and analyzed.

The following review also aims to demonstrate that there exists a dominant approach for how to manage and organize complex product development. In addition, as noted above, it will show that this dominant approach is no longer sufficient for understanding, explaining or creating development organizations which will be capable of repeatedly meeting specific targets in the competitive environments of today.

Efforts to effectively organize development are rooted in a search for solutions to two fundamental problems. The first is how to design, build and test the parts and subsystems of a product so that each element achieves a high level of functionality. In a car, for example, this means that the gearbox is smooth, quiet and of high quality, and that the wheel suspension is durable and built to last. Because expertise and depth of understanding and knowledge drive functionality at the component level, achieving it requires some degree of specialization. From an organizational perspective, this degree of specialization determines how narrowly the firm is divided into sub-systems, which affects everyone involved, down to the individual engineer.

The second problem facing the development organization is how to achieve product integrity. Returning to the example of the car, this means that the vehicle has a low noise level, is comfortable and offers the driver great driving pleasure. Product integrity has an internal dimension – *sub-systems fit and work well together* – as well as an external dimension - *the product is consistent with customer expectations*. Now consider a product such as a cellular telephone. To be a competitive supplier of cellular phones, it is imperative to master critical sub-systems and components (battery, transmitting and receiving) *and* to master the integration of these sub-systems to be able to deliver a phone that meets customer expectations for sound quality, talk time between charges, and design. How a firm approaches this dilemma varies – and so does performance.

Three theoretical schools will now be described below, which together represent the primary platforms for knowledge about managing complex product development. An attempt to bridge theories from these three main areas will be made so as to give an overview of the field of knowledge and to provide a foundation for further discussion. The survey of the *Management of Technology* school features leading representatives from the technical universities, while the review of the school of *Organizational Theory* cites those from the traditional universities and business schools. Key advocates for the *Project Management* school of thought are from the world of practical application in the business community. To wrap up this section, we will look at some documented applications in the field.

School of Project Management[14]

The *Project Management* school originally comes from and builds upon the accumulated experience and knowledge of project managers who have carried out one or more successful projects. Studies that have focused almost exclusively on successful projects provide an additional basis for this school of thought. The examples cited most often in the literature primarily come from the construction and defense industries.

The clearest and most distinct characteristic of the *Project Management* school is that of having a *temporary* rather than a *long-term* view. Engwall (1995, p. 63) describes the project organization as:

> *"…a temporary organization created for the purpose of carrying out a project. It differs from traditional organizations in that it is consciously designed and built to accomplish a specific task. When that task is*

[14] Engwall (1995) presents a broad over-view of the school of project management in his thesis and this over-view is to a large extent inspired by, based upon and recapitulates information from his work if nothing else is noted·

completed, the project organization is disbanded." [translated from Swedish]

This, according to Engwall (1995), can be contrasted with the traditional organization's goals of growth and long-term stability – *permanence*. Success in a traditional organization is defined in terms of age, size, market share and profitability. For a project organization, on the other hand, success is viewed from the perspective of how few resources are used and how quickly the entity can be dissolved.

The focus in this school of thought is on individual projects and how they can be executed in the best possible way. A pervasive characteristic is found in the differentiation between the project – *the work tasks* – and the finished products, *the objects*. The products (objects) are regarded as something related to the customer and as external to the project. What drives the actual project itself (the work tasks) is the goal of carrying it out as effectively as possible, with a minimum of interruptions or disturbances and with the greatest resource efficiency – *in order to meet set targets*.

> *"If the client is to be satisfied, the work must be completed and its objectives realized in terms of performance, cost and time. The completed project must work how it was intended to, or better. It must have cost what it was intended to, or less. It must be taken into use when it was intended to, or earlier." [Barnes 1985, p. 11; in Engwall 1995, p. 46]*

One project, however, can have a different focus and "critical point" than what is found in another project. Several authors have stated that the combination of best effectiveness and function in the shortest possible time at the lowest cost is impossible when considering that these parameters are mutually dependent. The prevailing opinion, according to dominant literature, is that: (1) a shorter time requires a larger budget and/or a lower performance standard; and (2) a higher performance standard requires a longer allowable period of time. It should be noted that these relationships have not been verified by a systematic method, and examples can be found of studies which would seem to show the opposite to be true (see for example Svensson 1990). The emphasis upon certain aspects can also change over time. Function may be more important in an early phase, while cost and time are more critical during a later period of the project (see for example Lambert&Slater 1999).

Project work is most often contrasted with ordinary assembly line work by using descriptions such as *unusual, progressive, chaotic, temporary* and *focused on change*. A project requires that the established, ordinary routines are abandoned and special conditions are created for a specific set of work tasks, due to the fact that a single project often stretches across several line units and, consequently, must be treated as its own unique entity. The point of departure used in organizing a project is the attention focused on the activities to be performed and their mutually dependent relationships.

According to the most authoritative literature (Archibald 1976, Taylor&Watling 1979, Selin 1980, Cleland&King 1983, Andersen *et al.* 1989 and Meridith&Mantel 1995 among others), a project goes through a life cycle in which every phase requires different organization, managers and workers. The life cycle is described as chronological and sequential. The work in each different phase focuses upon various types of problems. Though the methods suggested for determining a project's life cycle vary somewhat among the different authors, the following four principal stages are according to Engwall (1995, p. 50) usually represented:

1. *Goal Setting and Pilot Study*: The goals of the project are established, and the specifications determined for the products to be included in the development project. This phase often involves persons outside the project.

2. *Planning*: Having been given the goals, the project managers then draw up a plan for the best possible execution of the project.

3. *Execution*: The project management is responsible for the execution of the project according to the plan, in order to achieve the stated goals.

4. *Conclusion*: It is determined that the project has met the prescribed goals according to the agreed plan, and experience gained from the project is documented for future use whenever possible.

The literature strongly emphasizes the importance of systematic planning and structuring of the project work tasks, which are clearly considered a prerequisite for having the right activities occur in the right order. Since different work methods and activities characterize the various phases in a project, the use of resources and assets will vary over time. For example, there are often fewer persons involved during the earlier phases – resulting in a lower consumption of resources per unit of time. In the middle of the execution phase, however, the maximum number of workers is on the job and using the greatest amount of resources. Then, in the conclusion phase, expenditures are again reduced, as fewer people remain involved at the end of the project. A summary picture of the resource consumption over time for a typical project would resemble an *S-curve* (see Figure 2.1.A).

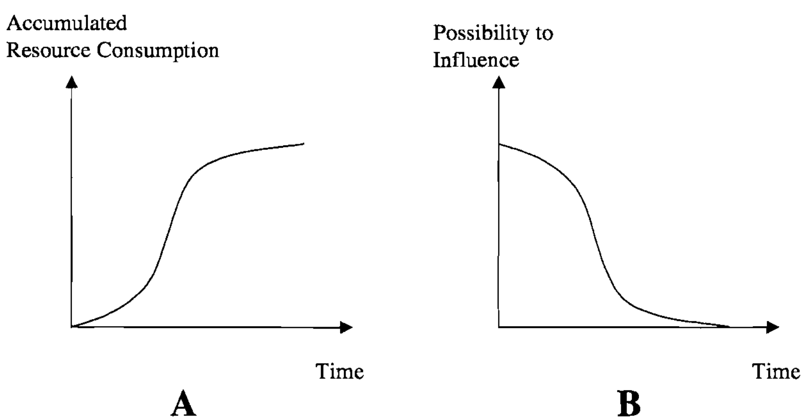


Figure 2.1. Resource consumption and the possibilities for influencing a project over time

At the same time, the literature provides a unified picture showing that the possibility of influencing the end result is best represented by an inverted graph (see Figure 2.1.B). This illustrates a situation where the prerequisites for the project's execution are *"locked in"* during the early phases, while the focus in the later phases is primarily directed toward how best to carry out the plans which were previously laid out.

In companies with greater experience in executing projects, there is often a *"standard operating procedure"* when it comes to how the definition of project phases should be related to the decision-making process in the project – and then in relationship to the overall decisionmaking process in the organization. Many of these companies have something that they refer to as their *project methodology*. This might consist of a more general basic product which has been customized with specific applications to their own corporate environment, or it could be a totally unique methodology built up as a result of the experience gained from earlier projects executed in-house by their own employees. Such a methodology according to Engwall (1995) usually contains four key elements:

1. *Checklists* with important items to consider and evaluate in each phase of a project.
2. *Instructions* as to which documents should be drawn up, when each should be done and what the contents should be.
3. *Planning guidelines* for the project managers.
4. *Descriptions* of the important decision points and suggested phase definitions for a project.

In addition to the sequential placement of activities which is done when a project's phases are determined and plans drawn in accordance with a specified timeline, the literature suggests that a project must be planned and structured with reference to the actual work tasks. Many authors propose that the project organization should be a direct and logical result of the work to be accomplished (c.f. Harrison 1992). In this view, the description of the work tasks becomes vital in terms of designing the organization. This is best accomplished by dividing the project into sub-projects, which in turn are divided into work tasks and individual activities. Through this division process, the point is eventually reached when each task or activity becomes as independent as possible, making it easier to manage and follow up. In the American literature, one often finds detailed discussions of how best to accomplish this break-down process and how to create logical and functional *work packages* – which themselves form the basis for a more detailed timeline, budget and overall project organization. (see for example Archibald 1976, Selin 1980 or Cleland&King 1983).

> *"Each work package is a performance-control element; it is negotiated and assigned to a specific organizational manager usually called 'work package manager'. Each work package manager is responsible for a specific objective (which should be measurable), detailed task descriptions, specifications, scheduled task milestones, and a time-phased budget in dollars and manpower." [Cleland&King 1983, pp. 255-256; in Engwall 1995, p. 64]*

The procurement division of the United States Defense Department is responsible for the development of a widely acclaimed standard for this style of project structuring, known as *Work Breakdown Structure (WBS)*. It is used to identify what work must be done, who should do it, and how the work tasks relate to the finished product and to each other. WBS is based upon a strict hierarchical subdivision of the project goals into intermediate goals, where each subsequent level provides a more detailed description of precisely what should be done. The end result is a hierarchy of goals, intermediate goals and work tasks (see Figure 2.2).

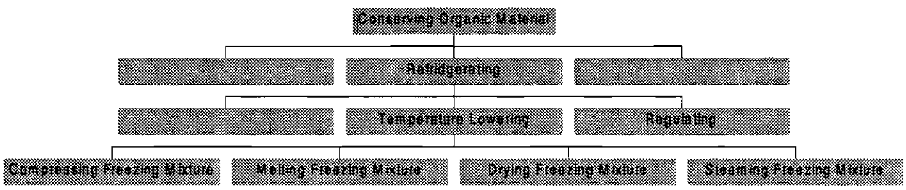


Figure 2.2. Example of a Work Breakdown Structure (WBS) (from Hammarlund 1977, p. 67)

A well-executed WBS defines the entire project in a systematic manner. The Pentagon gives the following description:

"A Work Breakdown Structure is a product-oriented family tree composed of hardware, service and data which result from project engineering efforts during the development and production of a defense material item, and which completely defines the project/program." [US Department of Defense, 1979; in Engwall 1995, p. 54]

WBS is the first step in a formal project-planning process. The literature (see for example Andersen *et al.* 1989) suggests that subsequent steps include: identifying the relationships between activities, determining the logical order in which they should occur, ascertaining when each respective activity must be completed in order that the next one can begin, calculating the elapsed time and quantity of resources required for each activity, and deciding who will bear the responsibility for the activities. The majority of examples cited in the literature are planning-oriented:

"Planning and scheduling is the language of project management." [PMI President Robert Yourzaks; in Engwall 1995, p. 56]

In project management literature, one finds discussions of planning at two levels: (1) a principal discussion concerning the need for planning, the individuals who should participate, how the work of planning should be handled and organized, and which planning methods are best; and (2) a more detailed and technical discussion about ways in which the existing methods and tools can be improved. The common thread through all these discussions, however, is the assertion that good planning is a prerequisite for effective project management (Archibald 1976, Selin 1980 and Packendorff 1993).

The most best known and most widely used methods for project planning are the Gantt chart and the networking techniques known as *PERT (Program Evaluation and Review Technique)* and *CPM (Critical Path Method).*

The *Gantt chart*, according to Engwall (1995), was developed in the early 1900s as a graphic method for showing the placement of different activities in relation to a schedule. The activities are depicted as horizontal bars running parallel with a timeline, each bar having a clear starting and stopping point. The pedagogical result was a clear overview of any proposed schedule – which made a major impact in production planning during the first part of this century.

PERT and *CPM* were born, according to Engwall (1995), at the end of the 1950s as by-products of mathematical network models used for optimization in the electric utility and transportation sectors. *PERT/CPM* are graphic presentations showing the sequence of, and relationships among, the individual work tasks that are required for the successful completion of a project. The network consists of activities, momentary events and the dependencies between the events and activities. When this matrix is laid out, a project's *critical line* can be identified – the sequence of activities which will require the longest time and, consequently, will determine the total amount of time needed to accomplish the entire project. *PERT/CPM* are built upon the assumption that the *shorter* the *"running time"*, the greater the amount of resources required. It follows that the investment of resources should be directed toward the critical line if the goal is to shorten the *"running time"* of the project. Conversely, *PERT/CPM* also demonstrates the presupposition that the *longer* the elapsed time, the smaller will be the total required investment of resources. This concept is then used to optimize the resources directed toward various activities in order to obtain the quickest and least expensive project possible.

PERT, according to Engwall (1995), is a refinement of *CPM* that recognizes that the exact values for each activity are difficult to quantify in advance. Instead, one uses what is most probable – an optimistic and a pessimistic estimate – and calculates the expected values and variances in a probability distribution. Both *CPM* and PERT are based upon the assumption that the functionality of the finished products is given, so the elements that should be manipulated are time and resources. Furthermore, the investment of both time and resources is viewed as being independent of the efforts made by specific individuals engaged in the execution of the activity. An example is provided by Engwall (1995, p. 61): an activity that will take ten hours to complete can be accomplished by one person in ten hours or by two people in five hours, or by ten people in one hour. A work hour on the first day of a project can be exchanged for a work hour on the 100th day. This presupposition that the whole entity can be divided up into "building blocks" permeates the most popular project management literature.

Each *work package* in the project is budgeted, assigned an account number and – by virtue of the placement of the work package in the matrix – given a graphic symbol representing the distribution of costs over time. This administrative process make possible the registration and follow-up of costs for each completed work segment or task. With this model, however, it is difficult to estimate what percentage of *work packages* have actually been completed at any point in time, making it difficult to obtain an accurate real-time progress update record. An activity which is delayed and has therefore not used all of the budgeted resources, or the existence of slow expense-accounting procedures, can give a false picture in the economic reports of a project which is being carried out more effectively than planned. In order to solve this *"in-progress"* accuracy dilemma, methods such as *Earned Value Techniques*[15] have been developed (Engwall 1995 suggests Fleming&Fleming 1991 or Kemps 1992 for a review).

A well-executed project planning process, according to the literature, forms the basis for the organization of a project. The organization can then occur according to various principles and standpoints. Selin (1990, p. 29) describes three typical principles:

1. building an organization according to the *finished product's intrinsic nature*
2. building an organization according to the project's work *phases over time*

---

[15] *Earned Value Techniques* is a method that monitor the value a project has created in a given set of time so as to compare the "actual" progress with the planned one and with the resource consumption.

3. building an organization according to the project workers' *areas of competence and special skills.*

This means that a sub-system's manager is responsible, in the first case above, for the sub-system, functions or physical parts of the end result – such as the chassis, steering system and interior of a car. In the second case, he/she would be responsible for phases such as fundamental project planning, detail construction and testing. His/her responsibility in the third case would include the traditional specialty areas such as mechanical construction and electrical systems. The organization of the project should be carefully related to the organizational structure of the assembly line, since that is the context in which the project work occurs.

Different ways of dividing work and responsibility between permanent – *the line organization* – and temporary – *the project* – entities have produced a classification system which ranges from completely line-dominated to completely project-driven operations (see for example Clark&Fujimoto 1991). In its extreme form, the line-dominated operation divides up the project assignment among the firm's normal departments. Coordination and management occur within the existing meeting schedule, reporting structure and information channels. No (formal) project manager (with a complete overview) is selected to be given overall responsibility.

At the other end of the spectrum one finds the project-driven operation, which is characterized by the creation of a special organizational entity whose only purpose is to carry out the project assignment. The project manager becomes a unit director responsible for all resources gathered for the exclusive purpose of executing the project. Clark&Fujimoto (1991) call this the *tiger team* model and suggest that, from the project's perspective, it has shown itself to be an effective organizational form. Other solutions between these two extremes are usually referred to as *matrix organizations*, where the line and project share the responsibility for the execution of the project. Typical hybrid forms are illustrated in the next section describing the *Management of Technology* school. See Figure

2.8 that presents the four principles of sharing responsibility between the line and project (as discussed in Clark&Fujimoto 1991).

The *Project Management* school can be summarized as follows. It provides a conceptual framework for focusing tools and principles in order to carry out the project assignment in the most effective way possible and to reach the predetermined goals. A project's goals are viewed as external to the project itself, and the focus in this school of thought is on the individual project. The predominant literature is planning-oriented. A project is organized in accordance with the sequential activities which are to be executed, the product which is to be developed and with respect to the sharing of responsibility between the project and the ordinary work line. It is generally assumed that the project has a unique set of goals and always goes through a typical life cycle consisting of many layers as described by various project management models. Among the most important principles are the following: to "lock in" the goals as early as possible, and to divide up the work tasks and activities according to a structured system such as *Work Breakdown Structures (WBS)*. Planning and organizing strive to achieve an optimum balance with the help of increasingly advanced support systems such as *Gantt charts*, *PERT* and *CPM* and more recent ones as *Project 98*. The currently dominant ideas and concepts are put forth by practitioners who are individual project managers, by special-interest associations such as the *Project Management Institute (PMI), International Project Management Association (IPMA)* and *Swedish Project Forum,* or by software producers of *support-systems* as *Microsoft*. The most prominent literature in the field is based upon the accumulated experience gained from project managers who continue to be active in real-world applications of these principles.

Figure 2.3 summarizes from the overview above central themes in effective and ineffective complex product development according to the *Project Management* school.

Problematic Product Development		Outstanding Product Development	
Characteristics	*Consequences*	*Characteristics*	*Consequences*
Focus on many parallel goals or aspects	Lack of focus on the project's primary goal	Focus on one specific project	Clear responsibility for set targets
Difficult to disband	Organizational inertia	Disbands upon completion of project	Organizational flexibility
Many individuals in the project share responsibility for the whole	Project faces risk of collapse due to unnecessarily complex tasks and unmanageable coordination requirements	Project tasks are broken down into smaller parts; work packages are created around these, reducing mutual dependence	Complexity of project tasks is reduced and the coordination process becomes manageable
Lack of planning with no help of specialized tools	Low efficiency – do not meet set targets	Rigorous planning by specialists in the earliest phases	Smooth execution and high efficiency

Figure 2.3. Central themes in effective and ineffective complex product development according to school of Project Management

School of Organizational Theory[16]

The school of *Organizational Theory* is built upon a series of different principles used to accomplish the fundamental goal of *dividing up* and *coordinating* work. Within the frame of reference of this school of thought, a number of sub-groups can also be clearly identified. Some of those that impact the concept of managing complex product development include (1) *the bureaucracy school*; (2) *human relations and organizational development*; (3) *institutional and neo-institutional theory*; (4) *cognitive theory*; and (5) *contingency theory.*

The *Bureaucracy School* advocates bureaucracy as the most effective of all organizational forms – a bureaucracy that controls, standardizes and predicts the actions of individuals. One of the most important building blocks, *Scientific Management* (Taylor 1947) is based according to Blomberg (1995) upon four main principles:

---

[16] Blomberg (1995) presents in his thesis an over-view of the relevant organizational theory building blocks for understanding project work and this over-view is to a large extent inspired by, based upon and recapitulates information from his work if nothing else is noted.

1. Scientifically study the components of various work tasks in order thereby to replace old methods that were based upon *"rules of thumb"*.
2. Scientifically select, train and develop the employees instead of permitting them (as was previously the case) to choose their own work tasks and obtain whatever training they could get along the way.
3. Create an atmosphere permeated by close and friendly cooperation between the company management and the employees, so that the conditions will be ideal for applying these principles.
4. Create a functional division of work and responsibility between the company management and the employees.

Later authors, according to Blomberg (1995), have proposed more elaborate thoughts on this same theme, such as the *"design school"* (Simon [1945] 1976), *"management and operations control"* (Anthony 1965), the *"technology school"* (Perrow 1986) or the *"machine metaphor"* (Morgan 1986). Their common message is that controlled tension, hierarchy and technology manage, organize and control the actions of individuals in the most effective possible way. The *Bureaucracy School's* solution to the problem of managing and organizing complex product development is this: a group of specialists is commissioned to design a hierarchical organizational system based upon bureaucratic principles, with clear areas of responsibility and a minimal dependence between the organizational entities overseeing different parts of the whole.

The *Human Relations and Organizational Development (HROD) School* is often described as a reaction against the *Bureaucracy School.* It made its breakthrough when a great deal of attention was given in the 1930s to the research at Western Electric showing the effect of socio-psychological phenomena on productivity (see for example Simon [1945] 1976 or Mayo 1933). Within this *HROD School,* the capacity of the human being to "stand against the bureaucracy" is highlighted:

> *"If people are given freedom, they will not only adjust themselves to their environment but will creatively develop new and improved*

conditions for their own existence and that of the people around them." [Blomberg 1995, p. 26]

Organizations that seek to be effective and efficient often strive to achieve some form of similarity or homogeneity among their employees. This is in contrast to a person's need, according to the *HROD School*, for diversity, heterogeneity and individuality. It is evident, then, that bureaucratic structures can be in conflict with the interests of the very people the management intends to control. The *HROD School* can be described as focusing on ways in which change is achieved through the element of human influence. The solution offered by the *Human Relations and Organizational Development School* to the problem of managing and organizing complex product development is to create sufficiently favorable conditions which allow room for the expression of each individual's creativity and energy.

Neo-institutional Theory (see for example Meyer&Rowan 1977, DiMaggio&Powel 1983 or Zucker 1991) explains the actions and relationships of individuals as being dependent upon external influences, i.e., unavoidably affected by factors which are outside of or above each person's control. *Neo-institutional Theory*, according to Blomberg (1995), has introduced the dichotomy between *conscious actions* and the *"self-evident" institution* – where greater degrees of institutionalization follow an inverse relationship with the degree to which the validity or clarity of something is "taken for granted" or assumed to be true. The *Neo-institutional Theory's* solution to the problem of managing and organizing complex product development is to create institutions, rules, principles and mechanisms that encourage the individual toward effective and efficient behavior. The more complex the situation is, the more support is needed in the form of clearly articulated principles and mechanisms or taken for granted assumptions.

Cognitive Organizational Theory (see for example Tolman 1948, Weick 1979, Sims and Goia 1986, and Argyris&Schön 1974, 1978) is built upon the assumption that the connection between an individual's thoughts and actions is complex. Argyris&Schön (1974, 1978) introduced the idea of *espoused theories* and *theories-in-use* in order to illustrate the normal discrepancies between outspoken motives and actions. The *Cognitive Organizational Theory* focuses on actual (tangible) organizational processes – rather than on optimistic, anticipated principles – for the design of organizational structures. This perspective draws relevance from the lack of such focus in other schools of thought.

> *"...much of what has been written about organizations has focused mainly on behaviors and outcomes, without an in-depth understanding of the cognitive processes that influence those behaviors and outcomes." [Sims and Goia 1986, p. 3; in Blomberg 1995, p. 43]*

Tolman (1948) introduced the concept of *cognitive maps* as a way of describing a person's hypothetical thought structure. This idea has been widely acclaimed in the field of *Cognitive Organizational Theory* and, according to Löwstedt (1989, pp. 196-197) it has been further developed and expanded into *cause-maps* (Weick 1979), *cognitive process charts* (Lord&Foti 1986) and *distilled ideologies* (Salancik&Porac 1986). The solution presented by *Cognitive Organizational Theory* to the problem of managing and organizing complex product development is to create shared cognitive maps among actors involved in each project, which will then influence the individual's actions and behavior. Research in this field (see for example Simon 1973) has shown that people primarily base their decisions and actions on their own simplified cognitive map when faced with complex situations or conditions characterized by a high level of uncertainty. When they find themselves in relatively safe or simple situations, however, they tend to draw on more varied information about the external world when deciding what to do next. This emphasizes all the more how important it is to have commonly held cognitive maps in complex product development environments.

The advocates of *Contingency Theories* contend that the suitability of various perspectives is determined by the specific assumptions and prevailing presuppositions in a given situation. Both Burns&Stalker (1961) and Lawrence&Lorsch (1967) have shown that different structural forms are appropriate for managing in environments where there exist differing levels of uncertainty, given a certain product that are to be developed.

> *"There seemed to be two divergent systems of management practice. Neither was fully and consistently applied in any firm, although there was a clear division between those managements which adhered generally to the one, and those which followed the other. Neither system was openly or consciously employed as an instrument of policy, although many beliefs and empirical methods associated with one or the other were expressed. One system, to which we gave the name 'mechanic', appeared to be appropriate to an enterprise operating under relatively stable conditions. The other, 'organic', appeared to be required for conditions of change." [Burns&Stalker 1961, p. 5]*

Burns&Stalker (1961) introduced the *Contingency Theory* as a counterbalance to the earlier ready-made solutions that offered one or more universally applicable principles for effective organization. The key message they espoused was that more bureaucratic systems should be used in more stable environments, while principles such as those found in the *HROD School* should be applied in situations which are more changeable or in which more variables exist. They demonstrated in their own studies, for example, that organic structures facilitated the rate of product change in electronic firms.

Woodward (1965), Thompson (1967), Lawrence&Lorsch (1967) and Mintzberg (1978) have created a continuum of typical organizational principles ranging from bureaucratic/stable structures to organic/dynamic solutions. The school of *Contingency Theory's* proposal for solving the problem of managing and organizing complex product development is, consequently – the right solution is dependent upon the environment in which it will be used. Under today's business conditions, however, the recommendation would in most cases be in favor of selecting from among the organic/dynamic solutions.

Other authors question the simple *design perspective* and *optimal solutions*, contending that one must also consider the importance of supplementing these principles with a political perspective. The neo-insitutionalists view is that institutionalizing secures conformism and therefor accesses to necessary resources:

> *"...organizations which adopt the appropriate forms perform well not because these forms are most efficient, but because these forms are most effective at eliciting resources from other organizations which take them to be legitimate. Conformism may secure access to resources, but not because of superior efficiency." [DiMaggio&Powel 1983, p. 154; in Blomberg 1995, p. 38]*

While others uses a power-related perspective:

> *"The relatively stable, ordered, bounded, predictable, rule-based hierarchical organization today seems an anachronism. The so-called 'postmodern' organization is characterized by fluidity, uncertainty, ambiguity and discontinuity. (...) Hierarchy is replaced by reliance on expert power; those with the best understanding of the problems take the decisions. In this (stereotyped) 'postmodern' context, individuals are stripped of the conventional resources of a relatively stable organizational position, and are deprived of a meaningful, predictable vision of their own future. This fluid and shifting context implies an increased dependence on personal and interpersonal resources, and on political skills to advance personal and corporate agendas. There is clearly enhanced scope for political maneuvering in a less ordered and less disciplined organizational world. There is clearly a greater need for critical understanding of the shaping role of political behavior in such a context." [Buchanan and Badham 1998, p. vi]*

Advocates of the political perspective suggest that the ultimate proposal for managing and organizing complex product development is to give the project manager a sufficient power base and the necessary political tools. Hence, so that regardless of the situation he or she will be equipped to create the right conditions for the project to succeed.

Throughout the discussions of various perspectives and schools of thought, one finds the following dichotomies: *development vs. stability* *and specialization vs. integration*. However, in work produced by Björkegren (1989), Schein (1992), Blomberg (1995) and Nakhla&Soler (1996), the assumptions concerning these dichotomies are called into question – with the authors providing suggestions for new perspectives which bridge the perceived gaps. Björkegren (1989) questions the supposed incongruity between stable relationships and altered actions, contending that there very likely could (and should!) be room enough for both development *and* stability to coexist in organizations simultaneously. He also puts forward following discussion: *that the conditions for combining the two are better in organizations with more developed knowledge structures than in those with more primitive knowledge structures*. Schein (1992) introduced a set of concepts considering the integration of innovation, learning and adaptation as stable elements in a company; i.e. that development actually becomes the stable state of affairs.

> *"When we pose the issue of perpetual learning in the context of cultural analysis, we confront a paradox. Culture is a stabilizer, a conservative force, and a way of making things predictable. Does this mean, then, that culture itself is increasingly dysfunctional, or is it possible to imagine a culture that by its very nature is learning-oriented, adaptive, and innovative? Can one stabilize perpetual learning and change? What would a culture that favored learning look like?" [Schein 1992, p. 361; in Blomberg 1995, p. 34]*

Blomberg (1995) suggests that participation in a large cooperative project is one way to bridge the chasm between organizing for change and organizing for stability and orderliness. Nakhla&Soler (1996) propose the creation of zones with *temporary stability*, and a balance between *centralization* – in the sense of integration – and *decentralization* in the sense of specialization. The zones with temporary stability, according to Nakhla&Soler, make it possible to: (a) ensure in advance the mutual compatibility between individual activities; and (b) leave open the options for dealing with unforeseeable events.

The *School of Organizational Theory* can be summarized as a spectrum of perspectives – from a recommended application of strict bureaucratic principles at one extreme to a total absence of principles combined with a complete freedom of action for all participants at the other extreme. Spokespersons for the *Contingency Theory* contend that the bureaucratic end of the spectrum is appropriate in stable and predictable situations, while the organic end of the spectrum is more suitable in changeable situations characterized by a high degree of uncertainty and complexity.

Figure 2.4 summarizes the central themes in effective and ineffective complex product development according to the above review of the *School of Organizational Theory*.

Problematic Product Development		***Outstanding Product Development***	
Characteristics	***Consequences***	***Characteristics***	***Consequences***
Bureaucracy School *Insufficient planning, management and control functions*	**Bureaucracy School** *Complexity is too great, with a low effectiveness in execution*	**Bureaucracy School** *Standardization and clear principles for responsibility and control*	**Bureaucracy School** *Effective execution*
HROD School *Standardization, regulation and regimentation*	**HROD School** *Low motivation among the participants*	**HROD School** *Large amount of room and good conditions for own initiative and shared responsibility*	**HROD School** *New possibilities are utilized and large dynamic capacity is achieved*
Institutional Theory *Lack of right institutions –assumed truths*	**Institutional Theory** *Complexity is too great to handle, and different views of the external world vie for control*	**Institutional Theory** *Established institutions based upon positive experiences*	**Institutional Theory** *Conditions exist for additive learning and effective behavior*
Cognitive Theory *Lack of shared mental models*	**Cognitive Theory** *Parallel and competing goals and actions with various participants*	**Cognitive Theory** *Shared mental models with all participants*	**Cognitive Theory** *Convergence and effective project execution*
Contingency Theory *Hasty application of principles*	**Contingency Theory** *Unnecessarily ineffective execution*	**Contingency Theory** *Application of the "right" principles for each individual situation*	**Contingency Theory** *The most effective possible execution*

Figure 2.4. Central themes in effective and ineffective complex product development according to School of Organizational Theory

School of Management of Technology

The *School of Management of Technology* has primarily originated from the management research carried out at universities of technology – with MIT and the Sloan School at the center of activity. The research in this area has traditionally been dominated by studies based on "*rationalistic approaches*" or the presupposition of "*bounded rationality*" (see reviews in Lundqvist 1996 and MacCormack 1998).

Using "*rationalistic approaches*" to study product development from a normative perspective (as a process that can be clearly planned), the fundamental assumption is this: if only a specific method or tool is used in the correct manner, and deviations from the plan are minimized, one will achieve the desired result. According to this perspective, processes and procedures are disengaged from history and context, i.e. they are independent of people and specific situations (examples can be found in Hice *et al.* 1974, Olsen 1976, Evans *et al.* 1983, Holt 1983, and Bruzelius&Hansen 1986).

Studies of product development processes based upon the concept of "*bounded rationality*" focus on the effective handling of information and uncertainty, where people are viewed as an imperfect mechanism for the processing of information. This perspective advocates that product development processes can be made more effective by reducing the uncertainties, which is accomplished through closing the gap between the information which the organization has and that which it needs. By analyzing the characteristics of the development process currently in focus – the nature of the *project task*, the *task environment*, and the *task interdependencies* – it will be possible to design a "*fit*" between information-processing requirements and information-processing capacity and achieve effectiveness in the development process (Tushman 1979). In this context, information is treated as a measurable and divisible entity (see Galbraith 1973, Allen 1977, Katz&Allen 1982 and Sjölander 1985).

A common thread in these two perspectives is that they have, to a large extent, studied development work as a linear process with sequential dependencies between the adjoining parts. Within this school of thought, there exists a large number of methods and tools used to improve the conditions for development work, including: *Design for Manufacturing, Quality Function Deployment, Total Quality Management, Concurrent Engineering*, etc. (Södersved 1991). Many authors (Peters&Waterman 1983, Womack *et al.* 1990, and Clark&Fujimoto 1991) have shown how companies can develop higher-quality products more quickly and at a lower cost using these methods.

There is also a fast-growing group of researchers that studies product development processes from a perspective based upon "*emergent rationality*" (Nonaka 1994, Hedlund 1994, Nonaka&Takeushi 1995, and Lundqvist 1996). Using this concept, development work is viewed as a knowledge creation process stemming from a series of dependencies – both sequential as well as pooled and reciprocal. Human rationality is in focus, characterized as *subjective, constantly growing* and *changeable in its very nature.* MacCormack (1998) places these earlier and new studies along a spectrum with *stage-gate models* (see figure 2.5) at one end and models based upon the *process of learning and adaptation* (see figure 2.6) at the other. The spectrum indicates only the presuppositions of the various perspectives that are based on the fact that operationalization can occur, and that it can occur in different ways – which is comparable with the work of Bucciarelli (1988). He identifies three discourses in managing product development: (1) *constraining discourse* – setting specifications early; (2) *naming discourse* – creating images of parts and functions of the product in the mind of participants; and (3) *decision discourse* – stage-gate models. Marples (1969) and Clark (1985) describe stage-gate models as a hierarchy of design decisions that must be resolved in a development project.

> *"...design proceeds in stages, the end of one and the beginning of the other being marked – usually quite dramatically at a recognizable instant – by a decision which sets a particular solution from a number*

and sets out the sub-problem to be tackled in the next stage. The decision is treated as if it were irrevocable. Major insights apart, every other designer on the project will subsequently assume that the decision will not be revised and will be able to work accordingly." [Marples 1969]

A stage-gate approach builds on serial thinking where concept design leads to frozen concepts before execution, and where execution is performed in a number of pooled activities before integration and test are initiated (see Figure 2.5).

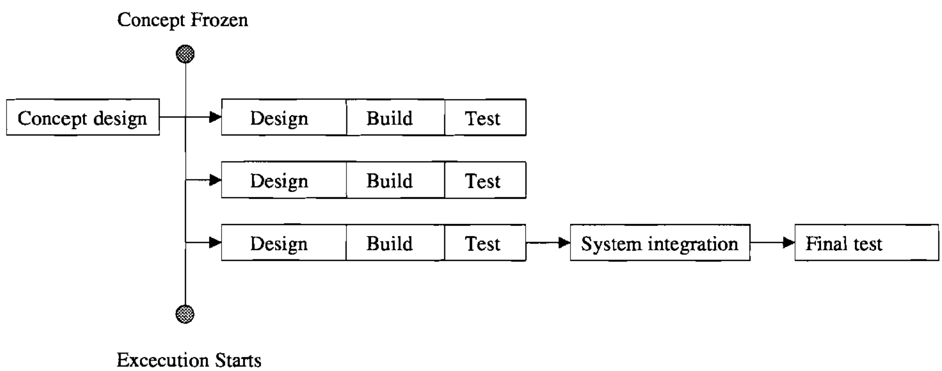


Figure 2.5. A "Stage-gate" approach to development [in MacCormack 1998, p. 4]

Since Marples' early work, several different phase models have been proposed in the literature, describing the optimal sequence of stages in this process (e.g., Brodin 1976, Booz *et al.* 1982, Pahl&Beitz 1984, Twiss 1986, Cooper 1990 and Wolfe 1994). Typical phases that are described include *concept development*, *product planning*, *and product engineering* and *pilot production* (often referred to as *ramp-up*). These linear phase concepts – all presumed to be performed in a sequential and chronological order – are closely parallel to the previously described steps found in the predominant literature in the *School of Project Management*.

> *"In the first of these stages, typically called concept design, the overall architecture of the product is outlined. This architecture is subsequently defined in greater detail, forming the design specification for the execution stage that follows. Typically, execution is broken into several independent paths encompassing the detailed design, build and test of separate modules. A final integration stage follows where these modules are brought together and tested as a system." [MacCormack 1998, p. 3]*

> *"Systematic design alone can produce a truly rational approach and hence generally valid solutions – that is, solutions that can be used time and time again." [Pahl&Beitz 1988]*

In the two first phases, information about market opportunities, competitive moves, technical possibilities and production requirements must be combined to create a representation of the new product's architecture. Companies often attempt to try out the concept through small-scale testing before large-scale development programs are approved. Once approved, the project moves into detailed engineering, with the primary aim to design and construct working prototypes of the final product, as well as the tools and equipment needed for production.

At the heart of detailed engineering is the *design-build-test cycle.* Both products and processes are laid out in concept, captured in a working model (computer-based and/or physical), and then subjected to tests that simulate product use. If the model fails to deliver the desired performance characteristics, engineers' search for design changes that will close the gap and the *design-build-test cycle* is repeated. The conclusion of this phase is marked by an engineering "*release*" which represents a final design that has met the requirements.

At this time, a company typically moves into a pilot-manufacturing phase where individual components are built and tested. All commercial tooling and equipment should be in place and all subsystems from suppliers should be geared up and ready for volume production at the beginning of this phase. The integration of all the various parts of the project now occurs.

The simple *stage-gate model* has been developed by several authors to cope with the demands of shorter development cycles. Some researchers have recently begun to explore alternative development models such as *"spiral"* (Boehm 1984), *"iterative enhancement"* (Boehm&Papaccio 1988), *"concurrent development"* (Pimmler&Eppinger 1994), *"synch and stabilize"* (Cusumano&Selby 1995), *"interpretive"* (Piore *et al.* 1997) and *"continuous integration"* (Staudenmayer&Cusumano 1998).

Many researchers (see for example Couglan 1992) were confronted with situations where the real-world experiences in their studies of complex product development did not meet the descriptions in the predominant literature. In their work, the process of development turned out to be simultaneous rather than sequential. Half or more of the manufacturing engineering activity was performed during the design phase, and up to two-thirds of their work started during the definition stage. Most testing activities had started up before any design activity was actually finished.

So the basic assumption that planning must be complete before execution of a project can start has been strongly questioned and reviewed at length. Solutions involving concurrency and overlapping phases have been proposed. The primary message is this: not all of the *planning* output is needed at the beginning of the *design* phase, not all of the *design* output is needed at the start of the *integration* phase, not all of the *integration* output is needed at the outset of the *testing* phase, and so on. These studies are further elaborations and refinements, but are largely based on the same basic assumptions of "*rationality*" or "*bounded rationality*" – delivering solutions which offer a number of critical steps to reach superior performance.

A number of authors have summarized their research into sets of *success criteria*. Wheelwright&Clark (1992) formulated eight steps for developing a superior aggregate project plan. Clark&Fujimoto (1991) presented four central themes used to effectively conduct product development, while

Smith&Reinertsen (1991) offered eleven keys to developing products in half the time. Nadler&Tushman (1987) outlined four steps to design effective formal coordination mechanisms. These all resulted from a small group of experts analyzing prerequisites and goals. Using a specific methodology – often including specific steps of analysis – they designed prerequisites that were introduced as superior in some dimension.

Wheelwright&Clark (1992) also distilled their work into five criteria for success: *customer focus, discipline, and coherence in detail, fit with mission* and *sharing the pattern*. Cooper (1979) and Twiss (1986) point to the great need for top management's support, as well as competent and experienced project managers. Maidique&Zirger (1984) explain how imperative it is that the direction and focus match the goals – that the product development process being carried out is taking advantage of the company's strengths. It is important that the most effective operation controls, choices, and follow-up systems be utilized. More recent studies have supplemented this field of research with additional dimensions, emphasizing how vital it is to understand *"the design of the design process"* as well as *history and traditions, the context, the object and the nature of coordination* (Karlsson 1994).

Improved coordination has long been a common thread in learning how to cope with intensified competitive demands (Allen 1977, Ancona&Caldwell 1990 and Iansiti&Clark 1994). Integration processes across *functions* (Dougherty 1992), *projects* (Meyer&Utterback 1993, Cusumano&Nobeoka 1992 and Meyer&Lehnerd 1997) and *time* (Adler 1996, Adler *et al.* 1997 and Gersick 1988) become increasingly important. Different strategies to effectively develop complex systems are being tested, such as: *modularization* (von Hippel 1990, Eppinger *et al.* 1994); *optimal strategies for testing and integration* (Dellarocas 1995); *new development tools and development environments* (Cusumano&Kemerer 1990); *close working relations between representatives from different departments* (Nonaka 1990 and Wheelwright&Clark 1992); and *enhancing mechanisms for self-organizing* (Lundqvist 1996). The universally applicable messages from this body of work are: (1)

integration is important for project success; (2) the earlier and the more frequent, the better (Nonaka 1990, Wheelwright&Clark 1992 and Cusumano&Selby 1995); and (3) physical distance and cultural distance (Hofstede 1991 and Zander 1994) make integration harder and, conversely, physical proximity greatly increases the likelihood of success (Katz&Allen 1982 and DeMeyer 1991).

With rapidly changing customer needs and technologies, the most recent literature makes abundantly clear that an alternative perspective must be created. A large number of researchers (see for example Iansiti 1995, 1998, Eisenhardt&Tabrizi 1995, Cusumano&Selby 1995, von Hippel&Tyre 1995, Lundqvist 1996, Adler *et al.* 1997, Verganti 1997, Thomke 1998, MacCormack&Iansiti 1998, Staudenmayer&Cusumano 1998, Hatchuel&Weil 1999 and Dougherty 1999) have clearly shown that *flexibility* in the design process is an important advantage and that this flexibility can be endangered by rigorous planning. In contrast to an *"early freeze"* of the entire design, the stages now overlap and the design "*evolves*" during the course of the project. The goal is to keep the "*window of opportunity*" open for changes as long as possible during a development cycle and to integrate subsystems early and frequently. In an iterative approach, the concepts are not frozen until the project has finished, and project progress is based on a number of design-build-test cycles towards increased refinement. System integration is performed continuously (see Figure 2.6).

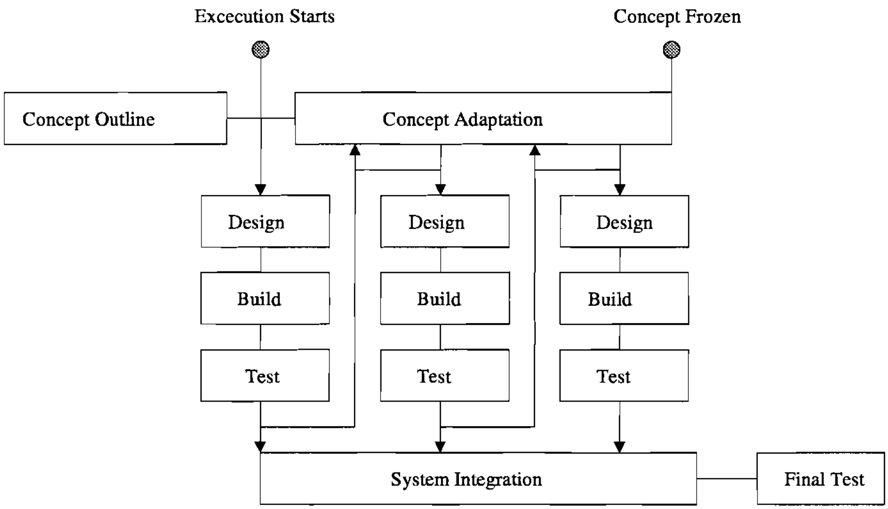


Figure 2.6. An "Iterative" approach to development [in MacCormack 1998, p. 4]

"An effective process in these environments must therefore be able to respond to new information as it progresses, whether this be feedback from technical experiments conducted internally, or feedback from external customers based on the release of early and rapid prototypes." [MacCormack 1998, p. 6]

Recent studies suggest that the different perspectives do not only represent different states in a continuum or a theoretical development over time. Rather, they represent different solutions to different situations (as in the earlier discussion of *Contingency Theories*). Wheelwright&Clark (1992), MacCormack (1998), and others describe the planning perspective as superior within stable markets and technologies, and/or when a clearly dominant design is already established.

"Not all development projects need deep, cross-functional integration. Where product designs are stable (or change only in a minor way), customer requirements are well defined, the interfaces between functions are clear and well established, and life cycles and lead times are long, functional groups may develop new products effectively with

a modest amount of coordination through procedures and occasional meetings." [Wheelwright&Clark 1992, p. 175]

During the last decade, the contours of an alternative and more practice-centered (Brown&Duguid 1991, Dougherty 1992, 1999 and Dubinskas 1993) organizing approach have emerged. It is practice-centered in that it looks behind formal structures and procedures and seeks to understand the actual "*theories-in-use*" rather than the "*espoused theories*" (to use the terminology from Argyris&Schön 1974). Recognizing that human beings are rarely deterministic information-processors, the emerging alternative paradigm builds upon two cornerstones. First, it has a focus on *knowledge* rather than on *information.* Secondly, knowledge should be seen as created and disseminated primarily through *dynamic and interpersonal dialogue.*

Knowledge, according to this perspective, can be transformed from implicit to explicit – *externalization* (e.g., by writing down instructions that previously have been tacit); from implicit to implicit – *socialization* (as in the relationship between master craftsman and apprentice); from explicit to implicit – *internalization* (by learning from written or espoused knowledge). Knowledge is no longer transferred only from explicit to explicit – *combination* – as described in the "bounded rationality" perspective (Hedlund 1994 and Nonaka 1994).

		To	
		Explicit	**Implicit**
From	**Implicit**	*Externalisation*	*Socialisation*
	Explicit	*Combination*	*Internalisation*

Figure 2.7. Different modes for knowledge creation (Nonaka 1994)

In order to achieve an effective knowledge and development process, therefore, it is necessary on a far-reaching basis to *remove barriers between individuals* (Purser *et al.* 1992, Purser&Pasmore 1992 and Pasmore 1994) and *enable self-organizing behavior* (Lundqvist 1996). Thus, while in the information-processing approach a rationale was given for reducing redundancy and unnecessary interaction, the more practice-centered approach proposes that redundancy and interaction can potentially help enable learning and the creation of new opportunities.

An alternative paradigm is suggested as appropriate when uncertainties are high and prerequisites (such as customer requirements and basic design) change frequently and/or are unpredictable. The advantages emphasized with an alternative paradigm based on early and frequent integration and a *"late freeze"* of specifications are: (1) helping to guide early design choices; (2) maximizing total system optimization; (3) early detection of potential integration problems; and (4) the ability to delay configuration decisions in order to incorporate late-changing information into the process. The disadvantages include: (1) the fact that these types of processes often require greater investments in experimentation capacity to cope with the need of continually updating design choices (West&Iansiti 1997 and Thomke 1998); and (2) the significant overhead associated with a frequent integration of components into a complete system, if this activity does not yield significant amounts of new information.

In summary, the prerequisites for complex product development vary according to the *nature of the project task*, the *task environment*, and the *task interdependencies*. Different *coordination mechanisms* have varying capabilities to deal with these prerequisites.

The potential paradigm shift and potentially new theoretical paradigm still remains in its infancy. One central component is a *dynamic system approach* (Nonaka 1988 and Purser&Pasmore 1992), with strong influences from the growing body of *chaos-theory research* (see Sommerhoff 1969, Gleick 1987 or Prigogine&Stengers 1984). This research focuses on identifying *mechanisms for self-organizing* (Lundqvist 1996, MacCormack 1998 and Studenmayer&Cusumano 1998), creating conditions which enable the *development and exploitation of core capabilities* in terms of competencies and business outlooks (Leonard-Barton 1992, 1995), and on knowledge and *mechanisms for collective learning* (Senge 1990, Adler&Norrgren 1995, Adler&Docherty 1998 and MacCormack&Iansiti 1998). Another focus in this research is directed toward *project leadership* – and the leadership qualities required during the change process (Buchanan&Boddy 1992 and Norrgren&Schaller 1996).

Instead of launching a *"set of best practices"* which, if adopted, would lead companies to the productivity frontier, a more balanced discussion is evolving. Which contextual factors would tend to mediate the relationship between managerial choices and performance outcomes? What will allow us to better discriminate between those practices that are uniformly *"good"* under all circumstances, and those that should be changed or revised as conditions change?

Regardless of which perspective is being presented, the literature is clearly unified concerning the concept that the organization of individual projects can be done in many different ways. Wheelwright&Clark (1992) outline four types of predominant project organization structures: (1) *functional* *team structure*, (2) *lightweight team structure*, (3) *heavyweight team structure*; and (4) *autonomous team structure*. These span the spectrum from *functional* organization to *project* organization. In later research studies (Clark&Fujimoto 1995), autonomous team structures have been redefined as *tiger teams*. Figure 2.8 depicts the four typical structures.

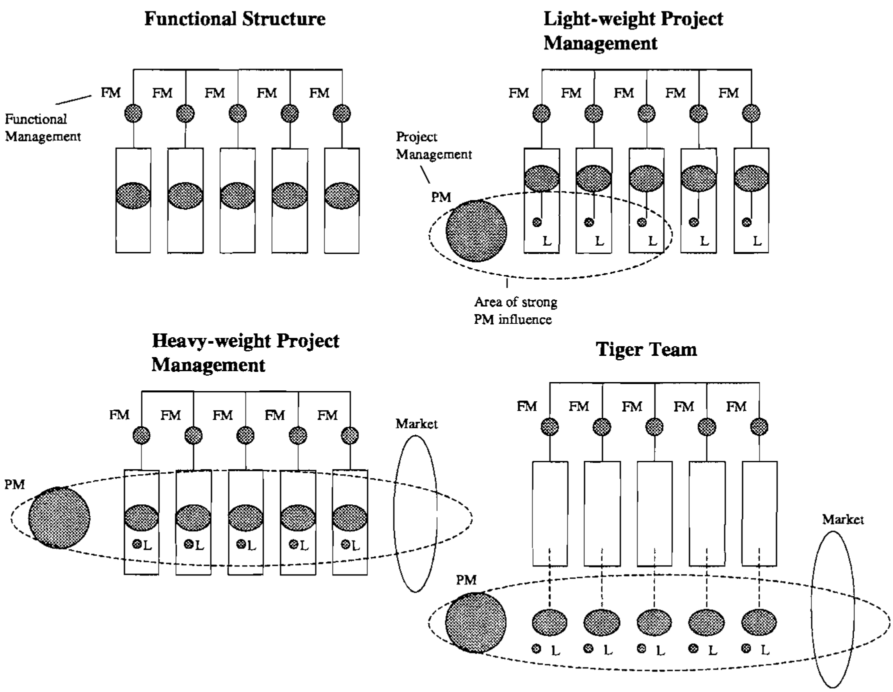


Figure 2.8. Four types of dominant project organization structures

Functional Team Structure refers to a situation in which the engineers are grouped together on the basis of discipline and are performing work on the basis of predefined specifications. The primary responsibility for the project passes sequentially over time from one group of functional specialists to another. The major strengths are that the same manager controls resources and sub-project performance; work is performed, judged, evaluated and rewarded in the same sub-organization; specialized expertise is brought to bear on the key technical issues; the functions and sub-functions gain the benefits of prior experience and become the keepers of the organization's depth of knowledge. The major weaknesses are limited total project coordination and lack of integration; individual contributions tend to be judged largely independent of the overall project success; and engineers tend to focus on developing the best component or sub-system rather than that which might be most appropriate for the total project.

Lightweight Team Structure means that those engineers assigned to the project reside physically in their functional areas, but each functional area designates a *liaison person* to represent the sub-system on a *project coordination committee*. These liaisons (representatives) work together with a *"lightweight"* project manager who has responsibility for coordinating the activities in each sub-system. The main strength (in addition to those outlined above) is that one person is designated to be a representative to a larger whole than the individual sub-systems. The main weakness is that this person is *"lightweight"*. Hence, power still predominantly resides with each respective sub-system.

Heavyweight Team Structure indicates that the project manager has direct access to and responsibility for the work of all those involved. Often, the core group is dedicated and physically co-located, but engineers are only temporarily assigned to the project. The major strengths are that more than one person is designated to participate in a larger entity; and the project manager has influence over critical decisions. The major weaknesses are that single engineers perceive span-of-control and responsibility between project management and line management as unclear; and the project can easily consume added resources at the expense of other activities.

Autonomous Team Structure – or *Tiger Teams* – refer to a situation where individuals from different functional areas are exclusively assigned and co-located to the project team, and the project manager becomes the sole evaluator of the contributions made by individual team members. Typically such teams are allowed to create their own working practices suitable for their overall mission. The fundamental strength is focus and cross-functional integration, while the major weakness is that little or nothing is *"given"* and teams tend to create unique solutions and expand their mission at will.

Common to all of the perspectives is the *"balancing act"* between using and making the most of the knowledge that is already available and developing entirely new knowledge which can eventually be utilized. This challenge has been called the balance between *mainstream and newstream* by Moss Kanter (1989), *exploitation and exploration* by March (1991) and *exploitation and creation* by Hedlund&Ridderstråle (1992).

The predominant research in the *School of Management of Technology* is based upon three different basic assumptions: *full rationality, the bounded rationality of human beings* and the concept of putting in focus the new things which are created during a project – *the knowledge creation.* In the center of these discussions are the *design-build-test cycles.* A number of authors highlight models that build upon various applications of these cycles. In the literature, one finds a considerable emphasis on universally suitable solutions in sequential multi-stage models and *"steps to success"* formulas. Another frequent perspective draws from the contingency theory where *"stage-gate"* models – which reduce uncertainties through rigorous advance planning – are considered more suitable in stable environments and tend to emerge under such conditions. By contrast, an iterative approach is required in more unstable environments where the option to respond to new information is of increasing value. The leading literature points out that integration and coordination are two main problems in complex product development, and proposals for a variety of solutions are presented in the form of organizational structures, project manager roles and support systems.

Figure 2.9 summarizes central themes in effective and ineffective complex product development according to the above review of the *School of Management of Technology.*

Problematic Product Development		Outstanding Product Development	
Characteristics	**Consequences**	**Characteristics**	**Consequences**
Rationalistic approach *Poor planning, lack of proven methods and a lightweight project manager*	Rationalistic approach *Constant changes, unclear focus and difficulty in creating proper conditions*	Rationalistic approach *Clear methods used in a disciplined manner and a heavyweight project manager*	Rationalistic approach *Smooth execution*
Bounded rationality *Poorly designed information management*	Bounded rationality *Considerable redundancy and dependence on individual persons' limited ability to process information*	Bounded rationality *Effective and well-planned information management*	Bounded rationality *Reduced uncertainty and increased efficiency of project tasks due to limited redundancy*
Emergent rationality *Rigid, formal structures which don't match the project's logic*	Emergent rationality *Energy wasted on internal processes rather than on advancement of project tasks*	Emergent rationality *Flexible and informal structures in which many are responsible for more than their own subsystem*	Emergent rationality *Good conditions for handling mutual dependencies and taking advantage of emerging possibilities*

Figure 2.9. Central themes in effective and ineffective complex product development according to the school of Management of Technology

The accumulated knowledge about managing complex product development may be summarized according to the following schools of thought: (1) the *Project Management* school's more practical contribution in the form of planning techniques; (2) the *Organization Theory* school's more diversified approach along a spectrum ranging from the bureaucratic to the organic; and (3) the *Management of Technology* school's call for rational, effective processes, well-designed information management and a future-growth orientation toward complex product development as a knowledge-creating and dynamic process. These various schools of thought emphasize different aspects of the phenomena that impact the system of *"managing complex product development"*. The following table (Figure 2.10) presents a summary of the key concepts and significant aspects relevant to the subsequent discussions in this thesis and to managing complex product development.

	IMPORTANT FOCUS	DOMINANT REFERENCES
PROJECT MANAGEMENT	*Project planning techniques*	Harrisson (1992), Spinner (1992), Archibald (1992)
	Temporary or short-term perspective	Sahlin-Andersson (1989), Archibald (1992), Lundin&Söderholm (1994), Packendorf (1994), Engwall (1995)
	Project phases and their characteristics	Archibald (1976), Selin (1980), Cleland&King (1983), Meridith&Mantel (1995)
ORGANIZATIONAL THEORY	*Complexity and uncertainty*	Lawrence&Lorsch (1967)
	Integration and specialization	Lawrence&Lorsch (1967)
	Efficiency and effectiveness of organizational structures	Simon (1945), Taylor (1947)
	Contingencies	Burns&Stalker (1961), Woodward (1965), Thompson (1967), Mintzberg (1979)
	Cognitive maps	Tolman (1948), Weick (1979), Sims&Goia (1986), Argyris&Schön (1974)
MANAGEMENT OF TECHNOLOGY	*Prescriptive project management tools and practices*	Hice *et al* 1974, Olsen (1976), Cooper (1979), Womack *et al.* (1990), Wheelwright&Clark (1992), Clark&Fujimoto (1995)
	Balance between exploration and exploitation	Moss Kanter (1989), March (1991), Leonard-Barton (1992, 1995), Hedlund&Ridderstråle (1992)
	Coordination and communication	Galbraith (1973), Allen (1977), Katz and Allen (1982)
	Knowledge creation	Nonaka (1990, 1994), Hedlund (1994), Ridderstråle (1996), Lundqvist (1996), Iansiti (1998)

Figure 2.10. Table of dominant theories in managing complex product development

The three schools – *Project Management, Organizational Theory* and *Management of Technology* – do present a number of unified perspectives based on many common fundamental assumptions on the development process as it pertains to managing complex product development. During the last decade, product development of many technically sophisticated durable goods has undergone dramatic changes. The day-to-day task of developing a complex product means coping with an almost endless amount of technical and assorted other interdependencies that often require mutual adjustment across many types of technical and organizational boundaries. The complexity increases even more in industries where the pace of technical development necessitates a greater degree of flexibility in order to add new technical solutions or functions during the development process. New interdependencies constantly arise that must be dealt with dynamically.

The predominant models for managing product development are becoming inadequate in many complex and dynamic development environments. A fundamental assumption in most prevailing theories is that it is possible – and even necessary – to plan extensively in advance the execution of a development process. Planning should precede action, while the activity should, in turn, follow the plan. For example, the development of knowledge concerning project management – which has been widely circulated within actual development environments – has a focus on the planning process. A project's maneuverability is assumed to be synonymous with the project manager's prospects of knowing in great detail what is to be accomplished in the project. If the project does not work, it is then assumed that the planning process was insufficient – and that a more finely tuned planning process would improve the result. The responsibilities and expectations of a project manager in this structure clearly follows the Fayolian principles (Fayol 1949) of *"command and control"*.

On a more theoretical basis, development work has long been considered an information-processing activity. With a fundamental assumption concerning human beings' limited ability to process information – i.e. *"bounded rationality"* – development work has come to be described as an information system (i.e. a computer) where individuals are the "processors" which manipulate digitizable information in accordance with various algorithms. The logical implication of such a perspective is to create an organizational architecture that minimizes redundancy in the processing of information. Focuses have been on how information outside of the organization can be brought into the system and how static structures and formal leadership roles can be adapted and revised in order to bring about a flexible information process.

However, during the past decade, the computer analogy has been criticized as insufficient – and for its role in all too often steering research and practice toward static and top-down structural thought patterns. Organizational concepts such as *teams* and *heavyweight product managers* can be seen as modern variants of this discourse. One problem with such concepts is their inability to prescribe how one should cope with highly dynamic and reciprocal interdependent work on a day-to-day basis. Any team constellation in complex environments, regardless of the degree of "cross-functionality", is likely to be inadequate in containing all interdependencies bearing on the daily workflow. A *"heavyweight"* project manager, even with extraordinary cognitive skills, will not be able to address all the emerging issues in a fairly large and complex project. Thus, it would seem that extensive planning and structures and roles imposed from the top down have great limitations.

The three schools have, however, utilized different concepts and taken different approaches in the attempt to suggest changes in terms of prerequisites and focus. Figure 2.11 presents an overview of the field *"managing complex product development"*, which shows the focus of each school or perspective and how they relate to the others. The figure is based on a spectrum of conceptual frameworks ranging from assumptions based on more stable and predictable conditions (on the left) to more dynamic and unpredictable conditions for performing complex product development (on the right).

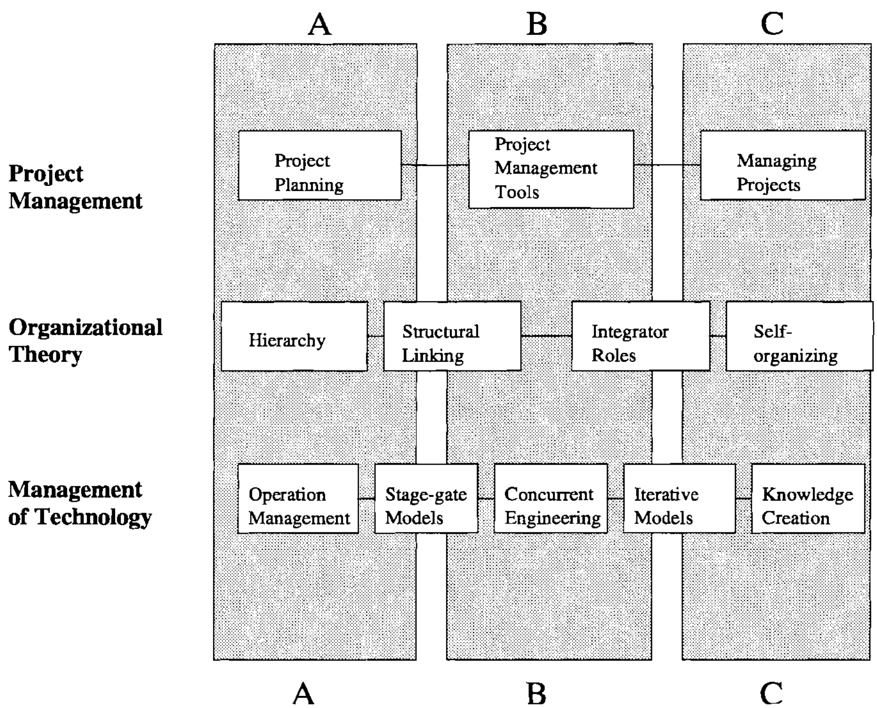


Figure 2.11. Matrix of dominant practices

The three primary schools of thought and their respective predominant perspectives are illustrated along the horizontal axis above – from the planning- and design-intensive perspective at the left to the organic/dynamic perspective on the right. By setting the three schools parallel to each other, it is possible to create vertical groupings of perspectives which cross over all scholarly boundaries: the planning- and design-intensive perspective (Group A), the organic/dynamic perspective (Group C) and the "*conditionally in-between*" perspective (Group B). This illustration does not presume to offer an elaborate analysis of the epistemology of each perspective and school of thought, but rather attempts to make a broad presentation of their various face value presuppositions as well as the differences and similarities among them.

Group A is based upon the assumption that complex product development consists of predictable processes best managed by breaking down the project goal into its separate parts. The activities in these parts then occur independently of each other. In this way, more manageable situations are created and – with the addition of good project planning – the goals are more efficiently accomplished. In this group of perspectives the notion is found that generally superior methods do exist for planning and execution and that it is possible to create optimum conditions through rigorous analysis prior to carrying out the activity or process.

Group B is based upon the assumption that complex product development is an information management problem, for which it is possible to design optimal conditions. Creating special roles, applying particular planning techniques attains a superior level of project efficiency or deliberately reducing the handling of information deemed necessary.

Group C is based upon the assumption that the emerging components in complex product development are so significant that the concept of rigorous prior planning should be abandoned. Instead, the conditions should be created to permit real-time management of situations that surface unexpectedly – solving problems and taking advantage of possibilities.

Wigblad (1997) develops a *stipulation model* that is used to categorize research approaches by analyzing the assumptions behind connections among various phenomena being studied. This stipulation model differentiates between the conceptual frameworks based upon *deterministic* causal relationships on the one side, and *voluntary* causal relationships on the other. It also addresses the differences between having a focus on understanding *wholenesses* versus explaining *connections and relationships*. In addition, this model distinguishes between the level of complexity in the causal relationships and the systemic presuppositions in the conceptual frameworks. Figure 2.12 illustrates the three groups described above (A, B and C) as they are placed within the context of Wigblad's stipulation model.

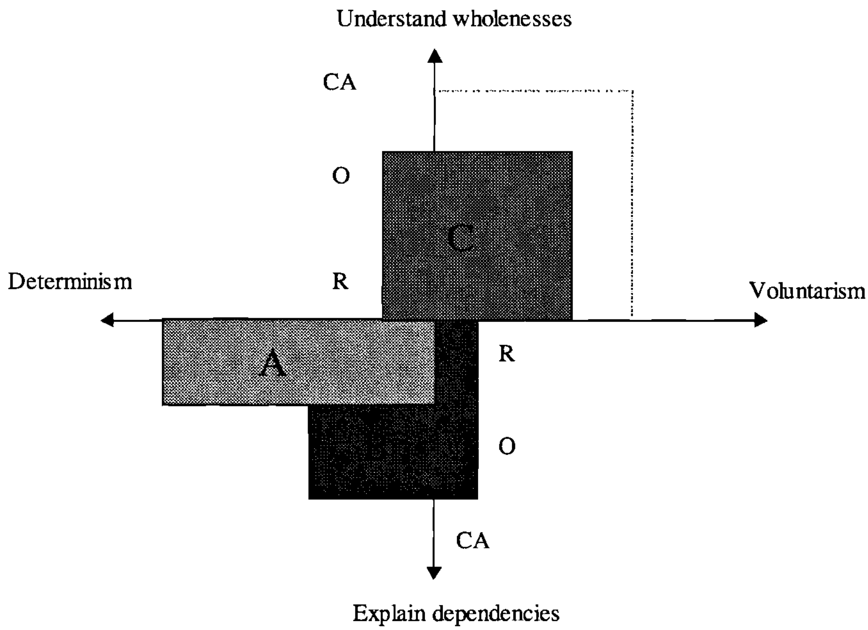


Figure 2.12. Basic assumptions of the different groups of perspective according to Wigblad's Stipulation Model (1997, pp. 128-132). (R = Rationalistic, O = Organic, CA = Complex Adaptive)

Group A consists of a conceptual framework based upon simple (rationalistic) systemic presuppositions, containing assumptions about strong to moderately deterministic causal relationships. The fundamental belief is that a certain structure will result in a person behaving in a certain way. The focus is on explaining specific relationships. It follows that the application of a particular organizational principle will produce a corollary effect in the organization.

The conceptual framework of Group B is based on both simple (rationalistic) and organic presuppositions, having elements of the deterministic and, to some extent, the voluntary relationship. While it is assumed that a specific structure will cause people to act in a specific manner, it also holds that an individual can behave in a way that is determined outside the prevailing structure. The focus is, as in Group A, to explain a specific relationship. Thus it follows that the application of a particular organizational principle will produce a corollary effect in the organization.

Group C also consists of a conceptual framework based upon both some examples of simple (rationalistic) presuppositions and mostly organic presuppositions, but contains assumptions on moderate to strong voluntary relationships. Individuals' actions are primarily derived from their own motivation. The focus is to engage many actors in understanding wholenesses, the *"big picture"*.

Corresponding to the different conceptual frameworks held by the participants in a process, there would be different assumptions and conditions for performing complex product development. Group A will be known as a *framework based on planning*, Group B as *a framework based on information management* and Group C as *a framework based on organic organization.* These vertical groups of conceptual frameworks will be used in further discussions later in this dissertation.

Some Examples of How It Is Actually Being Done

Despite the recognized importance of performing effective product development and the known impact of different organizing strategies, only a modest amount of a manager's energy is normally spent on deciding how best to organize complex product development and directing its execution. This section aims to present some frequently cited examples of performing complex product development in the automotive and software industries – often considered as leading in the development of work practices.

> *"As a means of managing complexity, firms divide projects into manageable parts. At the vehicle level, firms divide up the work among in-house engineering groups, engineering contractors, and suppliers. In the in-house groups, product engineering is organized by process step and component. Design and test are commonly split; body, chassis, and power train are usually organized into different*

departments. Actual departmentalization reflects relative emphasis on two principles: design-test specialization or merging of design and test into component departments (...) Further specialization occurs at working level. Individual engineers are typically assigned to an engineering step or component." [Clark and Fujimoto 1991]

The example from the auto industry clearly shows the deductive approach based on breakdown and minimized dependencies. Most textbooks, manuals and project management models describing how to manage complex product development apply (with a seemingly small amount of forethought) a sequential, deductive approach to the execution of projects. This is even more noteworthy in view of the commonly acknowledged difficulties in trying to carefully plan complex product development prior to execution or in early phases. There are many iterations and uncertainties about means and ends, and large bodies of evidence supporting the fact that a linear or predictable process does not characterize projects. Analysis supports that actions undertaken by project members, leaders and groups of participants – rather than concentrating on predefined plans – are often haphazard and messy. It is the *iterative* action between project members, which often determines its outcome rather than project planning tools review meetings and formal documentation. Most *"textbook recommendations"* seem to reflect yesterday's competitive atmosphere, today typically found in the military-industrial complex where the tasks were well-defined, the development was directly or indirectly paid for, and a specific production volume and pricing structure were guaranteed if the development process was successful. In those situations, there was a clear picture of the intended goal and anticipated performance level to be achieved (see for example Engwall 1995 or Norrgren *et al.* 1997). The computer software industry and extensive descriptions of the leading actors' way of working have offered a somewhat new depiction of how complex product development is managed.

"We have labeled Microsoft's style of product development the synch-and-stabilize approach. The essence is simple: continually synchronize

what people are doing as individuals and as members of different teams, and periodically stabilize the product in increments – in other words, as the project proceeds, rather than once at the end. When team members build components that are interdependent but difficult to define accurately in the early stages of the development cycle, the team must find a way to structure and coordinate what the individual members do while allowing them enough flexibility to change the product's details in stages. This is useful to do as developers test the product with customers and refine their designs during the development process.

In software and other industries there are now many companies that use prototyping as well as multiple cycles of concurrent design, build and test activities. In the software research community, authors have talked about "iterative enhancement", a "spiral model" for project management and "concurrent development" since the mid-1970s. Many have been slow to adopt these recommendations formally, such as for U.S. government contracting. Nonetheless, the basic idea is that user needs for many types of software are so difficult to understand that it is nearly impossible or unwise to try to design the system completely in advance, especially as hardware improvements and customer desires are constantly and quickly evolving. Instead projects should "iterate" as well as concurrently manage as many design, build and testing activities as possible while they move forward to complete a product. If possible, team members should also involve customers intimately in the development process.

(...) We believe, however, that Microsoft is distinctive in the degree to which it has introduced a structured concurrent and incremental approach to software product development that works for small as well as large-scale products" [Cusumano&Selby 1995, pp. 14-15]

However, these examples are often limited to applications in the computer software industry connected to a number of important contingencies such as the age and interest of employees, age of and ownership in the company, demands and type of demands from customers and the products inherent characteristics.

Analysis of Dominant Practices, Earlier Research and their Origin

The above-described schools of thought surrounding the managing and organizing of complex product development have different origins and have emerged within a diverse set of contexts. This section will analyze each school and set of perspective in its origins and historical development.

Danielsson (1983) and March&Olsen (1986) state that various problems and solutions can co-exist over a long period of time as separate and distinct phenomena. But when a connection between them is successfully made, a body of research material is created – containing hypotheses and proofs – which gains a foothold and becomes a theory or a school of thought. In the literature one finds descriptions of solutions which have existed as part of companies' common practice in the managing and organizing of complex product development. Danielsson (1983) states that, in order to understand the origin of a refined concept or theory, it is necessary to analyze: (1) the perceived problems; (2) the perceived solutions available at the time of origin; (3) the participants involved in the situation; and (4) the point in time at which the connection was made between the problems and solutions. Danielsson (1983) also states that for an idea to gain a foothold, it must have such a breakthrough that its validity is perceived to be entirely obvious, at least in the eyes of a key group of participants.

What follows is an overview of the origins and evolution of the various schools of thought. Though not purported to be complete in every facet, the goal is to lay out a sufficiently detailed history and review in order to create a basis for the continuing discussion framed by this dissertation's statement of purpose: *"How to understand and explain the process of managing complex product development"*.

The *Project Management* school was, according to Hatchuel&Weil (1999), born in the field of architecture and civil engineering and had, according to Engwall (1995), its breakthrough in the American defense industry during the 1950s and has consistently grown as a unique area of concentration in the area of administration and business management. The fast growth of interest in and dispersion of the school has been a direct effect of the increasing necessity to develop better products while reducing costs and delays. The *Manhattan Project*, begun in 1942 with the purpose of developing the atom bomb, had 120,000 employees and participants at its peak. Its success can be viewed as a crucial step in the establishment of this school of thought. The next important stage came with the *Atlas Program* (to design and develop an intercontinental guided missile system), that in 1954 introduced parallelism in development processes and launched the *"doctrine of concurrency"*.[17]

During the past 30 years, a vast quantity of articles and books has been published within this field, a majority in the form of manuals or textbooks. The *RAND Corporation*[18] developed the first systematized principles for project management. With few exceptions, the literature presents bodies of evidence based upon the authors' own project experience. The content of these standard reference works is a combination of administrative techniques, general management discussions and practical advice and counseling (Archibald 1976, Taylor&Watling 1979, Selin 1980, Cleland&King 1983, Andersen *et al.* 1989 and Meridith&Mantel 1995). The organization examined is no longer perceived as a bureaucracy characterized by long-term stability, but rather as a temporary and flexible

---

[17] Bernard A. Schriever, manager of the Atlas Program introduced, according to Engwall (1995), this doctrine to reduce lead-time and thereby increase novelty in the newly developed missiles. The sequential order of decisions was replaced by an ambition to plan and develop the whole weapon system at once. The Atlas Program accomplished its tasks in five years in comparison to the planned six to eight years.

[18] *RAND [Research And Development] Corporation* was, according to Engwall (1995), founded 1946 outside Los Angeles as a joint research and development group between the airforce and the airplane producer Douglas, with both multidisciplinary ambitions and a broad network in both academic and military organizations.

coalition of key experts specifically brought together for the project. Two international professional associations – the *International Project Management Association* (*IPMA*)[19] and the *Project Management Institute* (*PMI*)[20] – coordinate networks, conduct training, seminars and publishing in an active pursuit of increased professionalism in this area of knowledge. Those who initiate and carry out the knowledge development efforts and dissemination of ideas are primarily project managers and their advisors, who are active in real-world situations.

The most prominent examples of the literature is, according to Engwall (1995), comprised of sturdy, tried-and-true methods (e.g. those described in manuals and normative textbooks) offering practical help to project managers. This field of knowledge does not feature any one basic concept or a limited number of consistent hypotheses built up around a set of specific assumptions. Hence, it is easy for critics to point out inconsistencies in advice based upon *"rules of thumb"* and then-current phraseology (Sahlin-Andersson 1989 and Packendorff 1993). The conceptual apparatus of the day is, according to Engwall (1995), clearly depicted as quite abstract and generalized. Examples of this include: the innumerable attempts made to launch a universally applicable project management or planning model; the suggestions (as described earlier) of roughly dividing a *"typical"* project into phases. And also, all the efforts to crystallize and systematize general and abstract principles with the goal of successfully carrying through a project to completion, e.g. *PROPS*[21].

---

[19] *IPMA* has according to Engwall (1995) its headquarters in Zurich and organizes approximately 10 000 (primarily European) members through more than 20 national member associations. *Swedish Project Forum* is one with over 600 members.

[20] *PMI* has according to Engwall (1995) its headquarters in Drexel Hill, Pennsylvania, and organizes approximately 9 000 (primarily North American and Canadian) members.

[21] *PROPS [the PROject Planning System]* is a method for planning, establishing, managing and finishing projects. The method divides projects into five distinct phases and describes the activities to be performed in each phase. The method clearly specifies who is responsible for what and how documentation must be performed. Demands and reminders are described in detail in a rigorous manual for project managers, line managers and project participants.

The literature features many types of checklists and is most often authored by engineers with personal experience in project work. Almost all of the material follows a similar outline, showing how a project was done – or, more accurately, how it *should* be done. The *project* is a task and the *project management* is a systematic and rational methodology. The *task assignment* is the key element under consideration, and the time frame is simply that which is required until the project task is accomplished. The *project manager* has the key position and role. The project assignment and work tasks become the centerpoint from which the rest of the world is observed. This dominant line of thought is based on the same assumption found in operations analysis; i.e. that reality can be controlled and optimized.

Much of the earlier research surrounding *project management* – which forms the foundation for many established models used today – is based upon studies done in the construction and defense industries (examples are found in Archibald 1976, Hammarlund 1977, Selin 1980, Cleland&King 1983 and Meridith&Mantel 1995). These environments differ markedly in a number of ways from the software-intensive system products for commercial customers that today comprise a large proportion of the complex product development efforts in the telecommunications field. Development in the defense industry often focuses on the primary goal of creating products capable of achieving the best possible performance, without taking into consideration the *"commercial"* aspects of lead-time requirements or the project's total costs. The development expenses are most often paid in full, and minimum orders frequently wait in the event that the development process is successful. In the case of the construction industry, a project is almost always focused on implementation of an already drawn and approved plan, where a significant portion of the assumptions are stable from the beginning. So it can be seen that the existing models and theories in the *Project Management* school are, to a great extent, based upon something which might be referred to as *"yesterday's prevailing business assumptions"*.

Even when narrowing down the study of project work to exclusively encompass complex product development, there seems to be a preoccupation with one or two aspects. Hence, either investigating the manageability of projects by analyzing the impact of specific methods or tools (e.g. *concurrent engineering, risk analysis* etc.) or exploring how best to use planning methods to control project activities. Also found in the most authoritative *project management* literature is the clear and all-pervasive attempt to eliminate uncertainties through extensive planning rather than to build in the capability for handling unexpected situations when they arise.

The *Organizational Theory* school's original application of principles in complex product development may, according to Blomberg (1995), be traced back to Comte's work concerning *orderliness* and *development* (Comte [1844] 1991; in Blomberg 1995, p. 23). Comte introduced (according to Blomberg 1995) a perspective of development as *a change with a positive connotation*, i.e. with a direction toward the better. In addition, this perspective is linear – step by step, the evolution toward improvement rolls on without detours or dead-ends.

> *"Through knowledge, planning and management, the changes will be brought about. " [Blomberg 1995, pp. 23-24]*

According to Comte's perspective, stability, orderliness and development fuse together in a harmonious evolutionary process. Evolutionism's breakthrough can be explained by the contemporary successes of scientific efforts. Durkheim ([1893] 1969) can, according to Blomberg (1995), be considered as another early contributor, who contended that increased specialization provides a better social order and that all individuals could find their ideal function in the social structure with the help of sociological expertise.

> *"The individual represents the variable or changeable and, if ignorance prevails, the chaotic and anomalous. The structure, the collective consciousness, represents stability, orderliness and harmony." [Durkheim [1895] 1991; in Blomberg 1995, p. 24]*

At the beginning of the 1900s, new thoughts were introduced concerning how efficiency could best be achieved in organizations. A group of researchers and practitioners presented a set of concepts that have come to be known as the bureaucracy school. An early contributor was Weber ([1922] 1947), who stated that the formal, legal bureaucracy is the technically most effective organizational form since it prevents individuals from subjectively acting either rationally or irrationally. The bureaucracy controlled, standardized and made the individuals' actions predictable. It was the most effective organizational form in terms of the consequence of human beings' subjectivity – which was indirectly assumed to be inefficiency. This development was surely a "natural fit" in the middle of industrialism's increasing specialization and in light of the growing concentration of large populations that offered the possibilities for manning the fast-expanding businesses.

Noteworthy research at Western Electric during the 1930s (described earlier in this chapter) showed the effect of sociopsychological phenomena on productivity, which gave impetus to the rise of alternative perspectives that came to be known as *Human Relations (HR)* and *Organizational Development (OD)*. Much of the research continued to deal with principles for designing organizational structures. As a complement to these studies, the cognitive organizational theory also took root and grew according to Blomberg (1995). Tolman introduced the concept of cognitive maps in 1948 as a way of describing a person's hypothetical thought structure. The *Cognitive Organizational Theory*, *Bureaucracy School* and *HR & OD school* all focused upon the articulation and design of general models, while Burns&Stalker (1961) launched the *Contingency Theory* as a counterbalance to the earlier ready-made solutions which offered one or more universally applicable principles for effective organization. Today these schools of thought appear to be quite parallel and share the same perspectives with regard to managing complex product development.

The *Management of Technology* school grew in direct proportion to the increasing importance of questions surrounding the management of technology in the business world. The risks and volume of investments in technology (R&D) made by companies increased substantially during the 1940s and 1950s. Rubenstein (1957) reported, according to Sjölander (1985), that 4,834 R&D laboratories were operating in 4,086 different companies in 1956, compared to none in 1943. As a consequence of this dramatic increase in costs, it became essential to obtain the greatest possible return on the investments. Principles, mechanisms and structures for managing complex product development became vital issues. Researchers – primarily at American technological universities – began to investigate various dimensions of R&D effectiveness and R&D efficiency. Early examples of such research on organizational structures and performance include March&Simon (1958), Burns&Stalker (1961), Lawrence&Lorsch (1967) and Allen&Cohen (1969). This research showed that organic structures facilitate innovativeness and an increased rate of new products, and that specially designed boundary-spanning roles – such as *technological gatekeepers* – were positively related to performance in R&D projects. Communication patterns and performance were studied by Mentzeil (1965), Allen (1970, 1977) and Edström&Galbraith (1977). This research showed that informal oral contact was the primary means for coordinating R&D and that the variety and frequency of this contact had a positive correlation with performance. Some early examples of research done on individual perceptions and performance are, according to Sjölander (1985), found in Hall (1963), Pelz&Andrews (1966), Hage&Aiken (1966, 1967, 1969) and Friedlander&Margulies (1969). They set forth the arguments that the perception of the organizational climate and participation in decisionmaking are of vital importance with regard to performance.

Organizational structures and principles used for managing complex product development in the early days seem to have been inherited from production functions with a considerable degree of formalization and centralization. Following a period during which the fast growing central R&D laboratories performed this complex product development function – and after experiencing such clear dysfunctional problems as weak market couplings, low degrees of manageability and minimal capacity for renewal – a trend of decentralization to specific business units began (Sjölander 1985).

The school of *Management of Technology* can best be summarized as descriptive, utilizing primarily normative concepts, models and methods. It also focuses on classical methods, portfolio selection methods, project appraisal methods and decisionmaking models (where most of the models are prescriptive rather than descriptive). The research into the applicability of these methods has not been given much space in proportion to the vast quantity of recorded and documented methods.

Figure 2.13 summarizes the *sedimentation process* (Danielsson 1983) of the various schools of thought by reflecting: the perceived problems; the perceived solutions available at the time; the participants involved in the situation; and the point in time at which the connection was made between the problems and solutions.

	School of Project Management	School of Organizational Theory	School of Management of Technology
The perceived problems	Increasingly common to carry out extraordinary, time-limited efforts in industrial environments, but little knowledge of how these best were carried out. Organizational models and structures based on linear perspective, but these were experienced as insufficient to explain and understand what happens.	Leading larger and more complex (knowledge-based) operations with dilemmas such as integration/specialization and stability/development.	A need to find a balance between exploration and exploitation. A need to meet the ever-greater investments and risk-taking that are made in industrial development of advanced technology. An emerging need to be able to meet set targets.
The perceived available solutions	Experience of conducting products such as the Manhattan Project and the Atlas Project from US Defense. Experience from extensive project activities in RAND Corporation and in the building industry.	The different perspectives: bureaucracy, HR and OD, institutional theory, cognitive organization theory and contingency theory.	Two schools, one assuming full rationality and one assuming man's limited rationality as well as, later on, an alternative school education based upon an assumption about knowledge-seeking.
The actors involved	Management in industrial corporations, military industries and building industries.	Researchers, experimenting practitioners, trade unions, and industrial interest associations and organizations.	Management in industry companies and management researchers primarily from technical universities.
Time of connecting problem and solution	From the mid-1960s onward.	Bureaucracy school between 1900 and 1920s, HR and OD schools during 30s and 40s, cognitive theory in 1970s and neo-institutional theory in 1970s.	1960s-1970s, but alternative solutions are still sought for the difficulty of meeting set targets.

Figure 2.13. The different schools' process of sedimentation according to the framework presented by Danielsson (1983)

To sum up, complex product development is predominantly organized according to *the linear planning models* of the *Project Management* school, according to *the bureaucratic models* of the school of *Organizational Theory* and according to *rationalistic* and *bounded rationality* approaches in the school of *Management of Technology* – the vertical group of perspectives called A in Figure 2.12. This design perspective has traditionally made projects become sequential and fragmented into functional areas which are supposed to be managed through extensive planning models, standardized project methodology, work breakdown structures and formal organizational structures. During the last few decades, as described above, new approaches have been developed, highlighting the need for functional integration, parallelization of activities and lengthened windows of opportunity. The *dominant practices* still reflect a basic, linear logic, focusing on reducing uncertainties, minimizing deviations and aiming for planability. Hitherto the notions of *iterations* (Lindell 1988, Eppinger *et al.* 1994 and Thomke 1998), *deliberations* (Pava 1983), intense need of *coordination* (Allen 1970, 1977 and Galbraith&Edström 1979) and *dynamic project models* (Wheelwright&Clark 1992) have been acknowledged in the dominant linear logic. Hence, is regarded as inevitable error variance or as being caused by the bounded rationality of man. This thesis is based on the assumption that projects performing complex product development are grounded in a conception of a whole – *an Artifact* (Granath 1991) – in terms of desired end result. This means that complex product development is initiated when an (often incomplete) vision or goal is established by one or a set of internal or external actors who wish to achieve something that differs from the existing base of knowledge. The project is initiated to create knowledge of how this conception of the whole should be materialized. The traditionally labeled conversion process – from ideas to products – is thus about diverging in terms of knowledge creation rather than through reducing uncertainties in a linear, converging information process.

The general argument for adopting a linear logic is risk reduction. A *linear logic* (see Gustavsen *et al.* 1991) is based on the assumption that the higher the risks are, the more detailed procedures are necessary. Linear logic is based on assumptions of uniformity and the imperative need for supreme, universal master plans. When outcomes differ from the planned outcome, such differences are explained by weaknesses in existing planning and control procedures. An *interactive logic*, on the other hand, starts from the assumption that risk cannot, will and shall not be reduced by careful planning beforehand. The general strategy highlights the necessity of coping with complexity and high risks in all subsequent phases of a project. In planning-oriented perspectives, the full effects of projects are believed to be foreseeable and quantifiable and, through choice and design of *"profitable"* projects, the risks of new projects can be reduced to reasonable levels, but a project plan always runs the risk of differing from the real outcome. An interactive logic is based on intense exchange of information on unexpected and unsolved problems of relevance for parallel activities, as well as on arenas and routines for mutual adjustment of action, and is focused on creating a capacity to cope with changes rather than trying to avoid them.

Several researchers have criticized pure planning models and planning methods (Marshall&Meckling 1962, Rehnman 1969, Pearson 1983, Segelod 1986, Engwall 1995 and Blomberg 1998) – comments directed mainly toward the application of these methods and less toward the actor's conceptual framework and approach. The dominant criticism, according to Lindell (1988), can be summarized thusly: the company managers have not seen the planning systems as an integrated part of the total company management, and the management lacked sympathy for the different dimensions of the planning. This means that the research problem as such must be reconsidered. The imperative question regarding how best to master the process of managing complex product development that lies ahead is not primarily about how best to design optimal configurations, or whether steady-state models or more dynamic ones are most appropriate. It is rather the question: *which frames of reference make the project meet set targets?*

Important Limitations of the Dominant Practices

The insufficient performance in complex product development of today in general, and in telecommunications specifically, can be explained by different ways of reasoning. Three possible explanations will be discussed below. First is *the nature of knowledge work and specific characteristics of work performed in complex product development* in relation to dominant theories and practices on how to manage complex product development. Second is *the issue of learning and performance in knowledge work and complex product development* in relation to dominant theories and practices on how to manage complex product development. And third are *the changes in competitive conditions for managing complex product development in the telecommunications industry* in relation to assumptions on competitive conditions in dominant theories and practices.

The Nature of Knowledge Work

> *"Knowledge is the collection of facts, models, concepts, ideas and intuitions that shape our decisions (...) Knowledge work is any activity that helps remove uncertainty from a relevant decision or course of activity." [Purser&Pasmore 1992]*

An ever-larger part of the value-added work in firms is designated *knowledge work*, and consequently the management of knowledge work has grown into an important issue in management agendas. Knowledge work, in relation to *routine* or *non-knowledge work*, is often considered to exhibit some specific characteristics. These, according to Purser and Pasmore's (1992) and Shani and Stebbins' (1995) integrative work, can be summarized as: (1) *unpredictability*, (2) *many interdependencies and an intense need for coordination*, (3) *decisions based on incomplete and subjective data*, (4) *the difficulty of managing knowledge workers*, and (5) *the tightrope walk between resource specialization and resource integration*.

Knowledge work is *unpredictable* owing to a high number of exceptions and unexpected events. Steps for performing tasks are partially undefined at their outset; variances are unique and nonrepetitive, and are hidden and endogenous to the system. Steps for developing knowledge are nonsequential and nonrepetitive. Knowledge-based tasks are associated with considerable degrees of freedom in their execution. Long term horizons and high uncertainty make forecasting difficult.

Knowledge work is *highly interdependent* and has an intense need for coordination. The work involves reciprocal interdependencies with pooled and reiterative interactions among the knowledge workers. Project completion requires many interlocking tasks and multiple conversion processes.

Decisions in knowledge work are often based on incomplete and subjective data. Productivity is difficult to measure. Effectiveness is the main success criterion. Tasks lack objective computational procedures for dealing with exceptions and novel events. Knowledge and information relevant to the execution of the task may be difficult to elicit or acquire and are often not standardized. The lack of measurement criteria makes standardized control impossible; hence task discretion is higher than in non-routine work. Decisionmaking is often politicized and intuitive rather than logic based. The social systems have a high degree of influence on the application and utilization of knowledge.

Knowledge workers are *hard to manage* owing to their high self-direction and demand for special treatment. They define success differently, valuing personal self-expression, autonomy and freedom of choice. They are conscious of the value of their expertise and are resistant to the *"command and control"* model of management. They have a stronger need for operational autonomy than strategic autonomy. They resent and discredit performance evaluations and prefer to be assessed on the *"process integrity"* of their work as defined by their professional standards; they tend to be less identified with organizational goals. They derive more satisfaction from psychological and intrinsic rewards than financial and extrinsic rewards. The most important source of motivation is the nature of the work itself.

Managing knowledge work involves *the tightrope walk between resource specialization and resource integration* because task specialization increases with complexity, but specialization can be detrimental to organizational effectiveness when multidisciplinary cooperation is required. More contact outside the specialty leads to better conditions for creativity but poorer conditions for efficiency.

The Specific Characteristics of Complex Product Development Processes

The specific characteristics of complex product development processes are both the *nature of work* and the *way work is organized.* Complex product development exhibits many of the characteristics of knowledge work sketched out above according to Purser and Pasmore (1992) and Shani and Stebbins (1995), but also shows some other specific characteristics. The purpose of this section is to elaborate further on the specific characteristics of complex product development and to operationalize the schematic descriptions above.

As regards *unpredictability*, complex product development copes not only with allocation of existing resources and choices between existing solutions, but also with the development of new principles for allocation. The development of technical solutions is simultaneously a development of its context. A search process aiming at finding and developing both new principles and solutions is of a non-repetitive character, and this makes the process less standardizable and predictable. Traditional analysis and measurement tools used for evaluations and driving improvements have often proved to be less applicable and, therefore, to have less impact in this type of context. Tools developed to increase efficiency in product development processes, such as *Quality Function Deployment, Design for Manufacturing, Concurrent Engineering* and so on, have not met expectations in their applications in the more complex product development processes. The tools are often based on pre-analysis and early decisions, which are difficult in non-repetitive processes where critical activities and dependencies are often impossible to pinpoint beforehand since knowledge is created when changing the conditions for the processes, which impact possibilities for prediction and proactive planning. Technical decisionmaking is first and foremost compromise decisionmaking, which makes it difficult to identify beforehand. Even if it is known that deviations from plans will come, it is not known *when, what type they will be* and *what consequences* they will have. Complex product development is increasingly characterized by a need to be able to handle *latent* (unknown in advance) *functional* and *dysfunctional* courses of events. It is no longer enough to create a capacity for handling *manifest* (known in advance) functional and dysfunctional courses of events. Competitiveness rather emerge from building organizational systems that to an ever greater extent have a capacity to handle both possibilities and problems that cannot be foreseen or planned for in advance and a capacity for continuous replanning, reconfiguring and reorganizing in product development processes.

As regards *many interdependencies and an intense need for coordination*, work in complex product development is highly reciprocal interdependent (Lundqvist 1996) and has an intense need for coordination (Nonaka 1990, Lundqvist 1996 and Adler&Docherty 1998). Interdependence is caused by both technical and activity-based interfaces that may affect each other and change over time, as well as by difficulties in predicting effects of integration. The intense need for coordination is often caused both by dispersed resources and by the fact that important functionality is frequently created in the boundaries between subsystems.

As regards *decisions based on incomplete and subjective data*, performance in complex product development is hard to measure and evaluate in real time. How shall an individual development engineer, a group or a sub-project be able to judge the value of effort before it has been integrated into a complete system with the possibility of measuring performance? And this measurement gives, at best, indications of the technical performance. A judgment of the business or market performance requires even more time, and the return to a performed activity comes only much later. As an example, profitability in a development organization is usually measured by comparing costs for one year with income generated from many previous years. In larger and more complex projects, different types of information come from different sources, and the information is often difficult to compare and use as a basis for priorities and decisions. What, for example, is the capacity of a central processor worth in comparison with a somewhat more reliable final product, and what does a somewhat better speech quality in the final product mean in comparison with somewhat poorer coverage? Moreover, complex product development is characterized by a different use of language. A platform means the most important sub-systems to a systems engineer, whereas to a product manager it means the proportion of recyclable components. This leads to low visibility in terms of progress and results.

As regards the view that *knowledge workers are difficult to manage*, engineers performing complex product development are usually oriented toward theoretical values, are investigative by nature, and seek environments where they can use their problem-solving abilities in a free, creative manner. They are committed to finding solutions, not to doing business. At the same time, the leverage for motivated and high-performing engineers is significant. There is a pervasive difficulty in sorting problems hierarchically owing to low transparency for management and the great organizational complexity caused by far-reaching sub-system specialization. A variety of modes of debate, language in use and schedules for setting priorities are used. Research has shown (see for example Ekvall *et al.* 1983) that four climate factors are of special importance to create an innovative climate among engineers: (1) *challenge* (meaningful activity), (2) *trust* (confiding and supporting factors), (3) *freedom* (leeway for initiative and experimenting), and (4) *diversity* (many different opinions, experiences and kinds of knowledge, as well as clashes between these). The organization of work, the culture of these settings and the attitudes of the work force are, however, not geared to cope with high volume, cost-effective processes. Rather they still reflect the professional ideals of the past, where direct contact with clients was essential and competitors were fenced off. As indicated by previous research in these types of settings, professionals – and among them, engineers – prioritize, and are motivated by, advancing functional knowledge and maintaining autonomy rather than rationalizing the process of work or adjusting to customers' needs (see for example Kylén 1999).

Regarding the *tightrope walk between resource specialization and resource integration*, complex product development must, as mentioned above, both master both sub-system performance and product integrity. The first challenge is how to get a product's parts and sub-systems designed, built and tested so that each element achieves a high level of functionality. In a car, for example, this means that the drive train, gearbox, wheel suspension, bottom-plate etc. achieve competitive standards of both performance and robustness. Hence, as earlier described, because functionality at the component level is driven by expertise, depth of understanding and knowledge, achieving it requires some degree of *specialization*. From an organizational perspective, degree of specialization determines how narrowly the firm is divided into sub-systems all the way down to the individual engineer. The second challenge facing the development organization is how to achieve product integrity. Returning to the example of the car, this means that the car must achieve the qualities of comfort, pleasant acoustics and joyful driving. These total product characteristics are achieved in boundaries between sub-systems and are dependent on resource integration.

Besides the five categories of specific nature for knowledge work described above, complex product development is characterized by (1) *the temporariness of the organization*, (2) *the dilemma of enhancing creativity and efficiency at the same time* and (3) *specific conditions for improvements, learning and performance.*

As regards *the temporariness of the organization*, a considerable part of the refinement in development work takes place in temporary organizational forms (Packendorff 1993 and Hedberg *et al.* 1994), which set other requirements for dealing with farsightedness, continuous improvements and organizational learning. A temporary organization, by definition, is responsible only for a time-limited task and organizational learning or continuous improvements connected with a long-term objective must therefore be transferred between temporary organizational forms. Further, within the same organization, there often occur a large number of serial, pooled or reciprocal dependent temporary organizations as projects. The impact of temporary organizations is a source of difficulties in long-term manageability and in transformation of knowledge and experiences between different temporary organizations.

Regarding *the dilemma of enhancing creativity and efficiency at the same time*, there is a built-in opposition in the effectivization of development work. Concepts such as process control, continuous improvements and standardization rest upon logic that is incompatible with the creative and knowledge-creating components of development work. The balance between using already available knowledge and making the most of it and, on the other hand, developing entirely new knowledge that can be used in the future is central for firms performing complex product development. This challenge has, as previously mentioned, been termed the balance between *mainstream and newstream* by Moss Kanter (1989), *exploitation and exploration* by March (1991) and *exploitation and creation* by Hedlund and Ridderstråle (1992).

As regards *specific conditions for improvements, learning and performance*, complex product development improvements made in separate parts are hard to balance into improvements for the whole complex development process. There are clear difficulties in balancing improvements made in different parts of a complex development process so that a contribution to the whole results. Hence it is hard to exchange improvements in sub-units for improvements in the whole organizational system's effectiveness. Since the dependencies between parts are both numerous and of serial, pooled and/or reciprocal character, at the same time as many of them are unknown, the *"local"* improvements may yield impairments for the whole which are not visible to *"local"* actors. Many *"local"* improvements can even drastically increase the complexity. This phenomenon will be further discussed in the next section.

In summary, complex product development is characterized by high unpredictability, many interdependencies, intense need for coordination, decision-making based on incomplete and subjective data, managing hard-to-manage people, a tightrope walk between resource specialization and resource integration, temporariness, the dilemma of enhancing effectiveness and efficiency, and specific conditions for improvements, learning and performance.

As discussed above, earlier research can be summarized into three groups of conceptual frameworks. The dominant two are based on assumptions that complex product development consists of predictable processes that are best handled by breaking down the overall project goal into its components, which are made independent of each other. In this way, manageable situations are created which, together with good project planning, make possible efficient implementation. This group includes a notion that there are generally superior methods for planning and implementation and that optimal conditions can be created through rigorous analysis before implementation. It also involves the assumption that complex product development is an information-handling problem for which optimal conditions can be designed. By creating special roles, applying special techniques for planning, or consciously reducing necessary information-handling, a superior project efficiency is attained. These are assumptions which, at first glance, seem to fit rather poorly with the specific characteristics of complex product development.

This means that dominant conceptual frameworks do not reflect the specific characteristics of complex product development and that this may be one of many reasons why complex product development seldom meets set targets. The next section will discuss the specifics of organizational learning in complex product development.

The Specifics of Organizational Learning in Complex Product Development

Despite the growing awareness of the importance of *organizational learning*, the business strategy literature has focused primarily on production-oriented learning or learning in routine systems. Within this domain, *"learning includes the increasing efficiency of labor as a result of practice and the exercise of ingenuity, skill and increased dexterity in repetitive task situations"* (McKee 1992). The theory of *organizational learning* is based on an assumption that organizations can and will adapt their behavior to new experiences (based on real or false impressions). And if a behavior is perceived as successful by the dominant actors in the organization this behavior will change relatively little over time (see for example Cyert&March 1963). It has been recognized that organizations have the ability to learn both during and through their non-routine systems, and the concept of learning as a strategy for reaching competitiveness applies equally well to knowledge work processes and their effectiveness. There is, for example, evidence that companies can learn to innovate. Some companies are consequently more successful and meet with fewer product failures than their competitors (Cooper&Kleinschmidt 1987 and McKee 1992). Researchers and practitioners have, however, done little systematic work on the process of organizational learning in these organizational settings (McKee 1992 and Docherty 1996).

Organizational learning occurs, according to the dominant literature, when individuals – with their mental models and pictures of demands and their environment – meet and detect a match or mismatch with expectations. Given that discoveries and evaluations of these are put into some form of accessible organizational memory, in the sense that information is shared, stored and used in a form convenient to all members of the organization (Cooper&Kleinschmidt 1987, McKee 1992 and Cole 1994). Different researchers in the field of learning describe hierarchies defining a spectrum of different forms of learning, both on individual, team and organizational levels (see for example Bateson 1972, Argyris 1992, Leonard-Barton 1992, Cole 1994, Nevis *et al.* 1995 and Forslin&Fredholm 1996). This hierarchy can be described as stretching from simple forms of *behavioral adaptation* in well-known contexts to more complex forms of *generative learning* in completely new contexts.

The dominant literature on product development distinguishes between three levels of organizational learning: *incremental, discontinuous* and *organizational*, each needing a different kind of support (Batesson 1972, Argyris 1978, 1992, Jones&Hendry 1992 and Kim 1993). Studies have shown that *incremental organizational learning* requires expertise focused close to operational levels and emphasize integration of functions such as R&D and marketing. Incremental organizational learning can be seen as moving along an innovation curve to increased innovation efficiency and show the same characteristics as *single-loop learning* (Argyris 1992). *Discontinuous organizational learning* has been shown to require external high-level skills and a playful, creative internal climate and works best in small cross-functional teams. Discontinuous organizational learning can be seen as moving to a higher innovation curve with increased innovation effectiveness and show the same characteristics as *double-loop learning* (Argyris 1992). *Organizational learning* involves learning how to innovate, and examples have shown that it is generated through diffusing best practices, organizational memories, dealing with failures and organizational goals. Organizational learning can be seen as increasing both efficiency and effectiveness for incremental and discontinuous organizational learning and show the same characteristics as *triple-loop learning* (Argyris 1992). At each of these levels, learning must be managed and supported; it is not automatic (McKee 1992, Kim 1993 and Cole 1994).

It appears that an emerging consensus is that organizational learning (1) involves the organization's position *vis á vis* the environment, (2) is distinct from individual learning, (3) interacts with contextual factors such as the organization strategy, structure, culture and its environment, and (4) exists in different forms. In complex product development it seems that organizations can learn but, because of a lack of repetitiveness in action and organizational routines, the learning process differs in some critical aspects. The rather weak tradition of rationalization in these work settings, as well as the sparse research on process innovations, continuous improvements and renewal of design work, warrants an interest in the applicability of the traditional concepts in use in the school of organizational learning.

Earlier research and the specific characteristics of complex product development suggest that organizational learning at best will happen when dominant actors perceive the need as imperative, when the organizational system has developed a capacity for handling different types of learning, and when the specifics are taken into account. This means that using experience from more repetitive situations without adapting it to the specific characteristics of complex product development will not lead to any learning at the organizational level.

The next section will discuss changes in competitive conditions for complex product development in the telecommunications industry.

Changes in Competitive Conditions for Complex Product Development in Telecommunications Industry

As discussed earlier, telecommunications faces new competitive conditions due to intensified international competition. Firms must master the development of larger and more complex systems and to an increasingly extent use geographically dispersed resources in performing complex product development. In these settings, competitive strengths are not sustainable; they must be continuously updated, revised and renewed in accordance with the development of playing grounds and game rules in the arena in which the firm acts. Important trajectories are the increasing focus on individual and organizational learning and on dynamic effectiveness and the pattern of innovation in the telecommunications industry.

Organizational and individual learning is a prerequisite for long-term competitiveness

Competitiveness is essential to the survival of a firm. Short-term competitiveness is often defined as created in the positive exchange between the firm and its environment. This positive exchange demands competence from both individuals and organizations. Long-term competitiveness is often defined as created by sensitivity towards identifying and managing turbulence and changes in the firm's environment and by finding and developing new solutions and ideas. Researchers and practitioners regard organizational learning, too, as a key strategic competitive variable. It has been called *"an underlying variable* *explaining performance in strategic actions"* (Normann 1985). The business press worries that *"even in its current decentralized, lean and mean version"*; the traditional organization will not have the learning skills required to compete effectively in the 1990s (McKee 1992). Organizational learning in knowledge work can, as discussed earlier, be seen as a way to increase the effectiveness of activities and processes performed in order to increase a firm's performance and competitiveness. Organizations do not only have to change; they must also perform better and better every time they change. They must learn from every experience and change they meet to be able to constantly improve their performance. Organizations' survival and competitiveness are dependent on the (full) commitment of all their members – in particular their ability to anticipate change, adapt to new circumstances and come up with new solutions and ideas regarding products and production processes. Many authors (see for example Howard 1993) maintain that learning at all levels in the organization are not just an advantage in realizing its goals. It is imperative for the organization's long-term competitiveness and success. Companies are seeking new, innovative ways to manage learning and competence in order to improve performance and competitiveness.

The organizational competence of the firm is something more than the pooled knowledge, skills and experience of its members. It also includes such factors as values, culture and structural capital, the latter concept referring to the infrastructures in the firm. Hence, organizational learning and its conditions can be related to such features as common mental models, culture, values and norms expressed in firm strategies and policies and routines constantly revised to update best practice in the organization. But also to the system's infrastructure to support the collection, storage and distribution of new knowledge and experience as well as the models and frames of reference for interpreting these and to the creation of areas and other mechanisms to facilitate the exchange of experience and dialogue between different members of the organization. These features and conditions for organizational learning can differ markedly between different companies acting in the same market in the same country. Two studies (Arvedson&Magnusson 1995) of organizational learning in consultancy companies in Sweden illustrate this. The first case is a study of organizational renewal in a Swedish management consultancy firm whose culture may be regarded as highly individualistic. An extreme interpretation would be that the firm consists of individual entrepreneurs sharing certain administrative facilities. Top management's efforts are now focused on creating structural capital by developing organizational and information system solutions to facilitate the exchange of information and experience between the consultants. A basic prerequisite for these developments has been the introduction of a new incentive and reward system giving considerable rewards to contributions to collective learning. A similar study of an international consultancy provides a very different picture. The firm culture is characterized by a deep sense of identification with the firm as a whole on the part of individual consultants. Organizational databases providing highly systematic, structured and up-to-date information on the firm's experience from different assignments are an important tool in every project. Only teams conduct assignments – not by individual consultants. This is to facilitate a dialogue between consultants with different experience and professional training in the analysis of the assignment. The "obligatory" provision of time for reflection and composition of new contributions to the experience database, as well as exchange of experiences with colleagues from other offices, are essential features of the organization. The firm is probably the one that the authors regard as having coming nearest to realizing the ideal concept of *"the learning organization"* (Werr *et al.* 1995).

To summarize, long-term competitiveness is dependent on the learning within firms, and different approaches will give different effects. In telecommunication firms today, it is of vital importance to benefit from all the knowledge that is built up in the distributed competence structure. Firms must strive for learning at the system level – between parallel projects and project generations, and across functional borders –not only at the subsystem level and within the framework of individual projects.

Ericsson has recently introduced organizational innovations as a *competence management process*, aiming at creating a continuous strategic dialogue between strategic plans and actions and the existing and desired core competencies at different levels in the global development organization, and as *global product responsibility*, aiming at creating decentralized competence centers with the responsibility for worldwide product functionality to facilitate the processes of individual and organizational learning.

Towards Dynamic Effectiveness

Our business world is caught up in a change process with radical environmental changes. New market demands such as an increased time focus and modularized and customized products and services mean that organizations must exhibit great speed and flexibility as well as close cooperation with their customers. Demands for organizational flexibility and the extent of knowledge-based work in organizations are increasing steadily. This means that employees must be motivated and highly skilled and must possess considerable social skills to establish and develop contacts and networks. As capital-intensive technology increases, so does management's focus on the effective use of time and other resources. This means that employees must increase their theoretical knowledge and problem-solving abilities as well as their initiative. The increased use of on-line, computer-based, inter-organizational systems of networking companies with their suppliers and customers means that organizations must learn to master the systems and adopt a holistic view of their customers' needs and realize the increased importance of reducing time to delivery. This means that the work of production workers will become more abstract and theoretical, at the same time that they will have to acquire new cognitive, social and even business skills. The rapid fluctuations and changes in the marketplace, and the need to show high responsiveness to the constantly evolving needs and aspirations of individual customers, cannot be met while maintaining the division of responsibilities and authority and the fragmentation of work tasks which characterized organizations in the 1960s and the 1970s. Companies whose workers must constantly refer to the management chain in order to obtain new directives to meet the latest change requests from customers will quite simply not survive. The evolution of power and responsibility in organizations to the production floor has basically been a rational acceptance of the demands placed on the system, rather than a change in values regarding the equal rights to influence.

Globalization and intensified competition quickly expose weaknesses and slack in organizations. The Norwegian economist Viktor Normann coined the concepts of *static* and *dynamic effectiveness* (see Adler&Docherty 1998), by which he highlights that the key elements in efficiency and effectiveness differ depending on the environment in which the organization is working. If management regards the environment as stable or static, attention will be highly focused on rationalization, productivity and profitability. In the automobile industry, this is often referred to as *"Fordism"*. If management regards the environment as characterized by change and turbulence, it will give high priority to competence development and the abilities to adjust, develop and innovate. The 1990s have increased demands for *dynamic effectiveness*. Effectiveness has a new meaning under these circumstances. Static effectiveness means getting a great deal done in terms of fixed targets with given resources, but dynamic effectiveness will mean getting a great deal done with dynamic targets and changing resources. In Ericsson this means that achieving dynamic effectiveness it is not enough, or not always even wanted, to meet initial set targets. On the contrary, organizations will have to build a capacity to change set targets and respond to these changes, while the resource base will change in parallel due to real-time priorities and decisions.

Complex Product Development and Dynamic Effectiveness

The development of new products has, together with learning, become one of the focal points of competitiveness in many industries in recent years, as noted by several writers (Clark&Fujimoto 1991, Leonard-Barton 1992, Utterback 1994 and Iansisti 1998). Besides the traditional factors of cost and quality, the influence of time, as discussed earlier, is of increasing importance to the success of new product introductions. The time aspect is especially important when it comes to the development time and time of delivery (Stalk 1990 and Murmann 1994). An efficient development process and adequate timing are often closely related to new product success or failure (Maidique&Zirger 1984 and Cooper 1994). Many companies are now realizing that both the number and the success of new products rely on the performance of their product development process (see for example Calantone *et al.* 1997 or Ogawa&Ketner 1997). The same companies are also realizing that the more dynamic and competitive the market, the more fundamental is successful product innovation to business success (see for example Cooper 1994).

Product development in telecommunications has been characterized during the past years by a high degree of predictability and long development cycles (Gupta&Wilemon 1994). Companies have been able to compete successfully in this stable environment with development based on linear predefined processes and stable *step-by-step* models with a high degree of top-down management. It has been possible for a few talented specialists to predict the development process and to optimize it in advance in order to give tools and techniques to the great mass of ordinary development engineers. Key competitive factors and order-winning criteria have been factors such as *product functionality*, *degree of innovativeness* and *development potential*.

As mobile network operators are learning more about their business and as the technology is maturing, competition between operators is tightening. The rapid introduction of new services will become increasingly important to staying competitive, and companies must move from delivering a few things over a long time to delivering many in little time. In a turbulent business environment, product and process forecasting are becoming impossible. Demands are being raised to shorten innovation cycles and start development without having clearly defined objectives and specifications. Furthermore, design teams must be able to make instant adjustments in coping with changing conditions and handling parallel change requests. Changes and adjustments must be made simultaneously during the ongoing innovation process. Top-down specialist-formulated step-by-step models may no longer predict all insecurities that meet development engineers during a development process, the reason for this being that there are no normal states or conditions except that of continuous change (Rosenau 1988 and Stalk 1990). Key competitive factors and order-winning criteria are factors such as *flexibility, time of delivery, development time* and *development cost.*

In short, it can be said that product innovation processes in telecommunications are moving from a more technology-driven, stable and predictable context characterized by extensive pre-studies and a do-right-from-the-beginning mentality to a more market-driven, dynamic and unpredictable context. A context characterized by undefined specifications, change requests and a high degree of external involvement. There are examples of product innovation processes that reach even further in trying to cope with unpredictability, i.e. works without any predefined goals except for basic quality and functional prerequisites. In these cases, cross-functional design teams have been established to work without process barriers or predefined goals. These preconditions is created in order to continuously be able to choose the methods or models most appropriate for every given stage and situation in the process (Ellegård *et al.* 1991, Granath 1991, Adler&Docherty 1998 and Iansiti 1998).

To cope with intensified competition and new demands in most industries, product development effectiveness in terms of developing the right thing and product development efficiency in terms of developing the right thing in the right way become even more important issues for firm survival and success. It is not only that results from product development processes, i.e. doing the right thing, have an impact on conditions for other firm activities such as production or marketing and indirect firm performance. Thus, a large share of performed development work involves mature products and merely incremental innovations through adaptations of existing concepts to specific customer needs. Development process efficiency, i.e. doing the right thing in the right way, becomes an important competitive factor and enlarges the potential for process innovation.

In summary, effectively coping with continuous changes, taking advantage of emerging possibilities and meeting emerging and set targets will probably characterize dynamic effectiveness in complex product development now and in the future.

Patterns of innovation in telecommunications in general and in LM Ericsson specifically

Product development in telecommunications is following a movement along the pattern of innovation curve as it is described by Abernathy&Utterback (1988) and Anderson&Tushman (1990) and further developed by Utterback (1994); see Figure 2.14.

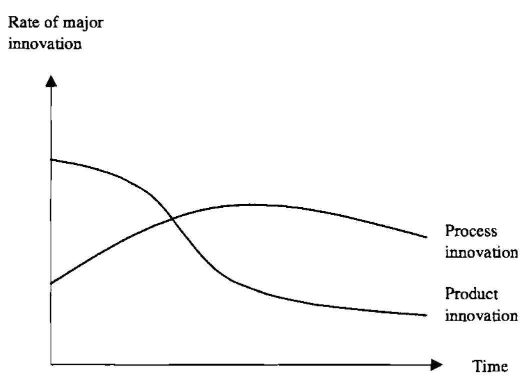


Figure 2.14. Telecommunications pattern of innovation according to the framework presented by Utterback (1994)

The particular industry under study has left the fluid stage where the main competitive instruments are substantial changes in products and where product innovation dominates. The emergence of *dominant product designs* and *standardization norms* that has taken place for some years indicates that existing telecommunication companies are in the midst of the *transitional stage* and are approaching the *specific stage* with its emphasis on decreasing costs and incremental technological innovations. However, on the other hand there is an increasing need for finding new ways to *"produce"* and thereby create competitiveness by renewing work practices. Bijker (1995) describes this stage as the process of *closure*.

> *"The bicycle case showed that the development of technical designs cannot be explained solely by referring to the intrinsic properties of artifacts. For example the high-wheeled Ordinary was at once a dangerous machine, prone to failure in the marketplace, and a well-working machine that allowed highly skilled physical exercise, resulting in a commercial success." [Bijker 1995, p. 270]*

> *"...I introduced the term closure which will be used to describe the process by which interpretative flexibility decreases, leaving the meanings attributed to the artifact less and less ambiguous; this process can also be described in terms of the artifact reaching higher levels of stabilization (...) closure results in one artifact – that is, one meaning as attributed by one social group – becoming dominant across all relevant social groups. In the case of the high-wheeled bicycle, closure resulted in the Macho Bicycle becoming obsolete and the Unisafe Bicycle becoming dominant." [Bijker 1995, pp. 270-271]*

Lundqvist (1996) summarizes the effects on companies' competitiveness when they enter *the specific stage* or a *closure*:

> *"The basis for competition is no longer just functional performance on a few critical parameters, but product variation and product integrity combined with a striving for cost efficiency" [Lundqvist 1996, p. 5]*

This means that product development effectiveness defines much of the competitive conditions and, given the trajectories sketched out above, to an increasing extent, the dynamic effectiveness. With a competitive situation where many competitors offer similar systems and/or the process of imitation is fast, work practices become an increasingly important determinant of performance, and it will be of importance to increase understanding of process innovations and renewal (Kogut&Zander 1992). What can be seen, as a development of the competitive situation in the industry, has however not been matched by a parallel development of how work is organized and rewarded and by consideration to what motivates engineers. In the case of Ericsson there has been an increasing adoption of working in projects. Hence, a shift of managerial attention towards emphasizing efficiency in the design processes (e.g. shorter lead times, modularity and reuse) and a standardization of work methods. However, there still seems to be a lack of understanding of how to implement and develop models for effective design work to fit the altered competitive situation in the everyday work of the thousands of engineers (see for example Norrgren&Schaller 1996).

Using the scheme presented by Abernathy&Utterback (1988) as a point of departure, the following aspects can be said to characterize the telecommunication business in its present stage:

Innovation: From frequent major product changes towards major process changes and incremental product changes. Even if today's systems undergo product revisions, they mainly reflect adoptions to different customers' needs rather than major technological breakthroughs.

R&D: From a rather unspecified focus towards a focus on specific features and incremental product technologies, more attention is given to process technology. The adding of complementary functions into the basic design illustrates this tendency, as do the investments made in support systems for design work and the automation of manufacturing.

Organizational control: From informal and entrepreneurial *"lack of control"* through project groups and towards structure, rules and goals. The extensive use of project work has for several years been supplemented by massive efforts to structure and formalize more than manufacturing. Training and managerial control have successively been more influenced by the application of formalized and rule-based design activities. Specific work methods, organizational models for the work processes and documentation of work have been extensively implemented.

In many other variants of the patterns-of-innovation model, it is the features of manufacturing processes that are taken as indicators of which aspects characterize the different stages in an industry. The fact that telecommunication has gradually become more design-intensive makes the use of manufacturing analysis less relevant. Rather, this thesis argues for applying a similar analysis in order to understand large parts of the design work, as the equivalent to manufacturing in the assembly dominated industries, which makes up the major source of the empirical underpinnings of Abernathy&Utterback's (1988) scheme in Figure 2.14.

A specific characteristic of the industry is a movement from mainly analogue and hardware development to mainly digital and software development. Ericsson estimated that it 1997 spended 86% of its total development resources in software and system development. Important consequences of this development are that the production interface and dynamic hardware-related properties become less important.

To summarize, playing grounds and rules of the game for complex product development have gone through a trajectory from stable, predictable environments to dynamic, unpredictable ones, with an intensified need for short-term effectiveness and profitability and a demand for meeting emerging targets. Besides changing the playing ground and rules of the game, non-repetitiveness and complexity in the process changes are conditions for learning and performance to a larger extent than what is taken into account in industry.

The Emerging Miss-matches in the Academic Literature and in Managerial Practice

The by the dominant literature described best ways of managing complex product development are closely interconnected to how leading firms actually manage complex product development. This interconnection is created because the descriptions is based on studies or stories on how leading firms do manage their complex product development. But also due to that leading firms normally want to learn how other leading firms manage their complex product development – a learning process that often take the detour over literature. Complex product development in general does not, however, as illustrated above, meet set or emerging targets despite great efforts in the dominant approach. With intensified competition and increasing demands from customers on meeting set and emerging targets, firms must find new approaches that help them to master today's business conditions.

Dominant literature and practices in the area of complex product development are based on the assumptions that (1) the total endeavor is best managed by separating the novelty (uncertainty) aspects from the complexity aspects, (2) complexity is best managed by breaking it down into its pieces, (3) novelty (uncertainty) is best managed by rigorous planning, and that (4) actual development work is best managed by allocating specialized resources to tasks to make them as independent as possible and integrate them when they are considered stable. The specific characteristics of learning and performance in complex product development are that: (1) learning is based on an integrated understanding of novelty and complexity aspects, (2) performance is most often realized in the boundaries between subsystems, (3) the most important novelty aspect in performing complex product development is unpredictability and emergence, and (4) learning and high performance both presuppose actors' cooperation. Today's business conditions for performing complex product development in the telecommunications industry are an intensified focus on time, intensified demands on continuous delivery of temporary results, and increased competition.

These fundamental assumptions in dominant literature and practices, the specifics of learning and performance in complex product development and today's business conditions in the telecommunications industry, when put together, show important anomalies. By managing complex product development as recommended in the dominant literature or by descriptions in leading firms, both learning and performance will be inhibited and meeting set or emerging targets will be difficult. These anomalies sketch out an imperative need for renewal in the way complex product development is being considered. Performance is deficient but there are no explanations for why this is so. Examples of high-performing environments exist that repeatedly meet set targets, targets that are set in harsh global competition – and there are examples of organizations that apply other perspectives, principles and actual models for organizing than those recommended, as well as approaches that depart from those depicted in theory. The emerging approaches are in their infancy, and further operationalizations and examples are of great importance to make them stable. Hence, new approaches must be developed to capture the endeavors and bridge the anomalies. New approaches including a more distinct focus on synthesis of wholes rather than analysis of single parts. New approaches, including the real-time capacity to handle emerging prerequisites and emerging novelty rather than rigorous planning techniques. New approaches including the handling of boundaries, continuous integration and common cross-functional responsibilities rather than systems based on break-down and *black-box engineering*[22].

[22] See Karlsson (1998) for a elaboration on the term.

CHAPTER THREE

PURPOSE OF THE THESIS

This chapter describes the purpose and the research questions of the thesis and their origin, given the current domain of knowledge sketched out in chapter 2.

Exploring Anomalies

As stated in the preceding chapters, complex product development projects normally do not meet set or emerging targets in terms of time, cost and functionality. Specified functionality is moved ahead into coming project generations[23] and delivery dates are often not kept, especially not on the sub-project level (see the diagram on the left in figure 3.1).

One common attempt to solve this problem at the project level is to plan for delays at sub-levels, i.e. building slack into the project. However, these attempts seem to underestimate systematically the time and effort needed for the integration of subprojects. Some authors (see for example Nonaka 1990, 1994, Hedlund 1994, Ridderstråle 1996, Lundqvist 1996 and Iansiti 1998) show early examples of new and different approaches for how to manage complex product development but do not give any operational or comprehensive explanations as to how this can be done. Therefore this thesis aims at providing an in-depth understanding of how complex product development can be managed so that products with desired functionality are delivered in time.

The method for approaching the aim of the research has been to describe and analyze two cases representing anomalies in relation to the viscous

---

[23] A project generation is one project in a series of projects referred to as a project family in this thesis. For further descriptions, see unit of analysis, p. 146ff.

circle that seems inescapably associated with the dominant practice of product development. I came across these two cases when I was carrying out research at Ericsson.

The investigated cases are examples of organizational settings that repeatedly perform complex product developments that do meet set *and* emerging targets. In some instances performance is even better than set and emerging targets. The approaches that are applied in these anomalous organizational settings are interpreted as exemplars of *emerging approaches* to managing complex product development. By describing and analyzing these exceptional cases, this thesis aims at formulating new principles or theoretical explanations of organizing for successful product development. I will refer to these principles and explanations an *"emerging paradigm"*. An important tool in carrying out the analyzes have been comparisons to principles that can be induced from the dominant approach.

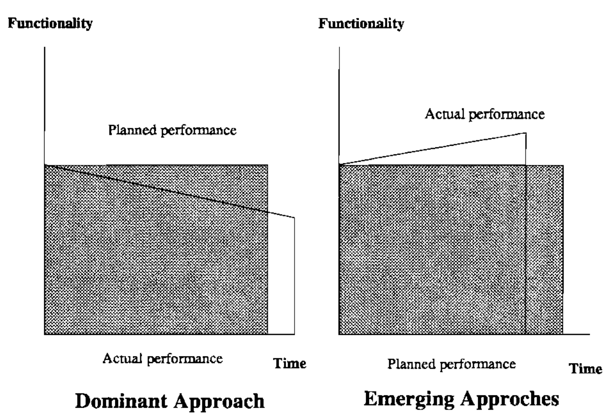


Figure 3.1. Planned and actual performance in dominant and emerging approaches

The practical application of these emerging approaches to complex product development have increased functionality and shortened development time. In one of the studied projects, functionality at delivery exceeded the one originally specified by 10 % In addition the system should be put into service two months earlier than planned, which corresponds to approximately a 15% reduction in total development time. It is to be noted that these evaluations of the performance of the case representing the emergent approach is based on a comparison with organizational settings representing industry best practice in terms of development time.

The driving force for the emerging approaches is threefold: specific non negotiable customer demands, a number of potential gains in decreasing tied up capital, and a desire to increase flexibility to incorporate technological advancements especially in later phases of the projects. Complex product development projects using these emerging approaches is described by the diagram on the right in figure 3.1.

The purpose of this thesis is to build *knowledge for action*[24]. The action aimed for is organizing complex product development. The blocks used for building knowledge are primarily perspectives, principles and models for organizing. The material for building knowledge is fetched from studying complex product development projects at Ericsson. In particular, I have attempted to discern characteristics that distinguish the emerging settings of high-performing business units from setting representing the dominant, problem-ridden approach. In all, ten different studies have contributed with material. A completely new research methodology has not been developed as part of the thesis. However, the ten projects have provided opportunities for experimenting with various and less orthodox research methods.

Research Questions

The dominant, traditional approach for managing product development has, as earlier described, primarily focused on how structures can be

[24] Argyris (1992) defines *knowledge for action* as a search for an interpretative understanding and regularities among events useful to both practitioners and for building theory. The implications for this thesis are discussed in chapter 4, pp. 157-159.

designed and processes planned in advance. Operational planning techniques and organizational principles have long been established in this approach. However, empirical evidence as well as operational and actionable concepts and models for the emerging approaches are scarce.

The main purpose of this study is to suggest an alternative theoretical foundation and a new conceptualization of managing complex product development that can guide further practical and theoretical development of the emerging approaches.

The purpose is achieved by exploring how new and successful approaches for managing complex product development have been developed and applied by organizations that are faced with extreme and challenging development tasks, and to compare these emerging approaches with the dominant approach.

The following questions can be formulated in to fulfill this purpose:

- *How did the high-performing organizational settings actually cope with the challenges and how did this differ from the dominant approach for managing complex product development at the firm and elsewhere?*
- *Why does performance in the high-performing organizational settings repeatedly differ from performance in business units applying the dominant approach?*
- *What are the enabling factors giving rise to the new approaches in the present cases and what disabling factors threaten their sustainability and dispersion?*
- *To what extent are the dominant theories insufficient for explaining repeatedly successful behavior in the organizational settings applying any of the emerging approaches?*

- *What new operational and actionable organizing concepts and models can be proposed from studies and analyses of the organizational settings applying the emerging approaches, and how can these patterns be interpreted as emerging paradigms and be made more general?*

Experimental Research Approach

Research methods designed for rendering an accurate description of the studied cases were not sufficient for fulfilling the aim of producing actionable knowledge. Therefore, the thesis work has involved experimenting with different research approaches. The settings, in which the research was carried out, were positive and open to such experimentation. The experiment was based on three major foundations: (1) using a transdisciplinary setting[25] as a vehicle for gaining a better understanding of the studied system, (2) using the ten projects on which the study is based as points from which bearings for triangulation can be taken, and (3) using practitioners from the organizational settings as fellow researchers. The transdisciplinary setting is primarily used to invoke a greater number of perspectives in the analysis of data. The multi-project base is primarily used to compare an align results obtained by using different focuses and methods. Practitioners from the organizational settings are involved in the process of research, defining research issues, research design, collecting data, making analyses and validating results. The specifics of the experiment in methodology are further described in chapters 4, 5 and 11.

[25] Transdisciplinarity is used by Gibbons *et al.* (1994) among others to describe the emerging convergence among researchers from different disciplines and the creation of a new (often temporary) discipline when performing research together. The concept and its implication for this thesis are further described in chapter 4, page 194ff.

Enlarging the Known Area

The focus of the study is to understand the differences between the dominant approach and new emerging approaches for managing complex product development used in the high-performing organizational settings. By depicting and analyzing these differences alternative approaches to the dominant one are introduced.

Hence, the purpose is to enlarge the known area to both researchers and practitioners in the field. To be able to do that, different actors' perceptions in their respective organizational settings are collected and concepts are developed to present a description corresponding to the smaller, inner half-ellipse circle in figure 3.2. The perspectives are then broadened and the approaches and their consequences are analyzed in a larger context to provide a description reflecting a deeper understanding. Thereby the known is enlarged to correspond to the larger, outer half-ellipse in figure 3.2. The goal is, from a systems perspective, to illustrate actors' perceptions and repeated patterns of action and to provide basis for increased understanding. Hence, an understanding of manifest functional and manifest dysfunctional attributes and also of latent functional and manifest dysfunctional attributes of both the dominant approach and the emerging approaches in the organizational settings under study.

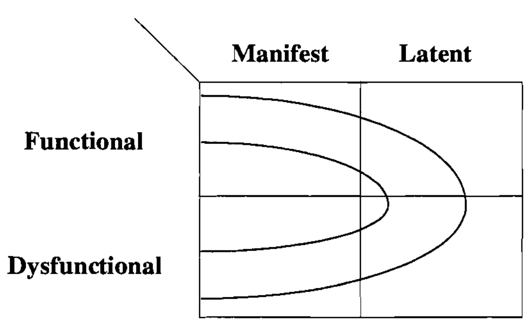


Figure 3.2. Purpose with the study - enlarging of the known area

This thesis aim at suggesting perspectives, principles, and models of organizing that are capable of explaining actual performance and behavior of settings using different approaches to complex product development. The explanations should take into account also the actors' perceptions, perspectives, models, tools, and principles. This research aim encompasses both actors' *espoused theories* and actors' *theories in use* (Argyris&Schön 1974) and their *dysfunctional* and *functional*, *latent* and *manifest* attributes. The purpose is to find *mental models* (Senge 1990, pp. 174ff), *images*, *discourses* and *foundations* (Asplund 1979, pp. 155 and Blomberg 1995, pp. 23) in order to capture the approach that controls the characteristics of the organizational systems and the performance of the actors.

Unit of Analysis

- Projects and Project Families Performing Complex Product Development

To improve the understanding of the limitations of the dominant approach and the possibilities for alternative approaches, the initial focus is on high-performing organizational units and on forming an understanding of what happens in these settings High-performing units (that do meet set and emerging targets) have been selected for study. They will be analyzed and compared to organizational settings applying the dominant approach conforming to normal practices and seldom being able to meet set or emerging targets.

The main part of complex product development at Ericsson, including settings from which I have gathered my empirical material, is carried out, in various types of temporary forms of organizations such as time-limited product development projects allocated to a defined task. The projects are primarily responsible for coping with factors affecting this defined task during the indicated period. At the same time the projects are embedded in an organizational context responsible for coping with extraneous factors affecting requirements in terms of tasks or time. The projects are organized in groups or families. These families are often related through with strong, sequential, pooled and reciprocal dependencies, potential synergies and connections. These families of projects cut across organizational boundaries such as business units and business areas in the firm. In spite of these interdependencies, the responsibility for coordinating different families is allocated to one business area. Such units constitute the basis for product groups overarching the whole company. The project families are, however mainly influenced by one or a few bounded organizational settings that constitute their principal context.

In order to reach sufficient understanding of the growth of new approaches and their efficiency, the logic of the projects as well as of project families must be considered. For this reason, the study has initiated a number of investigations of different project families together with different groups of actors of their constituent development projects. These studies have made it possible to form a complete perspective of the conditions for and approaches to managing complex product development. Separate *product development projects, project families* and the *organizational units* in which they are embedded constitute the organizational setting, which is the central unit of analysis in this thesis.

The thesis is based on extensive empirical investigations in seven different organizational settings performing complex product development at Ericsson. Out of these studies and product portfolios three different approaches have crystallized. Three of the seven organizational settings will be used as illustrations of one approach each in chapters 7, 8 and 9.

One reason for restricting the empirical work to seven different organizational settings in the Ericsson group is that it provides possibilities for gaining a deeper understanding and a more detailed empirical base. Another reason is to keep the scope of the study manageable.

Of the seven cases reflected, five represented the dominant approach and two emergent ones. The reason for choosing just two emergent cases was both their scarcity because they really represented intriguing anomalies in relation to the usual approach. Another reason was that the emerging cases required more research effort to understand because an accepted conceptual apparatus to describe them was lacking in the company as well as in the literature. The reason for choosing five examples of the dominant approach was that this number was deemed sufficient both for establishing if enough similarity between settings existed to justify the label 'dominant approach' and to discern the main features of that approach.

As a consequence of earlier contacts and the fact that Ericsson had shown great interest, it was natural that the empirical work focused on this company. Moreover, Ericsson has gained experience from managing numerous very complex product development projects. Ericsson is a leading company in the area of public telecommunication systems and the global leader in mobile telephone systems. Both these areas are characterized by complexity generated by technological change, globalized competition and market growth.

The study is also limited to investigating the perspectives and problems of the product development organization and treats interactions with other parts of the company from the perspective of the product development organization(s)[26]. The perspective of the product development organization here means dominant ideas among significant groups of actors in the different product development organizations.

Expected Contribution

The expected contribution of this thesis is twofold: to provide an extensive analysis of emerging alternative approaches for how to manage

---

[26] The division into different groups is based on Ericsson's own organizational division. The Ericsson group is largely organized according to the following: product development organizations are resource owners and are responsible for giving work to the global development resources and delivering products and systems given priority by project management and the marketing organizations. The marketing organizations are responsible for gathering customer requirements and influencing customers in a certain direction while the product management organization is a coordinating link between marketing and development, i.e. they are responsible for optimizing resource effectiveness and customer usefulness.

complex product development and to provide early experience from an experiment applying a new research approach.

The purpose of the thesis is not to develop a complete theory but to suggest concepts and explanations based on examples of emerging approaches that have led to repeated success in meeting set and emerging targets. These examples are illustrating alternatives to the dominant approach for how to manage and organize complex product development. By identifying key variables for explaining the repeated successes an extension of the dominant paradigm and an extension of theory for complex product development will be offered. Also suggestions will be made as to alternative factors than those that have commonly been assumed to drive behavior in the process of complex product development. Two illustrations of emerging approaches will be provided. There is no doubt more examples of this kind are needed. These two illustrations and the preliminary sketch of anew conceptualization of the development process will hopefully motivate some readers to further elaborate on the same theme.

The main purpose of the study has been to understand how complex product development can be managed with greater success than is common with the dominant approach. The methodology for achieving this goal has involved experimenting with some newer approaches to management research. One approach has been to carry out the research in a transdisciplinary setting. In these setting researchers with backgrounds in management, engineering, sociology, and psychology have co-operated. A second novel approach has been the active involvement of practitioners in the research. The experience from ten separate research projects will also hopefully motivate some readers to continue the journey towards new research approaches based on co-operation between different academic disciplines and practitioners from the organizational settings.

SUMMARY OF PART I – SETTING THE STAGE

In industries such as the telecommunications industry, complex product development in terms of man-hours represents an increasingly important share of total company expenditures and an increasingly important share of company competitiveness. Complex product development is performed mainly in different forms of temporary organizations such as projects. Complex product development projects do not generally meet set targets, but rather under-perform in terms of agreed time, cost and functionality. New competitive demands on speed, timing and increased functionality force companies to improve their ability to manage complex product development.

The dominant approach for managing complex product development does not master this challenge. Despite large investments in re-engineering structures and processes for performing work in this approach, complex product development performance is only slightly improved and still not sufficient in most organizational settings. Dominant theories also fail to explain why performance is low. However, there are few examples of organizational settings that repeatedly meet or even over-perform both set and emerging targets.

The main purpose of this study is to suggest an alternative theoretical foundation and a new conceptualization of managing complex product development that can guide further practical and theoretical development of the emerging approaches.

The focus of the study is on high-performing organizational settings and the growth of new approaches in these, supporting and impeding factors for this growth and an evaluation of the explanatory value of prevalent theory. The study specifically focuses on issues concerning conditions for high performance, leverages for high performance and conditions for learning in complex product development. Conditions for high performance concern the creation of prerequisites for actors, groups of actors and projects so that they are able to give high performance in accordance with prevailing norms. Typical norms are in this case time, cost and functionality. Leverages for high performance concern supporting factors for high performance. Conditions for learning concern both creating prerequisites for actors, groups of actors and projects so that they are able to consider their behavior in their context and creating a capacity in the organization for utilizing their thoughts. Two organizational settings that continuously fulfill set targets were identified in the company, and these formed the point of departure of the study. For comparison, a further five business units were used which are representative of dominant practice. The unit of analysis is complex product development projects in their own contexts, and the study is limited to the question of how to develop products and does not include the question of what to develop.

The second purpose is to experiment with the research approach by integrating different academic disciplines and practitioners from the organizational settings into the same process of research - by together defining research issues, making research design, collecting data, making analyses and validating results.

PART II - THE ACT OF IDENTIFYING EMERGING PATTERNS

"To proceed beyond the limitations of a given level of knowledge, the researcher, as a rule, has to break down methodological taboos which condemn as "unscientific" or "illogical" the very methods or concepts which later on prove to be basic for the next major progress." [Lewin 1949] "

This part of the thesis will describe the applied research methodology and the model for investigation that have been used. On the strength of Lewins' words, a research approach will also be introduced that is based on the assumption that the researcher does not automatically have the sole right or even first priority for interpretation in research questions, research design, data collection, data analysis and validation of results. The assumption is rather that this is a collective process involving both the researcher and key actors in the organizations under empirical investigation. The assumption is also that the process is not necessarily linear, from formulating research issues and designing the process to finally analyzing and validating findings. The research design, research principles and research methods used will be introduced and discussed, and the specifics in the use of a research approach called *"table tennis research"*, whose purpose is to build knowledge for action, will be analyzed. Finally, the specific contextual characteristics of Ericsson will be introduced.

CHAPTER FOUR

RESEARCH METHODOLOGY - A LEARNING PROCESS BASED ON "TABLE TENNIS RESEARCH"

This chapter describes how research have been performed in the research projects that together constitute the foundation for this thesis and what research methods that have been used.

Ontology and Epistemology in Building Knowledge for Action

In addition to being a journey in the area of complex product development, this thesis is an experiment in the process of knowledge creation involving practitioners from the organizational settings in the inner processes of research – research design, data collection, analysis and validation. Furthermore, this thesis is not a product of one research project but an except from ten research projects, all of which have followed their own logic, although with common characteristics. The knowledge that the thesis needs is *knowledge for action*, that is, knowledge that is meaningful for action and that can be translated into action.

The research context in which this thesis starts is characterized by the idea that knowledge is created in the same context as it is used and that the research setting crosses established theoretical boundaries, where researchers from different scientific disciplines together create new "*temporary*" disciplines (see for example descriptions by Hellström 1998). This is based on a continuous involvement of practitioners that come from the organizational settings in all activities related to the research process; problem formulation, data collection, analysis and validation of results. In these "*temporary*" disciplines, scientific quality is defined just as much by how useful the knowledge is as by scientific control and control by other researchers. The research is not necessarily defined as a linear process, from problem formulation to validation. The research design, the data and the patterns that are identified affect problem formulation. The validation are being performed in parallel to the research design and will become just as much a result of the data and the patterns that are identified as the result of a successive validation of the originally formulated research question.

The experiment in how research is performed in the studies behind this thesis is built on the assumption that this type of research process has the possibility to create useful and scientifically relevant knowledge in the same time. This is primarily made possible by giving the objects of the research - practitioners in the different organizational settings - the full possibility to being a part in building scientific result. These actors' knowledge is given great margin in which to act because they are involved in the research process and the nuances of their experience and action can be allowed to come forth more clearly (see for example discussions in Börjesson 1997, pp. 59-60).

Ontologically, this thesis applies a *system perspective*[27], assuming that the process of performing complex product development can be analyzed as a system, with individuals who have subjective opinions but are more affected by the system than vice versa, which makes the system describable. Describing and generating new concepts require a deep understanding of system components. Hence, a system perspective has been applied which implies that system comparisons are possible through an idea of both *"wholes"* and *"parts"*.

---

[27] The system perspective that is used is inspired by Stymnes (1969, pp. 33-34) where the studied organization is described as an open, complex, goal directed and adaptable social system. Katz and Kahn (1961) that has been an important source for Stymnes application defines organizations as: *"a special class of open systems have properties of their own, but they share other properties in common with all open systems. These include the importation of energy from the environment, the throughput or transformation of the imported energy into some product form that is characteristic of the system, the exporting of that product into the environment, and the reenergizing of the system from sources in the environment"* (p. 33)

The sections below will introduce three basic foundations for the experiment in table tennis research - clinical organization research, action science and abduction - and then discuss potential benefits and shortcomings with this way of performing research.

Clinical Organization Research

The idea that a certain proximity to problems in organizations and participation in change processes can facilitate the formulation of theoretical tasks and offer access to sources of data that are not normally open to research is not new in Swedish organization research. In the early research performed at *SIAR*[28], where Stymne's (1969) thesis is a good example, the term *clinical organization research* was introduced to describe research of both academic and industrial relevance. Stymne (1969, p. 25) formulates the use as:

> *"I use the term clinical organization research to denote research aimed at simultaneously solving organizational problems and acquiring increased knowledge about the way organizations function..."*

This research aim not only at building knowledge useful in both academics and industry, it also gives the organization researcher a new role as clinical researcher. Stymne (1969, p. 25) formulates this new role as:

> *"Clinical organization research takes place when social psychologists or business economists participate actively in formulating and observing organizational change."*

Clinical organizational research is thus based on two major principles that separate it from traditional organization research. First, that the organizational settings are actively involved in formulating the research

[28] *Swedish Institute for Administrative Research*, a former independent research institute founded in 1965 with the purpose to research on organizations.

tasks, which gives the researchers access to more substantial sources of data, and second that the researcher takes an active part in formulating and observing organizational change. Stymne (1969) emphasizes two primary problems in this type of research. There are *the goal problem*, which has to do with the researcher's own values and their effect on the research process. And there are *the effectiveness problem*, which has to do with that the organization as a system can function more or less effectively and that the researcher tends to adhere to the process in which he happens to be an expert, regardless of whether it functions well or not.

Action Science and Actionable Knowledge

Over the years, action research has often been held separate from theory building and testing. Leading social scientists distinguish action research from basic research by asserting that that the intention of action research is to solve an important problem for a client and not necessarily to test features of a theory (c.f. Argyris *et al.* 1985). Action and science are central concepts that are more often contrasted than conjoined. The concept of *action science* (Argyris *et al.* 1985) proposes to bridge these conceptual chasms and is based on the belief that there is value in combining the study of practical problems with research that contributes to theory building and testing. Action science have the following characteristics: (1) empirically disconfirmable propositions that are organized into a theory, (2) knowledge that human beings can implement in an action context and (3) provides alternatives to the status quo that both illuminate what exists and put light into the fundamental changes based on values freely chosen by social actors (Argyris *et al.* 1985, p. 4). Hence, action science attempts to both create valuable knowledge for and about action in concrete situations and to test general theory. This means bridging the concepts of empirical solutions and normative theory.

Action science is based on a search for an interpretative understanding and regularities among events useful to both practitioners and for building theory and therefore to bridge applied research with basic and pure research by building *actionable knowledge.*

> *"Creating usable knowledge is becoming an increasingly important topic in the social sciences. Lindbloom and Cohen (1979), for example, have written about producing knowledge that can be used to formulate policies. Our focus is on knowledge that can be used to produce action, while at the same time contributing to a theory of action. The concept of usable knowledge has produced an uneasy mixture of enthusiasm and skepticism. It has generated enthusiasm because we need more usable knowledge to help manage interpersonal, community, and organizational affairs. Moreover, technological spin-offs from the physical science suggest that the social sciences might generate similar benefits for social practice. But there is widespread skepticism as well. Policies for dealing with poverty, discrimination, and unemployment bog down in the complexities of implementation, and in retrospect, some observers argue that these policies have made the problems worse. Programs for transforming organizations succeed each other with the seasons, leaving in their wake the weary wisdom that nothing really changes. Responsible social scientists may respond to these disappointments by turning inwards to research that seems increasingly esoteric to practitioners." [Argyris et al. 1985, pp. x-xi]*

There is however a dilemma in performing *action research* using methods developed for standard scientific research (Argyris 1980) and therefore a challenge in developing new methods to build *actionable knowledge* within the framework of action science. Argyris *et al.* (1985) highlights two major challenges for action science: how to explain to colleagues how you know what you think you know and how to systematically make interpretations and judgements.

As with *clinical organization research*, *action science* proposes a bridge between practical problems with theory building and testing and suggests that the researcher take an active role in the processes that are being analyzed. The main difference between the two is the intention of doing so. *Clinical organization research* involves practitioners in formulating problems and participating in action to gain access while *action science* does so searching for a unique value in combining the two tasks and perspectives.

Abduction

Alvesson and Sköldberg (1994) present the concept of *abduction* as a description of what they mean to be the most common research effort in case studies.

> *"It means that an (often surprising) individual case is interpreted with a hypothetically overall pattern that, if it were correct, explains the case in question. The interpretation is then to be confirmed in new observations (new cases). The method thereby becomes a sort of combination of the two previously mentioned inductive and deductive, but also adds new parts. In the process, the empirical area of application is developed and the theory is adjusted and refined (i.e. the proposed overall pattern). In this orientation toward underlying patterns, abduction differs favorably from the two other, more shallow explanatory models. The difference is, in other words, that it also includes understanding." [Alvesson&Sköldberg 1994, p. 42, translated from Swedish]*

Abduction thus is according to Alvesson and Sköldberg (1994), a continuous dialogue and a meeting between theoretical assumptions and models and empirical observations and patterns. The purpose is to reach the greatest possible understanding of the phenomenon being analyzed, an understanding that goes beyond surface structures and the individual case to deep structures and the more general case. Neither empiricism or theory define on their own the research process; the phenomenon being analyzed and the meeting between the two and that which is created in this forms the basis for the abductive research design.

> *"Abduction proceeds from empirical facts, like induction, but does not reject theoretical pre-notions and lies in that sense closer to*

deduction. The analysis of empirical data can, for example, easily be combined with, or be anticipated by, studies of earlier theory in the literature: not as a mechanical application in individuals cases but as a source of inspiration in the discovery of patterns that yield understanding. Thus, in the research process, there is an alternating between (previous) theory and empiricism, at which both are successively re-interpreted in the light of one another." [Alvesson&Sköldberg 1994, p. 42, translated from Swedish]

The strength of *abduction* lies in using the good parts of *induction* and *deduction* and simultaneously avoiding their weaknesses and rigidity. Their most important weakness according to Alvesson and Sköldberg (1994) is that their results are not able to be checked logically, and they state that a greater number of case studies increase the reliability of the results.

"...owing to the fact that abduction is not logically certain but allows errors, it must be checked in many cases." [Alvesson&Sköldberg 1994, p. 42, translated from Swedish]

The principal characteristic of the concept of *abduction* is that the researcher uses both theoretical models and empirical findings, which he continuously combines towards an increased understanding of the studied phenomena. The main differences between *clinical organization research*, *action science* and *abduction* are that *abductive research* does not formulate any ambition to build knowledge for action or involve practitioners in the process of defining research issues.

Intervention Research

Intervention research is introduced as a methodology by Hatchuel and Molet (1986) and further developed by Hatchuel and Weil (1995) to capture theoretical ideas from real life experiences in industries.

"..."intervention research is a process by which a firm and researchers establish a joint research program on clearly specified

issues. The research goal is not only to understand established behaviors, structures or processes (Denzin and Lincoln 1994), but to identify potential new models that can better fit to new strategies or new contexts..." [Hatchuel and Weil 1999, p. 7]

Intervention is, as the concept *intervention research* indicate, central for the very process of performing research and is different from the classical action research in the sense that it strives for the development of new concepts and ultimately theory in cooperation with practitioners.

> *"...The researcher goal in this type of methodology is both analytic and exploratory: this means that if the research field is Toyota, the goal is not only to describe "toyotism" but to develop the possible principles of "post-toyotism". This means that the researcher can experiment, in agreement with the firm, some new organizing principles for which his scientific role intervenes at three levels: identify these new principles and their differences with old well known ones; participate to experimental implementations; derive from these implementations a reformulation of these principles and establish their scope of practical validity; abstract from those principles insights of theoretical value in his field..." [Hatchuel and Weil 1999, pp. 7-8]*

As with *clinical organization research* and *action science, intervention research* proposes a bridge between practical problems with theory building and testing and suggests that the researcher take an active role in the processes that are being analyzed. The main difference between *intervention research* and the former two is using the actual intervention as the vehicle for building new knowledge.

Characteristics of the Study – Table Tennis Research

Inspiration from the early work of SIAR, Argyris *et al.*'s *action science*, Hatchuel *et al.*´s *intervention research* and Alvesson's and Sköldberg's *abduction*, together with early experience from working transdisciplinarily in close co-operation with key actors from organizational settings, constituted the foundation for an experiment in methods for performing research in this thesis. An experiment based on the involvement of practitioners one step further into the process of research, i.e. not only in formulating research issues but also taking part in the research design, data collection, analysis and validation of results. This experiment has resulted during the research journey in a research process I choose to call *"table tennis research"* to illustrate the intense interaction between the researcher(s) and practitioner(s) from the organizational setting. This research strategy has had five discriminating characteristics: (1) a striving to integrate the researcher(s) into the practitioner(s)′ traditional domain, (2) a striving to integrate the practitioner(s) into the researcher(s)′ traditional domain, (3) a striving to perform research in real time in red-hot issues, (4) a striving for transdisciplinarity and building new, often temporary research domains and (5) a striving for validate knowledge in work-shops.

Firstly, *table tennis research* is based on integrating the researcher(s) into the practitioner(s)' traditional domain - the organizational setting. To understand the deep structures in the phenomena analyzed, attempts were made to come as close as possible to the organizational settings in the ten projects on which the thesis is based. The motive for this attempt for closeness have been, as in *clinical organization research* and *action science*, to gain access to more information than would be possible in a more tradition research process, i.e. it would contribute to better data collection. However, the motive has also been as in the *abductive research* process, to set up a continuous meeting between theoretical models and empirical observations, i.e. to contribute to a better analysis of data. The researcher's integration into the organizational settings as a *participative observer* and *participative actor*[29] is also motivated by the notion that a deeper understanding of these two can contribute to a better research design and process of validating results. This original ambition has been

[29] The concepts are from Garsten (1994). Traditional ethnographic research distinguishes between four types of interaction with the organizational settings; observer, participant as observer, observer as participant and participant.

successively strengthened during the journey by finding arguments for attempts such as this in the literature and by positive experience from my own research. Weber stated early that social phenomena could be explained in a deeper way only through an understanding of the subjective meaning of the socially active actors. Regardless of the amount of data and regardless of what (statistical) methods are used to produce approximate pictures of this, such models are only surface phenomena that can be given deeper explanatory understanding [Weber (1922); in Blomberg (1995)]. Melin (1977) stated that interactive field studies (based on close interplay between researchers and practitioners) are the best strategy for reaching deeper understanding. According to Mintzberg (1978), new approaches arise only from a sophisticated understanding of rich reality. Thomas (1984) wrote that useable theory grows primarily from intensive field studies. In nine of the ten research projects, the researcher(s) spent a considerable amount of time in the organizational settings.

Secondly, *table tennis research* is based on integration of the practitioner(s) into the researcher(s)' traditional domain - the process of research. To gain an action perspective on research design, data collection, analysis and validation, efforts were made in all the projects to integrate practitioners into the research team. Shared responsibility for the whole research process can create good conditions for taking the unique characteristics of the organizational settings into consideration in all research steps. This integration is an experiment in bringing practitioners a further step into the researcher's domain. *Clinical organization research* and *action science* are based on involving practitioners in defining research questions, in the first case for the purpose of better access and in the second to go a step further in defining interesting research questions. In both cases, the researcher then alone has responsibility for the research process. When practitioners become participative observers, the conditions for effective research design are improved, there is triangulation in data collection, observations are put into a meaningful wholeness in analyses and the validation of results is given an action orientation. This integration also finds support in the literature. Intensive interaction between researchers and practitioners in organizational settings has been shown in earlier studies to be especially important for research aimed at understanding (Normann 1975, Czarniawska 1992 and Alvesson&Sköldberg 1994). Börjesson (1997) also elaborated on letting go of the *heretofor maverick monopoly on problem formulation* (s. 60) to facilitate the creation of new knowledge. In nine of the ten research projects, several practitioners participated in the research team and in the process of research.

Thirdly, *table tennis research* is based on performing research in real time on red-hot issues. Nine of the ten research projects were performed in real –time, contributing to ongoing processes in the organizational settings. All ten research projects focused on red-hot issues for the different academic disciplines involved and for practitioners in the organizational settings. Both the real-time aspect and the red-hot aspect have been of vital importance for integrating practitioners into the research domain. By providing a setting where potential knowledge created in the research project is of vital importance for the organizational settings and where knowledge created can be simultaneously used, evaluated and developed in action, practitioners can and do engage themselves in the process of research and acquire some principle tools and methods for doing so. The real-time aspect also provides opportunities for validating actionability in knowledge created through simultaneous creation and use.

Fourthly, *table tennis research* is based on transdisciplinarity and building new, often temporary research domains designed jointly by researcher(s), practitioner(s) and by the knowledge created in the research project. By this double integration of domains – researchers into the practitioners' traditional domains and practitioners into the researchers' traditional domains – researchers and practitioners will jointly create a new temporary research domain. Research ideals and rules in these new research domains are based on an ongoing dialogue between methodological suitability based on each of the studied organization's specific conditions and methodological correctness in terms of the scientific positions taken. The methods and tools used have not been defined in advance or limited in number; instead, many different types have been used in the different projects as well as within the framework of each individual project. The basis of the studies have however been unstructured and semistructured interviews together with the participants' observations, the participants' actions and frequent workshops together with different representatives of the organizational settings to discuss and analyze the results. There is also an important point in seeking data that support differences when making comparisons between case studies (as described in e.g. Whipp *et al.* 1989). The transdisciplinarity is motivated by the fact that complex phenomena such as managing complex product development changes depending upon the view one takes of it and an understanding thus requires several different approaches (Perrow 1986 and Czarniawska 1992). A triangulation method is a good base for cross-testing complex information (Pettigrew *et al.* 1988). The goal has been to capture impressions from different perspectives and to continuously relate them to one another. The purpose has been to gain an understanding of the system more than an understanding of the individual components in the organizational systems studied or, as Czarniawska (1992) expresses this: *"...how can we understand an elephant by studying only its ear or trunk..."*. All ten research projects have had transdisciplinary research teams and there have been examples in some of the creation of new, temporary research domains.

Finally, *table tennis research* uses series of workshops as primary tools for validate findings. The large number of work-shops that have been performed have worked both as an important mean for driving progress in the research projects but also for performing research, i.e. collecting data, analyzing data, making conclusions, testing conclusions and redefining research issues and focus. By composing the workshops of different types of actors the researcher(s) have been able to combine perspectives not normally held at the same time; insider/outsider, local/global, short-term/long-term and system/event. This intermingling of perspectives provides the researcher(s) with valuable multiplicity in line with anthropological ideals (see for example Garsten 1994). This set of perspectives also provides the research process support in gaining analytical distance and scientific objectivity by not being locked in to one single perspective. The large number of workshops, perspectives, applied research methods and participants in the process of research have also helped to bridge the inherent limits of any single act or form of representation. The intense use of workshops also facilitates short feedback loops both from analysis to the organizational settings and from the organizational settings to the process of further analysis.

Table tennis research is based on experience from *clinical organizational research* in terms of involving practitioners in defining research questions – the red-hot issues. *Table tennis research* is also based on *action science* in its aim to create knowledge for action and develop the process of interaction between researcher and practitioner. *Table tennis research* is also based on *abduction* in the continuous dialogue between a refining theoretical foundation and empirical data. *Table tennis research* is also based on *intervention research* by using intervention for validating knowledge. However, *table tennis research* also takes the integration of practitioners from organizational setting into the process of research one step further; i.e. it actively involves them in research design, data collection, analysis and validation of results. Hence, the organization researcher lets go of his first rights to interpretation to the advantage of the research team, including all actors involved in the project. *Table tennis research* is also based on *transdisciplinarity*; i.e. the research team is made up of researchers from different academic disciplines and representatives of different parts of the organizational setting with which research goes on. The research team will also change its composition according to which red-hot issues are being managed at the moment in the framework of the research project. In *clinical organizational research* and *action science*, the practitioner is taken into account in defining research questions but the researcher manages the rest of the process. In *abduction*, the focus is on the dialogue between theory and empirical observations but the researcher is entirely responsible for the process of research. In *intervention research* the researcher(s) withhold the process control and preferential rights in interpretation. In all four, researchers have their domain and practitioners have their domain, and all focus on how to make something from an increased interaction between the two. In *table tennis research*, the integration into each other's domains facilitates the creation of a new common domain with different types of actors - researchers from different academic disciplines and practitioners from different organizational settings – and the participating practitioners change over time.

If academicians and practitioners seek the same type of knowledge – *knowledge for action* – then the problems no longer have to do with the *"nature of knowledge"* or a transferal of knowledge but instead with its practical organizing. What is the best way to organize transdisciplinary research projects, where researchers and practitioners formulate research questions, make research designs, collect data and analyze and validate them together? This thesis is an experiment in and a development of the organization of building common knowledge in this way.

Approach	**Principal Characteristics**	**Basic Assumptions**	**Principal Purpose**
Clinical Organizational Research	Research aimed at simultaneously solving organizational problems and acquiring increased knowledge about the way organizations function.	Researcher(s) participation and co-operation may facilitate the formulation of more interesting research issues and give access to new sources of data.	Increase quality in research issues and sources of data.
Action Science	Research that provides alternatives that is useful in action and that is empirically disconfirmable.	There is a value in combining the study of practical problems with research that contributes to theory building and concepts. Toughest test of validity in social science is to create the phenomena.	To build useful knowledge and test the validity of concepts and theory.
Abduction	Research based on a continuous dialogue between theoretical assumptions and	This continuous dialogue is important in reaching greatest possible understanding	To provide the researcher(s) with more data and analytical

	models and empirical observation and patterns	of the phenomena being analyzed.	tools.
Intervention Research	Research that is not only focused towards understanding established behaviors, structures and processes but to identify potential new models that can better fit new structures or new contexts.	By performing real-life experiments new knowledge are created.	To capture theoretical ideas from real-life experiences.
Table tennis Research	Research performed on red and hot issues where researcher(s) and practitioner(s) take equal responsibility for the knowledge creation.	By exposing both the researcher(s) and the practitioner(s) for each others full complexity the process of knowledge creation are facilitated and better theories and solutions are developed.	To integrate many perspectives and traditional phases of and activities of research and thrive on its potential.

Figure 4.1. The different concepts and their characteristics.

Tools in Use for Performing Research

The studies that form the basis for the thesis are themselves, as earlier described, and based on ten research projects in seven different organizational settings. The studies were longitudinal case studies in six of the seven organizational settings, i.e. they were followed over a longer time period (more than two years) to give a picture of the whole and a continuous flow of first-hand data. The seventh organizational setting was shut down as an organization, making further follow-up impossible. The number of organizational settings was to a large extent determined by the different research projects. Another important dimensions in the choice of the number of organizational settings have been the focus of deep structures and proximity rather than surface structures and breadth, the limited time and the difficulty in identifying organizational settings that repeatedly meet set targets. A pattern became clear in these seven organizational settings, with five settings representing the dominant approaches and two settings representing two alternative approaches. One of the five, together with the other two organizational settings, is used as a more full-fledged illustration of the three different approaches for performing complex product development in chapters 7-9.

The research tools used are different types of interviews, activity and process charts, communicograms, participating observation and action, questionnaires, analyses of written documentation, workshops and performance measurements. The use of these tools is described below. Common for all the tools described below are that they were not only used for data collection but also as tools for integrated analysis and validation. This was possible owing to an integration of practitioners into the research process and owing to simultaneous creation, use and evaluation of knowledge.

Interviews

The study is based on a total of 243 interviews in seven different organizational settings that range from completely unstructured to structured interviews, but with an emphasis on posing the questions in an open form. The ambition was to get the respondents to give a narration more than just answer the questions. Interviews were done in connection with more focused studies in each setting. The points of the focused studies are given in the descriptions of the empirical organizations. I (with few exceptions) did the interviews at the workplace of the respondents and by myself or in some cases together with a colleague. The interwievs were carried out over a relatively long time period but the majority of those done at each individual workplace were done within a certain given time. I primarily performed the interviews as the single researcher using the questionnaire with important areas as the base. I took notes during the interview and also used approximately one hour more afterwards to write additional notes from memory. The following can be seen as a typical interview situation:

> *The researcher contacts a key person – usually by telephone – and introduces the research project that the interview in question will be a part of and describes the stakeholders behind the project and the context in which the results will be used. The researcher then asks the*

respondent whether it is possible for him/her to be interviewed for this project. The respondent normally shows great interest in cooperating in the project – probably owing to the ambition of the project to focus on red-hot issues. The researcher and respondent make an appointment for the interview, usually for two hours at the respondent's workplace. At the time of the interview the researcher begins by describing his own background, re-introducing the research project, stakeholders and the intended use of the results. After this introduction, the respondent is given the opportunity to describe his or her background and current role. At this point, the interviews take one of two main paths. The respondent feels secure in his or her role as respondent and begins to speak openly about the subject of the research project. The researcher takes on a relatively passive role, expressing only a certain encouragement and slight control signals if the discussion moves outside the domain of interest for the research project. The researcher also notes important areas that the respondent emphasizes. When the discussion begins to wane (or the interview time is coming to an end), the researcher sums up the picture that he (up to that time) has received from the respondent. In most cases, this leads to a recapitulation that the respondent adds to, illustrates and further develops statements. The other path is that the respondent does not feel entirely secure in the situation or the role as respondent. If the situation cannot be improved by adding background information, the researcher takes a more active role and poses more direct questions. The researcher also sums up his impressions at the end of the interview. In closing, the researcher in both cases asks whether he may return with more questions and straighten out any eventual unclear points. The researcher invites the respondent to participate in the next workshop and asks the respondent to think of any other key persons he should meet.

Directly following the interview, the researcher compiles his impressions and tries to contact the respondent that day or the next in the event that there are unclearness or gaps in logic. In the case this *must wait until the next workshop or if the respondent cannot be present at the workshop, the researcher sends a draft of his impressions – often drawn from a number of interviews at the same setting – to the respondent. The respondent most often returns his or her comments to the draft.*

Twenty of the 243 interviews were taped and transcribed in complete, but it was chosen to not tape all interviews. This decision was made partly because of the background effect. Hence, a great amount of information is collected, owing in part to the openness of the respondent, that does not further the search for knowledge. The decision was also made partly because of a wish to give broadness to the studies that could be gained in a great number of interviews. The decision felt right at the time but in retrospect it would have been a certain support to have some of the more central interviews on tape. As a number of researchers have been involved, documentation of observations and exchange of documentation was made continuously. These notes have then been combined with other data collection and continuously been refined to be able to function as a basis for workshops. These interview data, just like other data, have thus been successively integrated into written documents as early as possible so that it would be possible to give feedback and start discussions on the red-hot issues at the focus of each research project, i.e. according to the ideals in table tennis research.

Activity and Process Mapping

The development work has been activity and process mapped in the organizational settings. The purpose was to capture the actual work processes on a detailed level and thus contribute to an understanding of the logic of the development work in each setting. About 50 persons in two organizational settings were investigated more carefully while the others have more been maps on a more overall level. The detailed mappings focused on capturing each work activity carried out by the persons involved in the projects, finding patterns, grouping these patterns and identifying dependencies and flows between the different work activities. One of these maps resulted in a colored figure 2 by 1.5 meters in size with a total of 308 activities and the way in which these were related to each other when a new product was developed. This map was probably more important for the researchers´ understanding of the complexity of the development processes than it was a contribution to action in the organizational settings. The map on a more overall level focused on views, frameworks of ideas, focus, dominant actors and basic assumptions, that is, phenomena on another level of analysis. The principle for this change of focus was that the growing paradigms were better understood through analyses on this higher system level and that the process facilitated table tennis research.

Communicogram

Communicograms were used to measure communication patterns and coordination needs among actors in the organizations studied. Three types of networks were analyzed: communication and coordination in running work activities, problem-related communication and coordination and communication and coordination for support and trust. A total of 87 persons participated in these analyses. The analysis consisted of a more general questionnaire where the respondent describes with whom he has contact and how frequent this contact is. This analysis is performed to capture the three different networks; (1) of running work activities, (2) problems and support, and (3) trust. The analysis also consisted of a questionnaire of the same type but in which the areas of communication in the running work activities and in problem-solving were specified more clearly, e.g. delivery of base stations. The latter questionnaire has been found to be valuable in environments where the intensity of communication is high and it is a complex task to analyze the complete networks. It has also been found valuable to allow all respondents to supplement these questionnaires by answering a number of factual questions on the specified area of communication, for example when the base stations will be delivered, where they shall be delivered and how many will be delivered.

One of the advantages of the method used has been its strength in illuminating more informal sides of each organizational setting by focusing on actual social relations rather than formal rules, work descriptions and official routes. *KrackPlot 3.0* developed by D. Krackhardt, J Blythe, C. McGrath and M. Herbert was used to draw and count the networks indicated by the respondents. The results of this counting and the illustrations were then used as a basis for discussion in a number of workshops.

Participative Observations and Actions

Closeness with the cases studied was continuously maintained during a five-year period. For two years, more than half of the researcher(s)' time was spent in these settings and the researcher(s) had the opportunity to observe and participate in a variety of formal and informal meetings, discussions and events. A diary was kept during the entire time, marking important events and observations that were then successively grouped and aggregated into patterns. There was also a continuous dialogue with a group of representatives of the organizational settings.

Questionnaires

Questionnaires were used to map agreement in targets and purposes, climate variables, understandings of key activities and key competencies in the organization and to validate identified patterns or phenomena. In total, 218 persons participated in these questionnaire studies. The results have represented important contributions to many of the workshops that were carried out.

Written documentation

The studies are also based on continuous reviews of documents and written data from each business unit. All available material written about the organizational settings and which had to do with the research project's problem areas were systematically collected. This was made to reach a further understanding of each organizational setting and the logic within which they work and to get more exact data than could be gained from other approaches. The first type of document is descriptions of organizations, process descriptions, policy descriptions etc., the second type of document is project follow-ups with respect to time, functionality and productivity, manning plans, minutes of meetings etc. and the third type is internal investigations of specific problems.

Workshops

The study included a total of 63 workshops with representatives from the organizational settings and others in the firm. Over 1000 persons participated in these workshops over five years. The workshops had between three and 200 participants, although most often there were ten to fifteen. In each workshop, the researcher(s) functioned as chairman and inspirer and as the person taking charge of the results it gave. Input to each workshop was preliminary results of ongoing research projects and the output was refined results, new research designs, alternative interpretations, validations of early results or new research questions. The workshops are the methodological foundation of this thesis and the platform to which other tools have contributed. They have also been the most important contribution to the results of the thesis and created the conditions for table tennis research.

The purposes of the workshops have been to present preliminary results of the research and to involve actors from the organizational settings in collecting and analyzing data and validating and developing the preliminary results, setting out new red-hot issues and designing further research. This means that the ideas, models and suggestions presented by the researcher, as well as the process for further research, have continuously been open for redesign and even important changes during the workshops. Further research is moving towards an increasing number of red and hot issues, where many can contribute to this refinement. This procedure implies a series of potential risks for the research process but has also been one of the most important bases for gathering results.

The workshops were used as a main tool for gaining a greater understanding and joint knowledge and, during periods of intense empirical research, were held between once weekly and twice monthly. Each workshop resulted in everything from discussions of evident misinterpretations to analyses of implications and changes in the research process and new perspectives that ought to be described or new research projects that ought to be initiated. The design and contents of the workshops varied a great deal. The early work-shops had more of a character to be based on pure presentations of research results and discussions of these while the latter had more of a character to be based on performing research together and shedding light on all aspects of the research process. To give the reader a more elaborate description of the concept of table tennis research, one typical workshop and its context are described below.

In December 1995, a workshop was held at Ericsson Telecom Systems, Telefonplan. The focus of the workshop was a comparison of two large, complex product development projects to explain differences in performance at two different business units; Large Switches and Japanese Systems. Eighteen persons participated; six line managers, four from Large Switches and two from Japanese Systems, four project managers, three from Large Switches and one from Japanese Systems, three members of the personnel department at Large Switches, two from organizational development at Large Switches and three researchers, of whom one was the author of this thesis.

The comparison was based on preliminary results in an on-going research project and the researchers had invited key persons from Large Switches and Japanese Systems to participate in analyzing the findings. As a basis for the workshop, an early draft containing the most important findings was distributed two days before the workshop to a larger group of actors than the participating group. This draft had been used for extensive discussions the day before the workshop and most participants were interested in learning more *about the basis for the findings. One of the researchers started the workshop by restating the goals and purposes of the research project and the methods being used and briefly summarizing the contents of the draft. The hypothesis presented was that Japanese Systems showed better performance in product development than Large Switches owing to differences in perceptions of the development process in the projects and differences in the degree of convergence in the projects. A hostile discussion first took place where participants among various parties from the two organizational settings defended their projects. After intervention by the researchers, this discussion turned about and the focus was reset on finding explanations for the differences in performance.*

After an intense one-hour discussion of the hypotheses presented in the draft, the participants agreed that these differences existed, that they impacted performance in the projects, that the findings in general were reasonable and that Large Switches had to face the challenge. The group however argued for another explanation for these differences than the draft and the researchers initially gave. The new hypothesis was that the prerequisites created by other sub-units than the sub-unit performing the projects in the organizational setting lead to dominant perceptions and degree of convergence in the projects.

The group agreed that gaining a better understanding was a high priority and the last hour of the three-hour meeting was spent in designing a new research project trying to describe and analyze how prerequisites for the large, complex product development projects were created. A line manager from the Japanese Systems management team proposed himself as a responsible client for such a project and suggested that he and one of the researchers work out a proposal based on the discussions in the group to which the other participants could give their reactions. This proposal ended the meeting, and three other participants, one from organizational development at Large Switches, one project manager from Large

Switches and one project manager from Japanese Systems, expressed their interest to the line manager and the researcher in participating in shaping the proposal. The researcher and the three practitioners booked a meeting two days later to initiate the new project. One of the researchers summarized the meeting and promised an invitation to a new workshop to discuss the new proposal. He also asked the participants to think about whether there were further people who should participate in the coming meeting and to contact him with new names.

After the workshop, the three researchers met to discuss and analyze what had happened and why and what consequences this might have for the emerging hypothesis. They also analyzed how the new proposed research project best could be of interest to on-going research and agreed upon some critical demands on the upcoming project.

Two of the line managers and one project manager from Large Switches initiated their own investigation to search for alternative ways to increase the degree of convergence and change dominant perspectives in parallel with the new research project.

The workshop described above illustrates at least nine important characteristics of "*table tennis research*": (1) the workshop was based on a *red hot issue*, i.e. a specific theme of major interest to both researchers and practitioners explaining differences in performance in complex product development, (2) the workshop was based on *research results* – the draft and initial presentation, (3) the participants of the workshop had *different perspectives* – line managers, project managers, personnel department staff, organizational development staff, transdisciplinary researchers and participants from two different organizational settings, (4) a *researcher acted as chairman, intervener and inspirer* – initial presentation, intervention and summaries, (5) the *results analyzed were not seen as fixed* – an alternative hypothesis emerged, (6) the researchers did *not have preference as to the interpretation of research questions, research design or the very processes of research* – a line manager proposed, (7) *new projects, phases or themes were easily initiated* when they were perceived as containing research and being of practical interest – a meeting was planned two days later to initiate the project, (8) the workshops were used as *important input for the research process* – the researchers met for discussions and analysis, and (9) the workshops *led to changes/action or change/action initiatives* in the participating organizations – the organizations initiated their own investigation and searched for new paths.

Performance Measurement

In addition to annual reports, balance sheets, internal company follow-ups[30] and reports of project performance in each organizational settings we were forced to rely upon on the information given by the interviewees and were not able to go so far in the verification of successes as we initially wished.

[30] Ericsson collects and analyzes data on all their product development projects after three major dimensions: price, quality and time. These data have been used for comparing performance between the different approaches.

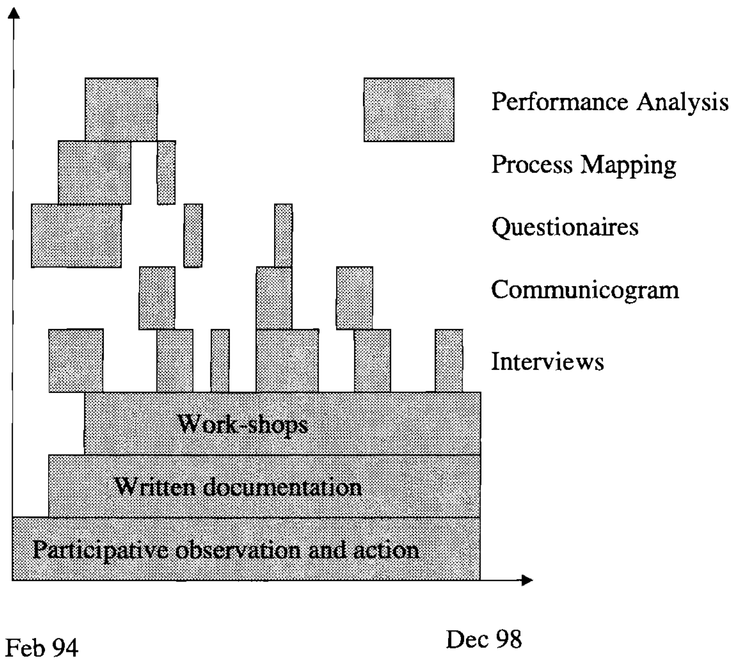


Figure 4.2. Matrix of methods for data collection, analysis and validation over time

Hence, as the figure shows, *participative observation and action*, together with *written documentation* and *workshops,* have worked as the principal vehicles for the research projects. From the emerging analysis, findings and patterns, a number of focused *interview studies*, *questionnaires*, *communicogram studies* and *process mappings* have been conducted. *Performance measurements and analysis* have been used to focus the study towards "analyzing two high performing organizational settings" and then, in the next phase, to validate findings.

The Process of Selecting Respondents

The selection of respondents for interviews, process and activity maps, communicograms, questionnaires and workshops followed two major principles; to *capture key persons* given the red-hot issues that were focused upon and *the snowball effect*. The initial partners from the organizational settings were an important resource in defining key persons in each setting given the first formulated red-hot issue(s). These key persons were the first respondents in each project and were an important resource in the subsequent selection of respondents. Given the red-hot issue(s) those were in focus during the initial interviews, measurements and analyses identified the first group of new respondents. The summarized impressions from the interviews also create conditions for finding new key persons. This process was then repeated until the research project was concluded. The limitation in the number of interviews was made according to two primary strategies, one being that the time and resources allotted to the project was given and the other that a certain scope of results was desired. Parallel with this, all respondents and other key persons were invited to workshops during which new key persons were often identified. The instructions that the researchers gave for the process of identifying respondents were only to capture different perspectives and views of the red-hot issue.

Practical Handling of the Empirical Data

Two guiding principles led the practical handling of empirical material: (1) to take it to a level of analysis as quickly as possible and (2) to test preliminary results as quickly as possible with other researchers and practitioners in the organizational settings. Documentation of data focused on refined data, i.e. constructions of patterns, hypotheses and thought models, rather than untreated raw data. There has been a continuous effort during the entire project to integrate observations into models and systems. Even though an ambition has been to create a new research domain in which researchers from different scientific disciplines and practitioners are actors on the same level, the process has required that results have sometimes been documented in two different target groups. Hence, one package to the traditional domain of practitioners and one package to the traditional domain of researchers, where workshops and/or more accessible reports in the organization's own language were meant for the former, and scientific articles, reports and PMs were meant for scientific advisors and colleagues. However, in most cases, both practitioners and researchers have used the same documents and presentations.

The Process of Interpretation

The process of interpretation has been characterized by (1) reconciliation across sources, (2) breaking perspectives and (3) comparisons by selecting pairs of phenomena.

Firstly, there was an attempt in all projects to verify and reconcile findings across sources and make use of the multi-method approach, a strategy proposed by Glaser and Strauss (1967), Yin (1984) and Eisenhardt (1989) among others.

Secondly, there was an attempt to make parallel analyses and use different perspectives in data collection and interpretations to make use of the transdisciplinarity and integration of practitioners from the organizational settings into the process of research.

Thirdly, comparisons were used to analyze similarities and differences. The comparisons were made by selecting pairs of phenomena in categories such as how project plans were made or how co-ordination was handled in different settings. Then similarities and differences in each category were listed in different settings and grouped them according to variables of interest such as project configuration or co-ordination mechanisms. Of particular usefulness during this process were various forms of analytical matrices as support in finding patterns in data, a strategy proposed by Miles and Huberman (1984), among others. These matrices not only facilitated comparisons across projects and across organizational settings but also served as an aid in reconciling the data across sources and identifying patterns in the large set of qualitative data.

Group of Actors in Focus

As the study is based on ten different research projects, it has followed the logic that was steered by each individual research project. However, it also followed its own logic throughout. The study, with its system perspective, focused on "*sway groups*" and other key actors for the system involved in managing complex product development in the organizational settings. This focus functioned well both for the study as a whole and also as an important contribution in each project. An organizational sway-group is, according to Stymne (1969, p. 29):

> *"...a set of persons (or sometimes a single individual) that uses a certain organization as a tool (...) A sway-group conceives objectives for the total activity of the organization, has the power to affect the decisions that govern the overall activity in the organization and wants to influence the organization in accordance with its objectives..."*

The primary purpose of the sway-group is by definition to single out those in power, regardless of the sub-system in the organization to which they belong. Power is determined by the critical uncertainties and problems facing the organization and in turns influence decisions in the organization. Power is most often shared in organizations, and it is shared out of necessity more than out of concern for principles of organizational development or participatory democracy - no one person or sway-group controls all the necessary activities in a firm (see for example Salancik&Pfeffer 1988). When an organization faces a number of lawsuits that threaten its existence, the legal department will gain power and influence over the organization's decisions. When gains in market shares are of the greatest importance, the marketing department will gain power. When a stable production line is of the greatest importance, the engineering department will gain power and so on. In large and complex firms many things evolve at the same time and many sway-groups can evolve that have preferential rights in interpretation in different forums in parallel. The studied organizational settings are good examples of organizations in which there exist more than one sway-group in parallel depending on the issue being discussed. There are many examples from typical situations in which no single sway-group is in control. Power derives from activities rather than individuals; an individual's or a sub-group's power is never absolute and derives ultimately from the context of the situation. One individual's or one subgroup's power is dependent on other individuals' and subgroups' perception of what the critical activities are and their perceptions of the individual's or subgroup's specific contribution to this/these critical activity/ies. Other key persons can be individuals that have an important role in a specific question that is in focus in the research project but is not automatically in focus in other questions.

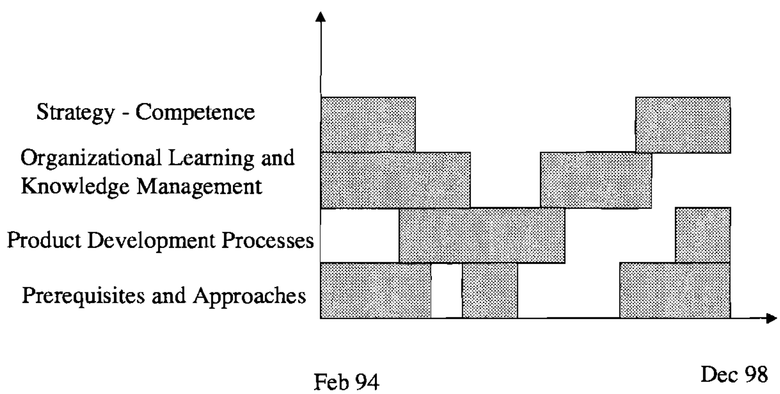


Figure 4.3. Group of actors and criteria in focus over time

The research projects that together constitute the foundation for this thesis have continuously been performed together with single engineers and design teams to provide primarily middle management (project management, line managers, specialists and support functions such as personnel, business development, operations development etc.) with in-depth analyses and patterns. The focus on the coupling between strategy and competence and also the focus on prerequisites and approaches has however mainly been formed together with top management.

Integrating Key Actors from Organizational Settings into the Process of Research

In addition to the workshops described above, a number of practitioners have worked actively in the research projects together with other researchers. Their involvement has varied from conducting individual interviews, participating in analyses before and after workshops, discussing suitable research designs and alone or together with researchers to suggesting new research issues. This participation was made possible by the workshops' successive development toward involving all participants in the entire research process. This created a curiosity not only about the research results but also about research design, data collection, analysis and validation.

By integrating practitioners into the traditional domain of researchers - research design, data collection, data analysis and validation - and integrating researchers into the traditional domain of practitioners - performing action – conditions, as stated earlier, are created for a common domain. A domain where both researchers and practitioners search for same type of knowledge and use the same tools for validating the knowledge created. If such a domain is created, traditional problems of transferal will no longer exist; the problems will rather have to do with organization, i.e. how joint knowledge created on the basis of practitioners' and researchers' co-operation in research design, data collection, analysis and validation is best organized.

Research performed in close co-operation with industry is often considered to be affected primarily by short-term needs and availability in the organizations that have been studied. It is also often considered to lose objectivity owing to the closeness to the object under study. Action research, where the researcher takes an active role in the processes studied, is often considered to lose reliability because of difficulties in differentiating between the effect of researchers and other factors. These are all important risks that must be considered in the research process. It is complicated to handle these risks and overcome traditional shortcomings in research performed in close co-operation with industry including action components. However, it was found that the potential gains discussed in several different sections above were so substantial that it was worth the experimental effort to find ways. In order not to fall for the risks, we tried to keep a theoretical and scientific discussion alive among the group of researchers and in relation to colleagues that argue for alternative scientific and theoretical starting points regarding potential gains and shortcomings and their consequences. Chapter 11 contains further analyses of strengths and shortcomings and discusses alternative methods and their potential contributions.

Richard Normann (1975, p. 69ff), one of the researchers in SIAR and a representative of *clinical organization research*, emphasizes two ways to validate a framework of reference with data. Either, to take a small part of the framework of ideas (one or a few hypotheses) and confront this with a large number of observations. Or, to take a large-scope framework of ideas and confront it with a large number of points and a complex set of data in the form of a complex system of events. The strategy that underlies this thesis has been the latter, making the confrontation as complete as possible using transdisciplinarity, an integration of domains and multi-methods. Normann (1975, p. 256) writes:

> *"A theory about complicated relationships cannot be developed in any other way than through systematic confrontations between a framework of ideas and empirical cases. The basic principle is to place an entire framework of ideas against new cases in empirical reality, i.e. against companies, in as many points and as broad a front as is possible. For each broad confrontation, weaknesses in the framework of ideas in question are disclosed in the form of incorrect assumptions, irrelevant or unfruitful concepts, white spots etc. These weaknesses lead to revisions in the framework of ideas – in details and holistically – to be ready again for the next confrontation." [translated from Swedish]*

The main arena for these confrontations was the 63 workshops together with practitioners. Normann (1975) also shows four different objects of comparison for new knowledge created: (1) comparisons with other cases, (2) comparisons with (formal) theories, (3) comparisons between ideal conditions or ideal types and (4) comparisons with traditional norms and ideas. We have tried to use all four in the studies in this thesis: (1) comparisons between organizational settings that apply alternative approaches in chapters 7-9, (2) contrasting findings with dominant theories and models in chapters 2, 10 and 11, (3) contrasting different typical strategies in the different approaches in chapters 7-9 and (4) contrasting norms and frames of references in the new approaches with the dominant ones in chapters 7-9 and 11.

The studies upon which this thesis is based, joint knowledge creation and increased understanding of the red-hot issues have been given priority over a better understanding of how this knowledge is created. We have not experimented with absolute roles as observers and actors as we believe that this would decrease possibilities for creating knowledge as well as everyone's contribution to an understanding of the red-hot issues. In studies of emerging paradigms, there is also a lack of reference data, and then another type of validation is needed that we believe is supported by an integration of domains – the researchers' and the practitioners'.

Towards a Development of Practices under Study

This use of table tennis research influences the practices under study. This means that what is being studied is influenced by what is found, and what is found is influenced by what has been studied and what has been found earlier. If the research process names phenomena and constructs a language for emerging patterns, it helps to make implicit knowledge explicit and to influence conditions for sustainability and dispersion. This dual influence and these complex interdependencies are normally only considered a problem in performing research. However, in the studies on which this thesis is based, we have also perceived it as an important strength that can be used in performing research. The purpose of building actionable knowledge is to influence action with new knowledge that is won, and validation of actionability is only possible by performing action. By enlarging the known area, as in figure 3.2, the process of table tennis research provides actors with more knowledge on which to base decisions and on which to act. By integrating domains (reseachers' participation and practitioners' observations and analyses), it is possible to simultaneously, as proposed, reject or validate and develop new knowledge.

Presentation of Empirical Findings in the Thesis

A common problem in clinical and unstructured studies is the difficulty in finding a logical structure for presentation and analysis of the data that are collected. This study is based on ten different research projects, which further accentuates this problem. The investigation model has also grown with the different studies and received its final form only in the final project. This means that data have been collected and presented in different ways in each study. We also chose to present the ideal types as constant comparisons among each other.

The three approaches are reported in chapters 7, 8 and 9 in the form of three constructed case descriptions that consist only of the typical layers of knowledge that are relevant in terms of the research questions and frames of reference in the thesis. The descriptions are based on typical thinking and typical action among actors in the respective organizational settings and are made from a systems perspective. We have attempted to construct a comparison between ideal types that illustrate significant dimensions for the investigative model. This has been made in order to fulfill requirements for consistency (demands of treatment and scope), relevance (all data relevant for the analysis are included) and reporting (data used as a point of departure for the interpretation are included) without at the same time reducing the illustrations to a simple summation or description of empirical observation that it must rise above in order to gain sufficient reach. Quotes used in the illustrations have been linguistically revised, sometimes abbreviated and focused to give the reader a context, and parts of larger contexts are sometimes emphasized to illustrate a certain phenomenon. The aim has been for them to function as illustrations and descriptions of the phenomenon/a discussed. Precision does not mean mathematical precision in the qualitative method but sooner a depth of understanding for the studied phenomenon, so the ambition has not been to report the full scope of data but to use the complete depth. Glaser and Strauss (1967, p. 228) emphasize the importance of maintaining credibility toward the reader. Hence, to get the reader to understand the theoretical frame of reference and describe empirical data as vividly as possible so the reader can see and hear the people, although always in relation to the theory. The mutual integration of the domains of researchers and practitioners and longitudinal studies, support the validity of the pattern and results presented. Therefor, the focus are on presenting the sum of individual events and phenomena and not the individual events or phenomena. Intensive case studies over longer time periods can show more stable effects and phenomena sufficient for constructing ideal types and enabling a more fundamental understanding for the phenomenon studied.

Comparisons among ideal types are chosen owing to a lack of other equally as complete reference data. Glaser and Strauss (1967, p. 105ff) describe "the constant comparative method" as being useful in the development of new frameworks of ideas. They describe in this four steps: (1) coding and comparison of events that can be traced to each category – which is done in chapters 7, 8 and 9, (2) integration of categories and characteristics – which is done in chapters 7, 8 and 9, (3) making the theory concrete – fewer concepts and categories are needed – which is done in chapter 10 and (4) writing out the theory in statements or as a theoretical discussion – which is done in chapter 11.

In the structuring of the case descriptions (chapters 7, 8 and 9), attempts have been made to give each approach and its organizational setting as vivid a description as possible, given the purpose of the thesis. A general review is first made of the organizational settings, the specific characteristics, analysis of performance and potential changes from one approach to another. Some sort of *"partly"* cover names have been used in the descriptions that reveal the competitive setting in which they are embedded but not the specific names of each project or organization. They are ideal types, and the name of their source of inspiration would not add further value for the reader. In addition, it was necessary to protect the confidentiality in particular of the individuals who contributed. Chapters 10 and 11 present the different approaches' overall consistency, origin, and conditions for sustainability and dispersion. Finally, they end with contingency reasoning – that a certain approach gives a certain result in a certain context.

Discriminant and Convergent Validity

Hackman and Wageman (1995) introduced two types of validity, *discriminant* and *convergent validity*, to measure the value of research. They use *discriminant validity* to illustrate whether the concepts developed significantly differ from alternative existing concepts and use *convergent validity* to illustrate whether there is a high degree of convergence between the researcher's models and those in use in the empirical organizations. These concepts have been used as important dimensions to be taken into consideration in research design, data collection, analysis and validation of results in this thesis.

One circumstance that has been of great importance is that different actors have been primarily responsible for different types of quality insurance in the process and that these responsibilities have converged in interaction during the workshops. Validity has been secured through practitioners' need for useful results and research focusing on red-hot issues. Reliability has been secured through the use of triangulation and continuous validation. Generalizability has been secured through researchers' need of building models and theory[31]. The responsibilities have changed from workshop to workshop depending on group composition and focus, and there have been boundaries rather than borders between the roles and

[31] For further analysis see chapter 11.

responsibilities. The researcher throughout all workshops acted as chairman and inspirer, and the process has faced improvements over time with increased understanding and experience both in leading and facilitating the workshops and in getting as much as possible out of the workshops.

CHAPTER FIVE

THE MODEL FOR INVESTIGATION – A JOURNEY TOWARDS NEW APPROACHES FOR MANAGING COMPLEX PRODUCT DEVELOPMENT

This chapter describes both the model for investigation and its origin that is being applied in the thesis and the set of key concepts that are being used. The different studies and research projects that this thesis is based upon will also be introduced and analyzed.

A Multi-Project and Multi-Method Study

This thesis is based on a total of ten different research projects in which my role has changed during the journey. The research projects, their purpose, the focus of my work and my scientific production within these projects are briefly described in Appendix B. This descriptions will contain brief overviews of the seven organizational settings together with the research that has been performed as a basis for the thesis. For a more extensive review of the seven organizational settings, please see chapters 7-9 and Appendix A.

One of the effects of this multi-project background is that this thesis is based on the use of an extensive triangulation and multi-method because of the specific needs, contributions, focuses and prerequisites in each research project. From the start, each project helped me in defining my thesis focus and, over time, my research focus successively started to form the content and the focus of the research projects. This is a research approach that has firm support in the literature. As we know relatively little about the studied object and the characteristics that are important to measure, it is necessary, according to Normann (1975 p. 46ff), to have a method that contains as broad and comprehensive information as possible in order to successively construct a set of conceptions. Cook and Campbell (1979) also suggest that multi-method analyses are particularly effective when conducting comparative investigations as in this study where the emerging approaches are depicted by comparing them with the dominant one.

Each research project has had its purposes and has used methods appropriate to fulfill these purposes, given certain prerequisites in terms of characteristics of the studied organization, research team, management attention and time frame. Although main purposes, research methods in use and conditions have changed over the projects, my focus and interest in each project have followed an implicit line towards increased understanding of complex product development, and each project has been built on knowledge gained in earlier projects. This means that the main purposes are connected and have developed towards this increased understanding. There are also interdependencies between the projects through co-operation with the same organizational settings (see figure 5.1 and figure III.2, pp. 251-252), which has also supported the step-wise development of the focus in each project.

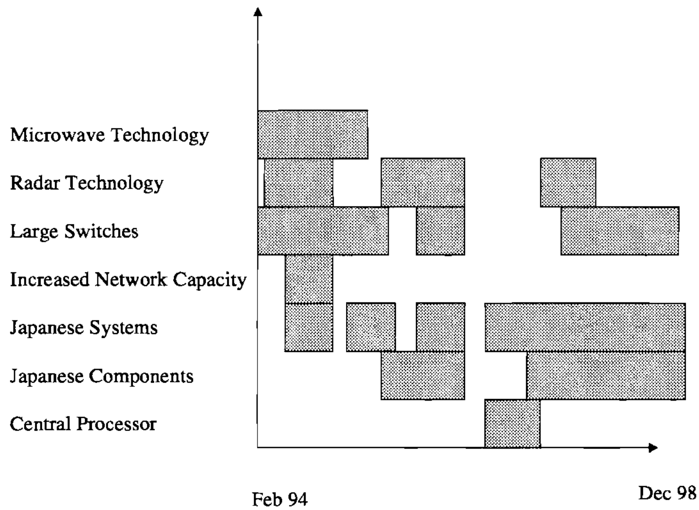


Figure 5.1. Matrix describing the different research projects and participating organizational settings over time

In total, the research projects[32] include 243 semi- or non-structured interviews with key actors in the seven business units, 214 questionnaires, 87 persons participating in defining their communication patterns, 20 persons participating in mapping activities they perform. The research projects also include continuous participating observations and participating actions during a five-year period, continuous spontaneous discussions with key actors in the seven business units, access to all kinds of written information in each business unit. Finally, the research projects include 63 workshops with participants from the seven organizational settings and other researchers searching for an increased understanding of complex product development. Figure 4.2 (p. 180) summarizes the different research methods that have been used over time.

[32] The two latest projects are excluded in this calculation, because others have been mainly responsible for performing data collection

The use of methods has somewhat changed over time and increased understanding of the phenomena under study has intensified co-operation and increased mutual trust. There has been a movement from a domination of open, written information, questionnaires and semi-structured interviews in the early phases to activity mapping and participating observations towards classified written information, non-structured interviews, participating actions, actors participating in analyses and spontaneous discussions. The workshops were used during all phases. The workshops were used as a vital instrument for co-operative formulation of research questions, research design, data collection, data analysis and validation of early results. However, their character changed somewhat depending on how well established the co-operative research approach was in each organizational setting at the time of the workshop.

Transdisciplinarity and Interaction with Organizational Settings as Science

An important point of departure for this thesis is the effort made since 1993 in a research group at the IMIT foundation and the Center for Research on Organizational Renewal (CORE) at Chalmers University of Technology to better understand the project-based development work. An effort that came to be developed into what is now the FENIX program. This research group has had three clear characteristics that have had great significance for the design, performance and results of the thesis: (1) a *transdisciplinary*[33] ambition, (2) a closeness to the organizational settings and (3) an openness to methodological experiments.

The research group has had researchers with different scientific backgrounds and origins. However, all have strived for not to allow themselves to be caught in their disciplinary origins but have allowed the

[33] *Transdisciplinarity* is launched by Gibbon *et al.* (1994) among others to capture the creation of temporary disciplines constituted by representatives of a number of different disciplines to build common knowledge.

research projects' logic and goals create a supplementary scientific platform or discipline that goes beyond the original ones. In other words, there has been a *transdisciplinary arena* in which theoretical structures, scientific methods and criteria for quality have been able to be discussed and developed. In this setting, researchers have been allowed to develop, evaluate and apply new methods and frameworks that best suit the research situation. The organizational and methodological multiplicity together with the set of different frameworks and series of recombinations that follow this kind of openness create a situation in which the academy ceases to be at the center of knowledge creation. And, also in which the preference of interpretation becomes distributed to all actors engaged in the research projects. The research rather seeks knowledge where knowledge exists – and it is to a lesser and lesser extent to be found at a specific academic discipline or institution than it is in different networks consisting of cooperating researchers and practitioners. Neither is the knowledge-creating work unit the single researcher or any single individual in these contexts but rather teams or networks of actors participating in the knowledge creation. These teams and networks are constructed and reconstructed depending upon the research task, the research interest and the applied value of the research focus.

Gibbons *et al.* (1994) among others have in their work described a way of performing research as *transdisciplinary research* or *Mode 2 research*, where, despite the disciplinary background of the researchers, the similarities in scientific ideas have often been greater in the research group than within each respective scientific discipline. This is a valid description for the research group in which the studies in this thesis have been embedded. The research group has also strived for a great closeness with the practitioners from the organizational settings that constitute the basis of the scientific studies. This has opened the door for an increasing cooperation in the entire research process, where industrial partners have participated in designing the research, in data collection and analysis and in the validation of results.

The research group has also (probably feasible due its heterogeneous scientific base and ideals) had a great openness in experiments in the use of methods, which has created conditions for allowing workshops to be such an important component of the research process that underlies this thesis. There has also been a conscious attempt to integrate junior and senior researchers in the fieldwork and in writing articles, which has created a good atmosphere for a rapid introduction to the role as researcher and research community. This has created a good situation for early development of self-confidence as researchers, which has enabled experimenting in the use of methods and in organizing the research projects.

Red-hot Issues as Research Questions to Gather Around

To gather representatives from different academic disciplines and practitioners in common endeavors, the assumption behind the research approach applied in this thesis is that it is of vital importance that this common endeavor is perceived as worthwhile for all actors. The concept of *Red-hot Issues*[34] will be used to illustrate issues that are perceived as both *red* and *hot*, i.e. current and important for different academic areas and for practitioners. The characteristics of red and hot issues are that they often are formulated at a conceptual level, that they reach beyond the single case and are based on researchers' and practitioners' common criteria for relevance. Examples of *red* and *hot* issues that researchers and practitioners have gathered around in the research projects that this thesis is based upon are: *how to create conditions for learning in knowledge-based organizations, how to create conditions for self-organizing in knowledge-based work-groups* and *how different frames of references impact performance in product development projects.* In a transdisciplinary setting, it is also of importance that the red and hot issue

[34] Inspired by a seminar held by Chris Argyris in Gothenburg, november 1998.

is perceived to make use of the different perspectives that transdisciplinarity can provide.

A successfully formulated *red-hot issue* creates the conditions for access to necessary empirical data, active contributions from the different perspective and great interest on the part of those participating in the project those with whom the participants come into contact in the project. If the research issue/s are perceived as both *red* and *hot* by both researchers and practitioners, there is good potential for the researchers and the practitioners being exposed to each other's full complexity. The researcher will perform research exposed to the full set of information and its interdependencies, and practitioners will perform research by using the full potential in scientifically developed methods and tools. These conditions are vital for the creation of joint knowledge and also for knowledge having a meaning for action and an impact on action.

A successfully formulated *red-hot issue* also functions as an artifact for the research project's goals and focus. The *red-hot issue* makes that which shall be achieved concrete and captures and describes the project's domain. This *red-hot issue* becomes a focus to be able to gather around and functions also as a guiding principle in making priorities and taking positions in the project. The *red-hot issue* can and should be reformulated to reflect major findings in the ongoing research project in order to make the focus narrower, to expand it or to change it so that the issue stays both *red* and *hot*.

An Integrated Model for Understanding Complex Product Development

Important shifts in approaches seldom happen overnight and does not always happen in a coordinated way. Accordingly, neither did my journey towards identifying the patterns of emerging approaches happen overnight or even in a coordinated fashion. Hence, in the work to form a basis for understanding the larger shift in approaches for performing complex product development that this thesis discusses, many smaller changes occurred. In retrospect, I would now like to picture my research as an undulating wave with *"crests of waves"* that leave both fragments and bodies of knowledge contributing to an emerging frame of reference for a better understanding of the area of complex product development. Many of those crests did not prove to be of any significance, but some did and contributed to the process of understanding. This non-linear process towards better understanding departed in a rather unstable frame of reference to finally land in something that feels like a valid foundation for further understanding. This section will describe the crests that have had a major impact on the integrated model for understanding complex product development.

During my journey towards understanding the intrinsic endeavor of managing complex product development and also through the process becoming a researcher, new schools of research in the area have been growing stronger, giving new perspectives on how to consider complex product development. Researchers such as Pava (1983), Nonaka (1990, 1994), Hedlund (1994), Lundqvist (1994, 1996), Ridderstråle (1996), Iansiti (1997, 1998), MacCormack (1998), Staudenmayer (1999) and Dougherty (1999) have, as described in chapter 2, sketched out complementary perspectives for how to consider the process of product development. Perspectives based on taking the knowledge created <u>during</u> the process into account. These emerging perspectives have been used to interpret patterns analyzed in this thesis.

Description of Important Crests of Waves

As described above, the journey towards an integrated model for a better understanding of complex product development has not been straightforward, but rather – in retrospect – a journey full of both detours and major findings. The concept *"crests of waves"* is used to describe the important insights that have resulted in a number of experiences that turned into sediments of knowledge that together constitute the integrated research model that is being applied for understanding complex product development in this thesis. These crests of waves are as shown in figure 5.2.

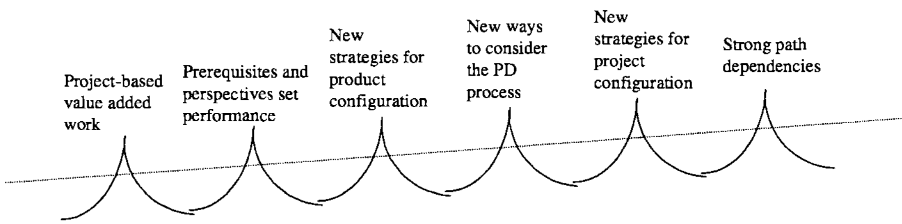


Figure 5.2. The important crests of waves

- ***Most value-added work is done in projects rather than in line organizations***

Part of the departure preparations for my journey was how key competencies among individuals and organizations were identified, supported, created and used in knowledge-based settings. This point of view was used in the first two research projects and partly in the third (described in Appendix B) in trying to understand how performance was improved in complex product development. The analysis did not however provide any evident explanation for why performance in general was insufficient. While analyzing the results of the third research project we realized that we had been using a perspective that did not correspond to the organizational settings. We analyzed the line organizations, while most value-added work was done in different projects intersecting a number of line organizations. Hence, certain conditions or improvements in the line organizations did not automatically provide improvements in total performance. Performance was rather found in the projects interacting between line organizations. This insight changed the perspectives used in subsequent studies in the thesis. We switched the unit of analysis from line organizations at different hierarchical levels to projects and project families. A series of emerging elements – or crests of waves – crystallized on the basis of this new perspective.

- ***Project performance is defined to a large extent by the conditions given at the start and the dominant frames of reference.***

The fourth and fifth research projects aimed at understanding product development project performance, and comparisons between different organizational settings were used to build increased understanding. A series of workshops with practitioners from the different settings led to the insight that the differences in performance between projects and project families could be explained by differences in frames of references among actors involved and differences in the specific conditions set at the start of a project. It was evident that the projects' possible actions were set and limited by the dominant frame of references in the settings. Projects do not work detached from their settings nor do they have the authority to break with the dominant frameworks of ideas. Two new concepts emerged to illustrate vital differences in the conditions that are set at the start; *convergence* and *transparency*. *Convergence* is used to describe actors' and groups of actors' concordance in their perceptions of goals, purpose, and strategies for action and context. *Transparency* is used to describe the ability of the organizational system to give actors and group of actors a holistic understanding. A further definition is given later on in this chapter.

- ***Products and their configuration can be considered in more ways than those prescribed by leading academicians or found in descriptions in leading companies.***

In the following four projects, where product development project performance was investigated further by analyzing more and less successful projects, it was evident that products and their configuration can be considered in more ways than those prescribed by leading academicians or found in descriptions in leading companies. The usual way of breaking a product down from the total system to small pieces based on technical suitability could be supplemented with a process of step-wise building functionality. Focus on and responsibility for the configuration were also found to differ from individual sub-systems to the project management or to most actors engaged in the project. There were also differences in using the current organizational structure as a foundation for the product's configuration and in allowing the unique conditions of the product to be the controlling factor. These differences are described in more detail in chapter 7-10. The insight that product configuration varies and affects performance helped to develop the investigation model earlier used by offering another independent variable.

- ***The process of product development can be considered in more ways than those propounded in leading textbooks and development models.***

In an analysis of the dominant frameworks of ideas in the different settings, we saw that sway-groups could have different perspectives on the process of product development. While most people supported the dominant perspective expressed in a strong belief in planning and a conviction that complexity is best managed by breaking it down into parts, there were also several alternative perspectives. These alternative perspectives are based on the idea that the development process is not sequential, that it is not fully "*planable*" and that it is not unattached from its context. They are also based the notion that an information management perspective is not sufficient in considering product development but that the process should be analyzed as a complex and multi-dimensional knowledge development process, where the output can be more than the sum of all input. Settings in which these alternative perspectives prevail also use development models based on the logic of the work more than the logic of the decisionmaking process – the starting point is the actual growth of knowledge rather than the pre-defined decisionmaking processes. The settings used development models based on test-driven design; i.e. development plans and work packages are created from a test perspective rather than from a design perspective. This insight added a further independent variable to the investigation model.

- ***Projects and their configuration can be considered in more ways than those propounded by leading textbooks and development models.***

The comparative analyses also showed that alternative views of the product and its configuration and of the very process of product development opened up new ways of looking at projects and their configuration. It was found that the more successful project settings used project configurations that were not only simple mirror reflections of the line organizations. Rather than using a strict product breakdown that results in work packages that are then distributed over sub-systems and persons responsible for components and rather than striving for a minimum of dependencies between the parts, a project construction was used that was built upon cooperation, early integration of parts and well thought out dependencies. As a result, mutual dependencies were not considered only to be problematic but were seen as creating value. The formal decision points are lost in these alternative perspectives to the advantage of mechanisms for coordination, and quantitative measures such as time worked, amount of code produced and amount of documents produced were replaced by more qualitative measures such as the actual growth of functionality.

• ***The processes of product development, product configuration and project configuration seldom follow a conscious strategy; rather, they happen often as a result of history.***

Despite the evident impact on performance, the research projects showed that the processes of product development, product configuration and project configuration are seldom results of conscious considerations or analyses or even follow a corporate strategy. The product development processes is often based on common corporate development models that in turn is based on general models developed by academicians and/or consultants. Product and project configurations are often based on the existing organizational structure, the existing power structure in the organization and on the way in which it has always been done. Dominant organizations responsible for vital sub-systems to a large extent define conditions for both product and project configuration. Even if the product and conditions for the project differ significantly from earlier products and projects, product and project configuration seldom differ from those of earlier products or projects.

Important Features in Understanding the Process of Managing Complex Product Development

Performing complex product development requires the orchestration of many complex and interrelated details. Creating an outstanding organization for performing complex product development is most often analogous to or at least supportive for creating an outstanding product. Both require orchestration of detail and are complex and intimidating. Complex product development can be analyzed by tearing it down into pieces and thoroughly examining each individual piece. The understanding of each individual piece is important, but what gives complex product development its character and makes it high performing is the way these pieces work together and their settings in terms of frames of references among key actors. The coming section will describe critical elements or dimensions of complex product development. Nevertheless, it is important that these pieces are continuously put into context in the total system of complex product development. Each description is therefore written as a summary by integrating the pieces to their least possible wholeness. This section as a whole will be introduced with an integrated model of important dimensions of complex product development (see figure 5.3).

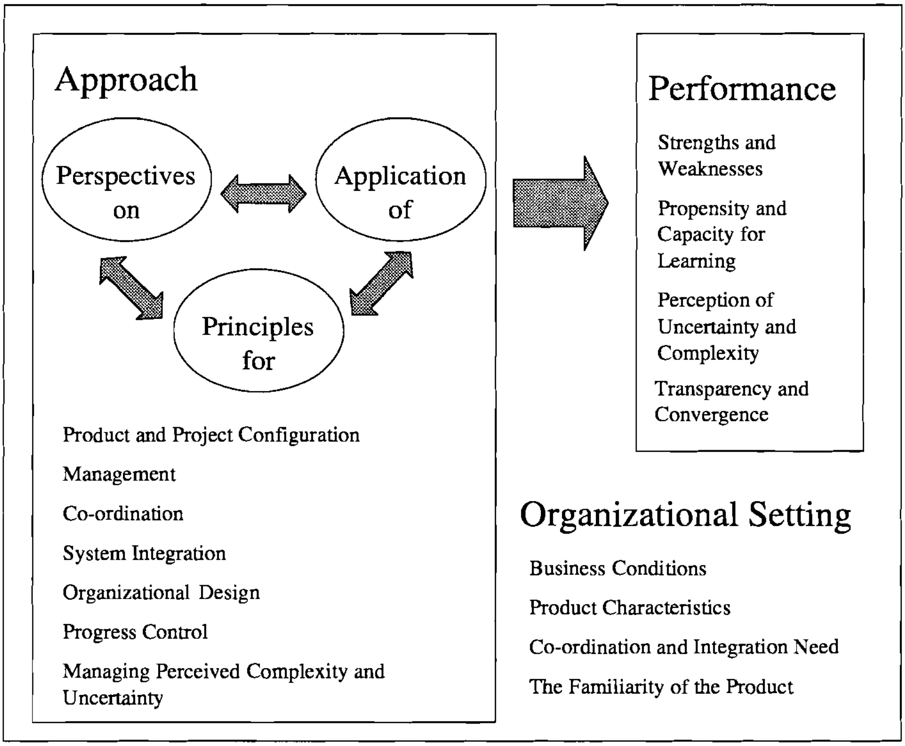


Figure 5.3. Model for investigation in the thesis - important features in understanding how to manage complex product development

The leading literature in the field and the *"crests of waves"* described above have had major impact on how complex product development is considered in this thesis. A number of *important features* or dimensions have been used in describing and analyzing the different approaches, based on the integrated *model for investigation* illustrated above.

Product and Project Configuration

Product and project configuration is normally closely tied and is in some cases a mere mirror image of each other's. Product configuration affects conditions for project configuration and vice versa. The way in which products and projects are configurated has a major impact on conditions for performing complex product development. As mentioned above, the concepts of convergence and transparency are used to capture vital dimensions of the product and project configuration in use. A further analysis of these interconnections is made in chapter 7-10. The features that will constitute the basis for further analysis are the *main principles for configuration*, *degree of convergence* and *degree of transparency*.

Management as Applied by Sway-groups

Performance in planning and product development is determined in part by the number and difficulty of trade-offs inherent in the design and by the character of management applied by sway-groups. Complexity - in the product, the market or the project - appears to be an important driver of difficulties in trade-offs and problems in managing product development. The features that will constitute the basis for further analysis are *sway-group focus*, *dominant value system*, *attitudes*, *roles of different groups of actors* and *division of responsibilities*.

Coordination

Various types of formal mechanisms can be used to link or coordinate the efforts of organizational sub-groups. Formal linking mechanisms that are not sufficient to handle linking requirements will result in poorly coordinated work, and linking mechanisms more extensively than necessary will result in unnecessary costs and complexity. The amount of co-ordination in a team is dependent on the number of communication links that team members need to establish and increases non-linearly with team size (shown by Allen 1977). Later studies have shown that the type of communication link is at least equally as important as the number and that the number increases with uncertainty. Observation studies in a large firm showed that developers spend half their time attending meetings and examples where developers attended up to one meeting for every line of code they wrote. Other field studies indicate that engineers spend between 50 and 75% of their time communicating with others (Tushman 1979). Verbal communication is a more efficient information medium than written or more formal medium because there is timely information exchange, rapid feedback, critical evaluation and real-time recording and synthesis of information. Co-ordination mechanisms are often sketched out along a continuum from hierarchy, structural linking by using liaison roles, cross-unit groups, integrator roles, matrix structures to mutual adjustments and self-organizing. Different dependencies require different coordination mechanisms.

> *"Given the complexity of development projects, and especially the uncertainty and ambiguity often associated with major projects like those assigned to heavy-weight teams, physical co-location has several advantages over even the best of on-line communication approaches. With physical co-location, real-time problems that arise are much more likely to be addressed effectively with all the functions represented and present than when they are separate and must either wait for periodic meeting or use remote communication links to open up cross-functional discussions" [Wheelwright&Clark 1992, p. 207]*

Several researchers have shown that the more complex the dependencies, the less formalized mechanisms are needed.

The features that will constitute the basis for further analysis are *perspective on co-ordination, co-ordination need, type of co-ordination mechanisms in use* and *frequency of and time spent in co-ordination*

System Integration

Technical expertise in a variety of disciplines is essential to developing an outstanding product rapidly and efficiently, but even more important is the way expertise is applied and integrated. Firms face a variety of choices about structure, procedure, assignments and communication to make system integration happen. Effectiveness appears to be a function of consistency and balance in managing the critical linkages within and across both stages of development and sub-systems.

Clark and Fujimoto's (1991) research in the auto industry showed a positive relationship between integration and speed of development, i.e.

where integration is high, development is fast, and there is a negative relationship between specialization and speed of development, i.e. where specialization is high, development is slow. External integration is associated with total product quality, and a strong project management is important for high-performance product development.

System integration will be used to capture an active process with the purpose of distributing responsibility for sub-system boundaries and project progress where actors from different sub-systems together create new knowledge. While *co-ordination* will be used to capture where representatives for each sub-system or task meet to exchange information that is necessary for the work in each sub-system and iterate in predefined borders based on predefined interdependencies.

The features that will constitute the basis for further analysis are *perspective on system integration* and *system dependencies*

Organizational Design

Different strategies for designing product development organizations have been shown to have significant effects on product development performance, and a number of organizational designs have been identified. Wheelwright and Clark (1992, p. 178) define four modes of interaction between reciprocal interdependent sub-groups in a project: (1) *serial interaction* where one group delivers its output and the next group's input when they are finished and sparse communication, (2) *early start in the dark,* where the second group starts its development before they receive input from the first group, (3) *early involvement,* where the first and the second groups start to interact intensely after half the work is done and (4) *Integrated Problem Solving,* where both groups work together from the start.

Wheelwright and Clark (1992) also outline four types of dominant project organization structures: (1) functional team structure, (2) lightweight team structure, (3) heavyweight team structure and (4) autonomous team structure, spanning from functional organization-dominated to project organization-dominated. In later work (Clark&Wheelwright 1996), they redefined autonomous team structures to term them tiger teams.

Functional team structures are based on engineers that are grouped together on the basis of discipline and the fact that work is performed according to predefined specifications. The primary responsibility for the project passes sequentially over time. Major strengths are that the same manager controls resources and sub-project performance, work is performed, judged, evaluated and rewarded in the same sub-organization and that specialized expertise is brought to bear on the key technical issues. Thus the functions and sub-functions capture the benefits of prior experience and become the keepers of the organization's deep knowledge. Major weaknesses are limited total project coordination and lack of integration and the facts that individual contributions tend to be judged largely independently of overall project success and that engineers tend to focus on developing the best component or sub-system and not what is most appropriate for the total project.

A *lightweight team structure* based on those assigned to the team residing physically in their functional areas but where each functional area designates a liaison person to represent the sub-system on a project coordination committee. These liaison representatives work together with a *"lightweight"* project manager who has responsibility for coordinating the activities in each sub-system. A main strength besides those outlined above is that one person is designated to a larger whole than the sub-system. A main weakness is that this person is "lightweight", i.e. power still resides with the respective sub-system.

A *heavyweight team structure* is based on the project manager having direct access to and responsibility for the work of all those involved. Often, the core group of people is dedicated and physically co-located, but engineers are assigned only temporarily to the project.

Autonomous team structure is based on individuals from different functional areas being formally assigned, dedicated and co-located to the project team and the project manager becoming the sole evaluator of the contributions made by individual team members. Such teams are typically allowed to create their own work practices suited to their overall missions. The fundamental strengths are focus and cross-functional integration. Major weaknesses are that little or nothing is "given" and teams tend to make unique solutions and expand their missions.

MacCormack (1998) proposes that, in environments with high levels of uncertainty, firms on average adopt processes with a greater ability to respond to changing information and shows that more complex products tend to possess processes with greater flexibility.

The features that will constitute the basis for further analysis are *base of knowledge, flow of communication, work packages and task allocation, degree of projectification, dominating area of competence, dependencies between project generations* and *dependencies on specialists.*

Progress Control

Progress in product development is difficult to measure but is vital to control. The status of the project is seldom the same as the sum of work spent on it or how complete different parts of the project consider them to be. There is a planning problem of determining how much work a particular part of product development in fact requires or how much work actually remains in a certain part and an integration problem that has to do with what happens in the interface between the different parts. To distribute resources and make priorities in a project and between projects, however, progress and control are a central focus for both project management and other key actors.

The features that will constitute the basis for further analysis are *focus for progress control, type of progress control* and *tools for progress control.*

Managing Perceived Complexity and Uncertainty

The complexity experienced by actors in a product development project is significant for their behavior and for prerequisites for action. If complexity is perceived to be very high, this has an effect on the actors' ability to focus; if it is experienced as very low, it can have an effect of actors' ability to renew their processes (Adler 1996). There are different ways for managing complexity and the strategy chosen for managing perceived complexity and uncertainty will have an impact on actors' perception of it. This perception can often differ significantly from the actual complexity that the product development project faces.

The features for further analysis are *principles for managing perceived complexity and uncertainty* and *actual perception among actors.*

Performance

Studies of product development often consider three major performance variables: lead time, resource productivity (project cost) and product functionality and its quality. These performance variables are frequently considered to be strongly interconnected, i.e. to increase one, you must decrease another. Given a specific corporate strategy, these performance variables can be given priority in relation to each other. Hence, if time to market is of vital importance, it may be possible to increase cost and reduce demands on product functionality to shorten lead-time or, if product robustness is of vital importance, it may be possible to lengthen the lead-time and increase cost. To grasp strengths and weaknesses, the project must also be considered in relation to its settings the project family and the business unit. It will then be important how knowledge is accumulated and shared between individuals and projects.

The features that will be the basis for further analysis is *strengths and weaknesses*, *actual performance* (in terms of project capacity, project speed, product quality and project cost), *propensity and capacity for learning*, *perception of complexity and uncertainty*, and *transparency and convergence.*

Organizational Setting

All the presented aspects of performing complex product development are applied in a given organizational setting. Hence, this organizational setting is important to consider when analysing the aspects and the integrated system of performing complex product development.

The features that will be the basis for further analysis are *business conditions*, *product characteristics*, *coordination and integration need*, and *familarity of the product*.

The Set of Key Concepts in Use

During a five year long journey with Ericsson, concepts from the organizational settings have been collected and applied and new concepts have been developed together with these organizational settings to put words to the emerging phenomena and new findings. This chapter defines the use of both established and new concepts. The central concepts that will be described in this chapter are *complexity*, *uncertainty, performance, leverage, organizational learning, product development, project management*, *organizational setting, paradigm, paradigm shift, sediment, approach*, *sense-making, transparency, convergence* and some *nomenclature specific to Ericsson.*

Complexity

> *"Complexity in a system is due to many and often unknown components that have many and often unknown dependencies and interdependencies between the components in the system" [Flood&Carson 1993].*

The dominant perception of complexity in a system is that it is dependent on the number of components, subsystems and interdependencies, the types of components, sub-systems and interdependencies, the types of context, the number and types of changes that affect the system and so forth. This dominant perspective considers complexity as an *objective* characteristic of a system. In this thesis, the ambition is to analyze complexity in terms of how it affects action, i.e. both actors' *perceptions* and *behavior*. This ambition is based on the assumption that it is important in order to understand complexity in a system to relate it to a perspective and the possibility of the perspective to influence and control the system. The assumption in this thesis is that different organizational settings offer both *"objective"* and *"subjective"* complexity, where the objective is often given but where the organizational setting has the possibility to work to reduce and handle the subjective complexity experienced by actors in the system. The complexity is considered by some researchers as socially constructed, i.e. complexities are:

> *"...neither nature or essence, they are what people perceive them to be..." [Czarniawska 1992]*

The world is not only out there but

> *"...exists in the eye of the beholder. Organizations paint their own scenery, observe it through binoculars and try to find a path through it" [Weick, 1979, p. 136]*

Any attempt to measure an actual or objective value of complexity will lose explanatory value in understanding action or the process of managing, done by and dependent upon humans. Hence, the analysis performed in this thesis is based on the assumption that it is the perceived complexity, not the actual complexity, which drives behavior and therefore affects the organization's propensity and capacity both for performing complex product development and for renewal. Perceived complexity can originate not only from *technical* complexity in the systems that are developed but also from both *market* complexities and *organizational* complexities generated by organizational choices[35].

This thesis assumes that it is the *subjective* picture (the *actors'*[36] *own perspective)* of complexity, not the *objective* picture of the project's complexity, that is decisive for the conditions that prevail.

35 Some studies have shown that the technical complexity can even be of less importance for how actors perceive the total complexity. See for example Adler&Norrgren (1995) or Adler (1996).

36 Actors are persons within the system and key persons acting in relation to the system (e.g. customers, top management, owners, politicians, suppliers etc).

The perceived complexity (experienced by the actors) is dependent on their *specific situation* (for example, the number of targets that an actor or group of actors has, the number of variables that must be studied, analyzed and controlled to achieve the targets, the number of possible measures that are available and the number of relationships between measures, targets and variables affect the ability to predict and analyze results in a system), on the *dynamics* in the system and on the uncertainty that is experienced by actors in the system. However, this thesis will argue that perceived complexity is chiefly dependent on *how complexity is managed* in the system and what *fundamental assumptions* drive the process of managing, in this case, complex product development.

Uncertainty

The uncertainty experienced by actors is a vital component of the perceived complexity and deserves its own description. Uncertainty is dependent on the impenetrability, on delays in feedback on results from action, on difficulties in extracting dependent and independent variables in the system, on difficulties in evaluating performance, on difficulties in predicting prerequisites that emerge and so forth (see for example Nakhala&Soler 1996). The uncertainty that is experienced can, according to Schrader, Riggs&Smith (1993), be categorized into three types: (1) *uncertainty*, i.e. where the system components and their interdependencies are known to the actors but their value is not, (2) *ambiguity level I*, i.e. where the system components are known to the actors but their interdependencies or values are not, and (3) *ambiguity level II*, i.e. where neither the system components, their interdependencies nor their values are known to the actors. If the values of the components and their dependencies are known, this means that there is not only knowledge that a component or a dependency exists but also of the significance of the component in relation to others, knowledge of the component's meaning in relation to others and knowledge of how the component or dependence functions. An example would be that, if actors in a system know what other actors are important to that system and what dependencies exist on what actors, then there is knowledge about the system's components and the critical dependencies that exist. If actors also have knowledge of the significance of different actors for the system, what their contributions are, how their contributions are related to other contributions and what significance these relations have, the system's actors have good knowledge of the value of components and dependencies (Adler&Norrgren 1995). This framework was developed to categorize technological uncertainties but will be used in this thesis to categorize all kinds of uncertainties experienced by actors. The terms uncertainty, ambiguity level I and ambiguity level II will be replaced by *low ambiguity, moderate ambiguity* and *high ambiguity.*

In summary, the term *uncertainty* will be used to illustrate actors' own perceptions of the uncertainty they meet in performing complex product development. The perceived uncertainty will, as the perceived complexity, then be categorized as inspired by Schrader, Riggs&Smith's (1993) set of conceptions into: *low ambiguity*, *moderate ambiguity* and *high ambiguity* depending on actors' knowledge about components, dependencies and their values in the different organizational settings.

Performance

Performance in an organization is of course of vital importance but it is also complex to define, measure and analyze. Performance can be defined according to an industry standard or according to some recommended key figures. However, this thesis focuses on performance of relevance to behavior – thus *actual* performance in a more objective manner is relevant but of less importance than performance as it is *perceived by actors*[37] in each organizational setting. In complex product development processes, one is often shooting at a moving target, i.e. evaluation criteria can change and thus the actors' understanding of these conditions is also an important source of information. As this type of judgement of performance in

[37] Actors are persons both in the system and key persons acting in relation to the system (e.g. customers, top management, owners, politicians, suppliers etc).

complex product development projects and product families is difficult and often insufficient, the analysis will be supplemented by different actor groups' picture of performance and a broader study and triangulation via a presence in the projects and organizations studied.

Actors' own *perceived performance* will most affect their behavior and will therefore affect applied perspectives, principles and actual models for organizing.

Perceived performance is based on both the *actual* performance, the actors' *perception of* performance according to the ideals applied in the organization, the sway-group(s)[38] *outspoken* performance and *the performance potential.*

Effectiveness in a development project or development organization may depend on a number of factors and combinations of factors ranging from pure luck to conscious, long-term efforts to build stable design bases and processes that are improved in each generation. Actual or realized performance is one aspect but it is not sufficient to describe performance in an organization. Potential but not yet realized performance or inherent capacity to perform is just as important an aspect. This inherent capacity is difficult to capture, and this thesis attempts to include conditions for high performance in the concept perceived performance by studying the organization's track record and by seeking an increased understanding of what performance is and what propels it. Conditions for performance also represent a collective term for actual effectiveness in relation to set targets and norms in the projects studied and for the capacity of the development organization to perform in relation to set targets and norms.

---

[38] *Sway-group* is introduced by Stymne (1969) to capture the group of actors that manages and/or defines the prerequisites for managing a specific activity or set of activities. Sway-group is used in the thesis to make the term management both broader to include other influential actors and more distinct by focusing on those actors that matter, independent of their formal title. The use of this concept is further described in chapter 4, pp. 183-184.

In summary, the term *perceived performance* will be used to illustrate actors' own perceptions of performance in relation to dominant norms, and the term *performance prerequisites* will be used to illustrate a potential but not yet realized performance in an organization.

Leverages

The study focuses on leverages, i.e. (relatively minor) actions and changes in structures or processes that lead to (relatively major) significant, enduring improvements. Leverages are activities with high effectiveness and/or marginal usefulness in their use as support for improving the conditions for effectiveness. Leverages are fairly simply implemented efforts that have a great impact on performance, the conditions for performance[39]. Examples of leverages that have been identified are *building dependencies, introducing responsibility not only for output but also for input or gestalting the product anatomy in an accessible format and clearly showing how "life is breathed into it" for all actors engaged in the development*[40]. Leverages are very important in complex product development processes, where the total complexity can otherwise create a feeling of chaos and hopelessness among actors. Leverages can reduce the perceived complexity and create conditions for performance and learning.

In summary, the term leverage will be used to illustrate *relatively minor actions* that lead to *relatively major, enduring improvements* in performance and/or conditions for performance in the organizational settings.

---

[39] The concept of *leverage* is used by Senge (1990) to illustrate efforts that follow the principle of economy of means, where the best results come not from large-scale efforts but from small, well-focused actions. The essence of leverages is according to Senge (1990) in seeing aggregate patterns instead of individual events.

[40] These are examples, and many more are developed in chapters 7-10.

Organizational Learning and Knowledge Management

Organizational learning (OL) and *knowledge management (KM)* represent important new ways to consider competitiveness in knowledge-based firms. They have begun to influence both the management literature and the practice of managing complex product development. The two discourses represent two somewhat different aspects of much of the same endeavor (and represent only a part of a much wider debate on building competitiveness in the future) – how to best manage knowledge in organizations. *OL* focuses on more broadly different organizational mechanisms and designs to facilitate the co-development of individuals and their organizations co-develop to continuously be able to face more and more demanding tasks, while *KM* focuses more narrowly on how the processes of knowledge production and use are managed. *OL* has two major paths, one offering universally applicable models or best-practice guidelines on how to become an *OL* and the other searching for the answer to how an organization learns. *OL* focuses on the need for doing more than simply adapting to changing prerequisites, while *KM* is often associated with products from the IS/IT industry. *KM* is more practitioner-driven and is founded on a resource-based view. Both *KM* and *OL* are related to both individuals cognitive skills but also on organizational and institutional characteristics as organizational structures, incentive systems etc. Scarbrough *et al.* (1998) provide a figure where *KM* and *OL* and related concepts are categorized along two principal axes: *relevance* and *breadth of impact* (see figure 5.4)

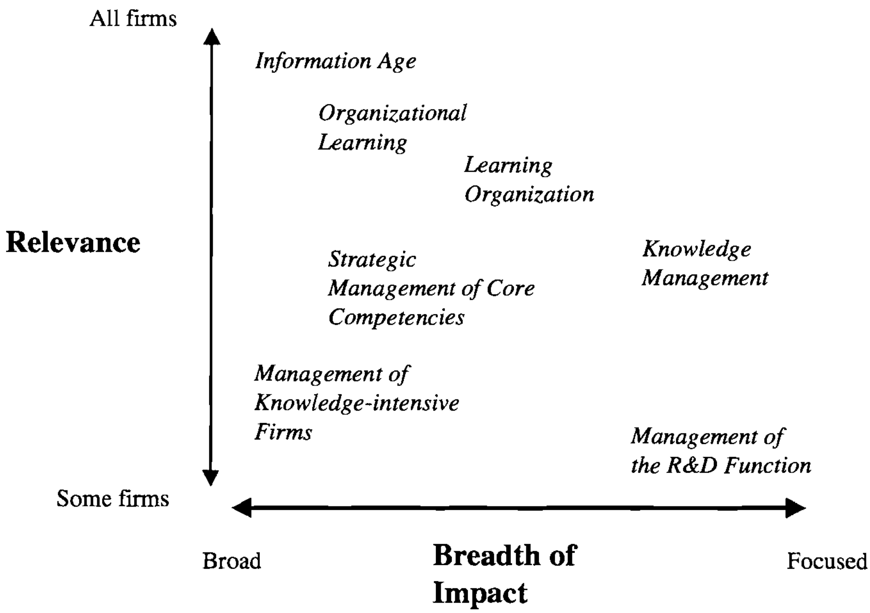


Figure 5.4. Some related concepts, their relevance and breadth of impact (from Scarbrough et al. 1998, p. 6)

The two concepts have been applied in different extension over time, where *Knowledge Management* the last few years have had a significantly larger impact. Scarbrough *et al.* provide a diagram representing the number of references of each over time (see figure 5.5)

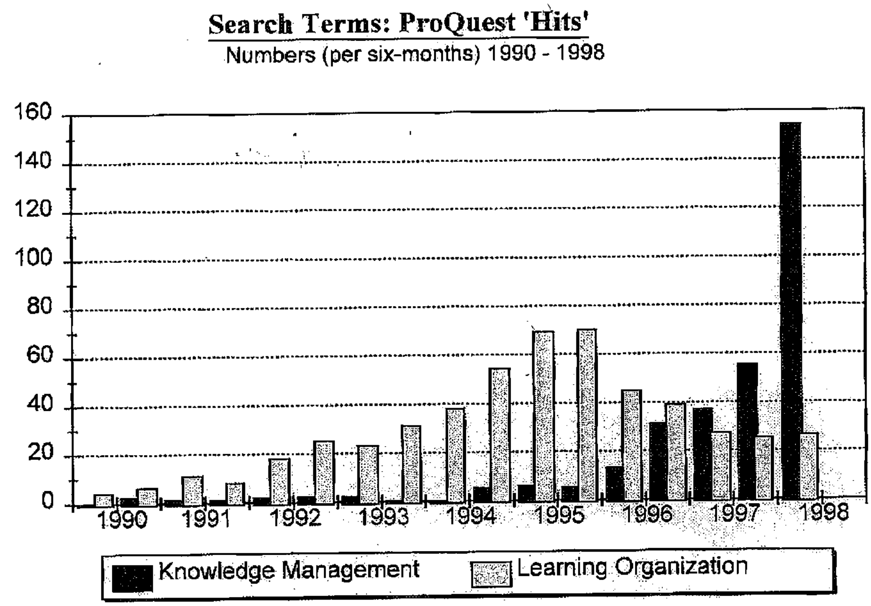


Figure 5.5. ProQuest references to "KM" and the "LO" (from Scarbrough et al. 1998, p. 21)

This thesis focuses on the system of knowledge and how this is managed and often uses the concepts of *OL* and *KM* interchangeably. How knowledge are managed and develops will have a central role in the coming analysis in this thesis, and the use of the concept is thus thoroughly discussed below.

> Organizational learning will be used in this thesis to capture both *knowledge use*, i.e. the processes of identifying, accumulating and institutionalizing existing knowledge from different sources internally and externally, and *knowledge creation*, i.e. the processes of facilitating the creation of new knowledge internally or externally.

Process effectiveness can be reached through both knowledge use and knowledge creation, but knowledge use is becoming more and more strategically important in the telecommunications business owing to the fluid stage in the pattern of innovation. However, firms can not create long-term competitiveness only by replicating their existing knowledge; they create competitiveness by recombining current knowledge

(Kogut&Zander 1992). One illustrative example of this recombination is Ericssons *MiniLinks*[41], which was realized by combining deep technological understanding of radio-links, originally developed in one organization in Ericsson working for the military industry, and deep technological and market understanding of radio switching, originally developed in one organization responsible for mobile switches. The knowledge base in an organization can consist of conceptual knowledge about technologies, processes and practices and about structures, procedures, methods and routines.

An important prerequisite for learning is that the organizational setting and its actors possess both a *propensity* and a *capacity* to learn. Organizations, teams and individuals have a natural resistance to change if it involves questioning traditional knowledge or is a threat to vital structures or values; i.e. the propensity for learning is not normally high. Organizations are based on infrastructures, i.e. rules, procedures, conventions, strategies and technologies, and they are supported or impeded by value dimensions such as interests, paradigms, codes, cultures, myths and knowledge. All of these dimensions are parts of an individual's tacit knowledge and are the foundation for professional practice, status and competence. However, they are also the most powerful obstacles to learning in the organization (see for example Levitt&March 1988). A need for learning does not make it happen, nor does awareness of this need among a minority or on a single level in the organization or even a perceived need by most actors and thereby a propensity for learning in an organization. The larger the need of structural adaptation, the more difficult it is. Argyris (1992) also points out that the more needed it is, the harder it is to perceive it.

An important assumption in this thesis is that organizational learning both prescribes a *propensity* and a *capacity* for learning in the organizational setting and among its actors.

[41] MiniLinks are Ericsson's radio-links, used for wire-less transmission.

What a firm has done before tends to predict what it can do in the future (Kogut&Zander 1992 and Alänge&Jarnehammar 1995). Change, learning and renewal are path-dependent processes. Success, in particular, ties individuals, teams and organizations to the past and current company locus. Bijker (1995) uses the concept of interpretative flexibility to describe the process of gradual preservation to certain given solutions. This means that the factors underlying company success, often referred to as core competencies, distinctive capabilities etc., can also be seen as major causes of long-term inflexibility and resistance to change (Leonard-Barton 1992 and Zander&Kogut 1995). The selection, implementation and use of any given organizational principle exclude others. The principles selected are then functional in the context in which they were chosen but often not in new contexts (Zander&Kogut 1995). The understanding and acceptance of the new situation, although widely spread among higher levels of management, seem to be only partly understood and accepted at lower levels. One reason for this might be that the situation is quite new to design workers and that, aside from formalized work methods and specialization, there does not exist the same tradition as in manufacturing departments for coping with process innovations. Hence there could be said to exist a situation calling not only for adopting new skills in how to carry out the work - there is a need to apply another perspective in the work - and this makes it natural to turn to learning theories to gain insight and develop methods for facilitating transitions among both organizations and their employees. Organizational learning, with its emphasis on involving employees in systematic approaches to increase the organization's competence through individual and collective learning processes, may constitute a leverage that independence-seeking intellectual workers might find challenging rather than feeling it to be imposed by management to achieve unilateral rationalization goals.

Organizational learning is path-dependent, and past success may turn earlier core competencies into core rigidities and major obstacles to learning.

In agreement with the limits of the study, the study focuses on the perspective of the product development organization. When operationalized, this means that learning is meant in relation to the targets that are formulated in the interface between the development organization and the one who make demands upon it. The conditions for learning are represented by the conditions that the organization has for reflection, learning, spreading and implementing activities and/or processes that improve conditions for reaching targets in the development organization. This can take place both by improving the conditions for the organization as a whole and by improving conditions in individual, significant parts that empower the organization as a whole. Internally in the development organization, this perspective is closest to that of the management perspective, and stakeholders such as customers, company management and owners evaluate parameters and organization. Even learning can be dependent on many factors and combinations of factors that can result from pure circumstance to conscious principles for management and learning organization. This study's focus on mechanisms for creating a capacity for learning has to do with conscious activities and/or processes for the purpose of increasing organizational capacity and thus conditions for learning in the individual project(s) and/or project family/ies. A purpose for learning must be set up as something to relate to when defining or measuring learning.

> This study presupposes that learning must be related to a strategically defined target (defined in interactions between marketing, product and project decisions) and in some way increase the success in meeting goals in order for there to be organizational learning. Considering the above limits to the logic of development organizations, learning in this study has to do with to whom it goes, its dispersion and the establishment of more advantageous work methods in the organization and an increase in the organization's ability to identify key dimensions within which learning should take place.

Advantageous here is taken to be in relation to targets and norms set up by the organization. Strategies and targets are not constant – they grow forth

(Mintzberg 1978) both in the company and in the interaction between marketing, product and project decisions. Thus learning also includes a continuous, dynamic synchronization against a number of moving targets over time. Learning mechanisms are activities and/or processes for improving conditions for learning in the organization and imply more for the organization in terms of potential than requirements on efforts to implement. Examples are; learning responsibility in the specification of different development projects defined by earlier project generations, a *"balancing of accounts"* in order to summarize experience from each project generation, reductions in complexity and planned turnover of personnel. Organizational learning will be catergorized into *incremental, discontinuous* and *organizational* as described in chapter 2, pp. 126-127.

This thesis is based on the assumption that organizational learning can and will happen in different forms. The learning will be categorized as *incremental, discontinuous* and *organizational.*

The purpose of mechanisms is to initiate and/or support learning; and learning processes are descriptions of different types of learning and their consequences. Mechanisms for learning can also generate new leverages for effectiveness and thus affect the conditions for effectiveness. Examples of identifying mechanisms are physical forms, arenas for benchmarks, oriented training, coordination/organization motivated by integration, troubleshooters, gatekeepers, master/apprentice concepts, well known product anatomy and use of second best.

Capacity for organizational learning means that conditions are created for actors, groups of actors, projects and project families so that they can reflect upon their experience and their effectiveness placed in a context and that there is a capacity in the organization to handle and use improvements based on these reflections - in terms of preparedness, maturity and insight and in terms of the organization's capacity to use and implement learning. An important component in the actual learning is that the organization learns to extract key competence from the activity in order to focus the learning and process and define within which area priority is given for the organization to learn. The actual results of the learning processes consist of illustrations and indicators of actual conditions, but they are not sufficient as a foundation.

In summary, the term organizational learning will be used to illustrate systematic performance gains in the studied organizational settings.

Dependencies

To understand complex systems it is of vital importance to consider how the different parts in the system relates to each other. The relations between the different parts will be called *dependencies* in this thesis. These dependencies are in the literature often categorized as *pooled, sequential*, or *reciprocal*. When dependencies are considered as *pooled* the parts only contribute to the same whole. When dependencies are considered as *sequential* some activities in any of the parts must be performed before other activities in another part. And finally, when dependencies are considered as *reciprocal* activities in the different parts relates to each other as both input and output. (c.f. Thompson 1967, Scott 1992 or Lundqvist 1996).

In summary, dependencies will be used to describe relations between different parts in a complex system and categorized as *pooled*, *sequential*, and *reciprocal*.

Product Development

The definition of product development that will be used throughout the study follows Ericsson's own organizational design. Hence, product development is performed by organizations responsible for project decisions and product development processes after product decisions have been made, that is, how something will be developed more than what will be developed.

The literature often distinguishes between pre-development and execution, where the former defines the conditions for the latter. However, in this thesis, the concept of product development will be used to capture both pre-development and execution, i.e. all activities that follow a distinct decision to start any activities involving product development resources.

In summary, the concept of product development will be used to describe activities in the business units under study that are connected to the development of existing products and systems and to the development of new products and systems. The thesis is focused on the development that takes place after market decisions and product/system decisions have been made. The focus is on how products and systems are developed, not why.

Project Management

Project management will be used to capture the group of actors that together constitute the project management function, i.e. the sum of total-project managers and all sub-project managers, or, in other words, actors that have the defined responsibility to manage the project.

In summary, the term project management will include total project manager(s) and all sub-project managers.

Organizational Setting

This thesis is based on ten different research projects run in co-operation with different individuals and organizations at Ericsson. Common for all the research projects is that they have focused on different aspects of managing complex product development. As earlier described, the system of managing complex product development has changed somewhat from being considered only from a line organization perspective to being considered primarily from a project perspective. However, the projects are embedded in a setting that must also be considered. The studies have shown that the settings that have the most important conditions for managing the projects are the project family to which the individual projects belong and the line organizations in which these projects and project families are primarily embedded. These projects, their project families and the line organizations in which they are primarily embedded will be referred to in this thesis as the *organizational settings*. The studies in the thesis cover a total of seven different organizational settings.

In summary, the term *organizational setting* will refer to the integrated set of individual projects, their project families and the organizations in which they are primarily embedded.

Paradigms

Kuhn (1962) somewhat introduced and used the concept of *paradigm* in the following way:

> *"A paradigm represents the established pattern of ideas that leads people in the treatment of the problems they face (...) paradigms gain status by becoming more successful than their competitors in solving problems that the group of practitioners has identified as acute..." [Kuhn 1970].*

and gave the following definition of a *paradigm*:

> *"...universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners..." [Kuhn 1970, p. viii]*

Hence, a *paradigm* is according to Kuhn an established pattern of ideas (based on, in competition, universally recognized scientific achievements) that guides actors (practitioners) in action. *Paradigms* have their significance in the following way:

> *"Scientists work from models acquired through education and through subsequent exposure to the literature often without quite knowing or needing to know what characteristics have given these models the status of community paradigms. And because they do so, they need no full set of rules. The coherence displayed by the research tradition in which they participate may not imply even the existence of an underlying body of rules and assumptions that additional historical or philosophical investigation might uncover." [Kuhn 1970, p. 46]*

and represent deeper structures than work practices:

"Paradigms may be prior to, more binding, and more complete than any set of rules for research that could be unequivocally abstracted from them." [Kuhn 1962, p. 46]

Kuhn describes *paradigms* as important and states that they always present frameworks that guide different sets of actors in their daily practice.

The concept of *paradigm* will be used in the thesis to capture the deeper structures, fundamental assumptions and set of rules that guide interpretations of a group of actors concerning a phenomenon. The groups of actors who are relevant in this study are actors who work in or in relation to the product development projects studied and influence the conditions for managing them. The concept of *dominant paradigm* will be used in the thesis to describe the idea framework(s) shared by most actors or groups of actors. The concept of *emerging paradigm* will be used in the thesis to describe the idea framework(s) shared by an increasing number of actors or groups of actors.

In summary, the concept of *paradigm* will be used to describe the set of rules for interpretation and fundamental assumptions on which actors base their perspectives, principles and actions.

Paradigm Shift

Paradigm shift is usually used to describe the transition from one paradigm to another.

"... we shall quickly find that they are not isolated events but extended episodes with a regularly recurrent structure. Discovery commences with the awareness of anomaly, i.e. with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science." (Kuhn 1962, pp. 52-53)

The characteristics of a paradigm shift is, according to Kuhn:

"... the previous awareness of anomaly, the gradual and simultaneous emergence of both observational and conceptual recognition, and the

consequent change of paradigm categories and procedures often accompanied by resistance" (Kuhn 1962, p. 62)

A *paradigm shift* is based on emerging alternative schemes for interpretation and new, detached elements of knowledge that are hard to interpret with by means of the existing paradigm. These elements of knowledge are then combined into a coherent body, and new orders emerge. The concept of *paradigm shift* will be used to describe the transition from one *dominant paradigm* to another *dominant paradigm.*

History has taught us that all paradigms are reconsidered sooner or later, and important paradigm shifts can be discerned only after they have taken place.

The concept of *paradigm shift* will be used to describe significant changes in those sets of rules for interpretation and fundamental assumptions.

Sediments

Danielsson (1983) introduces the idea that every set of ideas, beliefs and rules that imprints a certain time (the paradigm) will also have an impact on what will be perceived as a problem and what will be perceived as an acceptable solution to that problem. The perceived problems and acceptable solutions will then impact the prevalent set of ideas, beliefs and rules. Hence, it is not, according to Danielsson (1983), possible or meaningful to discern ideas or needs as principal causes for development. Rather, Danielsson suggests that the integrated set of perceived problems, ideas, acceptable solutions, beliefs and rules ought to be in focus when analyzing causes for development. To explain how ideas, needs and solutions meet, Danielsson describes the process of *sedimentation*:

"When a company has solved a problem, rules and routines are built to support the present solution" [Danielsson 1983, p. 24, translated from Swedish]

The larger the problem, the more important the solution and, after a while, a perceived successful solution will change any company so that it is adapted to the solution. The rules and routines will protect a successful solution, and an important inertia and a resistance to both perceiving problems that are not solved by the existing solution or ideas that do not accept the existing solution will be built into the company. Hence, solutions will, according to Danielsson, prevail for a long time in organizations, and new acceptable solutions to perceived problems in line with the governing set of ideas will lead to a new layer of solutions – a new *sediment.*

Approach

This thesis focuses on how to manage complex product development. To understand the system and process of managing, different aspects have been considered. As further described in chapters 7-10, three significantly different ways for managing complex product development has been found in the seven organizational settings. From a systems perspective, these three ways consist of perspectives among actors in the organizational settings, of principles or sets of principles for managing complex product development that guide decisions and actions and of actual models in use for organizing action in the organizational settings. These perspectives, principles and actual models for organizing all constitute reciprocal interdependent sub-systems that together make up an integrated system for managing complex product development. This integrated system for managing complex product development will be referred to as an integrated *approach* in this thesis.

The concept of *approach* will be used to capture the integrated system and set of perspectives, principles and actual models for organization. An approach is applied by a group of actors in an organizational setting, and fundamental assumptions or the prevailing paradigm drives the application.

In summary, the term *approach* will refer to the integrated set of perspectives among actors (primarily sway-groups[42]), applied principles and actual models that are used for organizing.

Sensemaking

> *"The concept of sensemaking is well named because, literally, it means the making of sense. Active agents construct sensible, sensable (Huber&Daft 1987, p. 154) events. They "structure the unknown" (Waterman 1990, p. 41). How they construct what they construct, why, and with what effects are the central questions for people interested in sensemaking. Investigators who study sensemaking define it in quite different ways (e.g. Dunbar 1981, and Goleman 1985, pp. 197-217) imply what Starbuck and Milliken (1988) made explicit, namely, that sensemaking involves placing stimuli into some kind of framework (p. 51). The well-known phrase "frame of reference" has traditionally meant a generalized point of view that directs interpretations (Cantril 1941, p. 20). When people put stimuli into frameworks, this enables them "to comprehend, understand, explain, attribute, extrapolate, and predict" (Starbuck&Milliken, 1988, p. 51). For example, people use strategy as a framework that "involves procurement, production, synthesis, manipulation, and dispersion of information in such a way as to give meaning, purpose and direction to the organization" (Westley 1990, p. 337)." [Weick, 1995, p. 4]*

As set forth in the quote above, sensemaking will be used to describe the process of making sense and building frames of references that are then used in guiding both analysis and action. Sensemaking is often though regarded as being in conjunction with action (see for example Feldman, 1989) or as a private and more singular activity (see for example

[42] *Sway-group* is used by Stymne (1969) to capture the set of persons (or sometimes a single individual) that *"...has the power to affect the decisions that govern the overall activity in the organization and wants to influence the organization in accordance with its objectives..."* (p. 29). The concept is further described in chapter 4, pp. 183-184.

Gioia&Chittipeddi 1991). However, in this thesis, sensemaking will be used to capture a collective process based on action and reflection upon action. Hence, sensemaking will be used to capture the collective process of reaching a convergence around interpretations of events and reaching a common and shared perception in the considerable perceptual ambiguity for actors to gather around. The process of sensemaking is assumed to be closely connected to action and reflection upon action, where the outcome of the process more often leads to a development of prior definition than to any fulfillment of this prior definition.

In summary, sensemaking will be used to capture the collective process of reaching a convergence around interpretations of events and reaching a common and shared perception based on action and reflection on action.

Transparency

Large and complex organizational systems are difficult to penetrate and to form an overview of. However, this thesis is based on the assumption that it is important that most actors are provided with this overview. Hence, the concept of *transparency* will be used to illustrate how well the organizational system functions in providing possibilities for actors to form that over-view.

In summary, *transparency* will be used in this thesis to capture the capacity of the organizational system to give actors an overview of the whole system. High transparency will mean a high capacity to provide actors with an overview.

Convergence

Large and complex organizational systems often consist of many different groups of actors with their own goals, strategies and theories upon which they base their action. In these settings, many different perspectives, guiding principles and actual models for organizing can occur in parallel. However, this thesis is based on the assumption that shared mental models are important for managing complex product development. Hence, the concept of *convergence* will be used to describe how concordant actors are in vital dimensions of their perceptions.

In summary, *convergence* will be used in this thesis to capture the concordance in perceptions of goals, strategies, context and theories upon which actors and groups of actors base action. High convergence will mean a high concordance in perceptions.

Ericsson-Specific Nomenclature

As the company is in continuous change, the following descriptions and definitions have come from the period at which the active phase of data collection ended, in late 1998.

<u>Product Development Projects</u>

At Ericsson, most product development is performed in projects, and these projects are responsible for developing coherent products and/or systems to set targets for time and functionality, within set limits in terms of resources and cost. The projects can influence how something is developed but not what is developed.

<u>Main Projects, Projects and Sub-Projects</u>

Large product development projects are organized in such a way that there is a main project responsible for total delivery and customer interaction. This organization is on the business unit level. The main project organization often works merely as a coordinating and administrative function, and no actual development work is done at this level. Below this level, a number of projects are responsible for important functionalities in the project. Project managers at this level are a part of main project management. The project organization, depending on its size, is then broken down into further hierarchical levels such as sub-projects, sub-sub-projects and so on, down to design teams of five to 20 persons. A large and complex product development project normally contains four to seven hierarchical levels.

Project Families and Project Generations

At Ericsson, most projects are embedded in a larger context, and it is not single projects that develop specific products or systems but rather multiple projects that develop specific products or systems and single projects that develop a specific version of a specific product or system. These multiple projects are called project families, and the specific versions are called project generations. Project families and project generations within this family belong to a specific business unit (referred to as an organizational setting in this thesis).

Business Units and Core Units

Ericsson has decentralized business responsibilities to a number of business units in each business area. Each business unit has its own support functions, sells its own products and systems and finances its own product development. Parallel to these business units are a number of core units; the difference between business units and core units is that core units do not have their own external customers but have instead a number of internal customers and are often responsible for a project in a main project. In this thesis, the concept of organizational setting is used to describe both business units and core units. For a more thorough organizational description, see chapter 6.

Marketing

Each business unit has its own marketing unit that is responsible for scanning markets as regards its specific products and systems. The marketing unit is responsible for market decisions; i.e. what markets and customers want and prioritize.

Product Management

Each business unit has its own product management unit that is responsible for scanning future and real-time needs as regards its specific products and systems. The product management unit is responsible for product and system decisions, i.e. what products and systems should be developed and in what order this should be done on the basis of information from marketing.

Product Provisioning

Each business unit has its own provisioning unit that is responsible for developing its specific products and systems. The provisioning unit is responsible for project decisions, i.e. how products and systems should best be developed given the roll-out plans presented by product management.

Functionality, Sub-Functionality and Functionality Growth

Products and systems will have a specific performance when ready, and this performance is called functionality at Ericsson. Sub-sets of this performance are called sub-functionality, and the process from zero performance to full performance is called functionality growth.

Documents

Most development at Ericsson is software development, and the lack of physical products is compensated for by the documents describing the program code and its purpose. Each block of code is represented in a document describing this code and its purpose.

Code

Ericsson still to a large extent uses its own programming language, *PLEX*, and code is what is produced using this language. This code is then integrated into blocks that are in turn integrated into sub-functionalities and so on.

PROPS

PROPS [the PROject Planning System] is a method for establishing, operating and completing projects. The method was developed at Ericsson for Ericsson-specific needs. It divides projects into five different phases and describes in an overall fashion which parts of the projects will be done in which phases. The methodology carefully specifies who is responsible for what and how the documentation should be done. Demands and memory points are described in detail in a large manual meant for project managers, people who work in projects and line managers.

CHAPTER SIX

LM ERICSSON – A CONTEXTUAL AND HISTORICAL PERSPECTIVE

THIS CHAPTER WILL give the reader a brief description of the historical development, revisit a number of important events in this history and elaborate on the specific character of LM Ericsson in general and product development at Ericsson in particular. The aim of the chapter is to give the reader a fair understanding of the context in which the dominant approaches prevail and from which new approaches have emerged. As a firm such as Ericsson continuously re-organizes and changes its focus and structural character, this chapter has chosen a specific time as its point of reference. Hence, this description and the discussions are based on the time at which the empirical studies behind this thesis ended, i.e. from late 1998. The descriptions below come primarily from a number of recent depictions of the company[43] formal Ericsson documents and Ericsson's own homepage[44].

It all started in 1876

Ericsson has, as a number of large Swedish companies, its origins in profound innovations in the late 19th century.

"The company's history dates back to 1876 when the founder, Lars Magnus Ericsson, opened a repair shop for telegraph equipment. Realizing that there was a need for improvements in the telephone instruments available at that time, he started his own production.

---

[43] Lindmark (1995) and Mölleryd (1999) have described the development of *Mobile Telephony* in Sweden and Ericsson's role in this development. Hellström *et al.* (1999) have given a short introduction to the Ericsson case.

[44] www.ericsson.se

Ericsson's first major product to be launched internationally, in 1892, was a desk instrument with a separate hand-held microphone" [www.ericsson.se]

A small home market together with an early identified potential with this new innovation made Ericsson an international player very early in its development.

"As early as the late 1890s, Ericsson had operations worldwide - including countries such as China, Russia and Mexico. The company's executive management already realized that the Swedish domestic market would never be large enough to fulfill Ericsson's business objectives. This foresight is one important explanation why Ericsson today has a very strong international base, with operations in more than 130 countries." [www.ericsson.se]

Ericsson has through this journey built a fair amount of experience and a capacity to manage both distributed product development and working in close co-operation with customers from a large number of countries and cultures.

Today, two main ownergroups; Handelsbanken and the Wallenberg sphere mainly control Ericsson.

LM Ericsson - a Company in Growth and Transition

Ericsson was one of the first companies to be able to provide systems for digital communication and launched the AXE system[45] in the 1970s that has been an important foundation for its growth and broad market presence. Another important foundation has been the close co-operation

[45] *AXE* is an advanced system for digital switching with the attractive character of being both flexible and possible to successively update to new generations of functionality, developed by Ericsson in close co-operation with the Swedish Telecom operator *Televerket* (later renamed to *Telia*). AXE is the world's single best-selling telephone system, with a total of 118 million lines installed or on order in 117 countries. AXE has captured about 15 percent of the world market share for digital telephone stations.

with Telia and Telia's work in early developing the Scandinavian market to a mass market for mobile telephony. These first mover advantages have helped Ericsson to exercise a major influence on the leading standards for the second generation of mobile telephony. Ericsson is today one of the leading suppliers of equipment for telecommunications systems and related terminals and has had major impact on the standards for the third generation of mobile telephony (WCDMA).

Ericsson had 100,774 employees at year-end 1997 who were on average 35 years of age and over one third of whom had an academic degree. Net sales amounted to SEK 167,740 million and order bookings to SEK 179,770 million in 1997. The company has, despite a number of missed challenges and fall-backs, experienced strong, continuous growth during the 1990s (see figure 6.1).

SEK m.	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988
Results for the year										
Netsales	167,740	124,266	98,780	82,554	62,954	47,020	45,793	45,702	39,549	31,297
Operating income	18,757	10,758	8,164	6,553	3,530	1,754	2,282	5,694	4,557	2,678
Income before taxes	17,218	10,152	7,615	5,610	3,108	1,241	1,595	4,855	3,715	1,840
Year-end position										
Total assets	147,440	112,152	90,832	72,999	67,490	56,637	50,080	47,167	40,856	34,625
Working capital[46]	53,095	36,180	29,394	20,899	20,869	20,063	17,497	16,965	14,975	12,944
Tangible assets	19,225	17,754	15,521	13,678	12,363	11,093	10,477	9,058	7,776	6,679
Research and development – expenses	20,906	17,467	15,093	13,407	10,924	7,377	7,054	4,901	4,329	3,529
as percent of net sales	12.5	14.1	15.3	16.2	17.4	15.7	15.4	10.7	10.9	11.3
Statistical data, year-end										
Backlog of orders	77,499	63,401	48,401	45,671	45,296	38,050	28,777	30,415	29,426	26,876
Number of employees – Worldwide	100,774	93,949	84,513	76,144	69,597	66,232	71,247	70,238	69,229	65,138
in Sweden	45,360	43,896	42,022	36,984	31,796	29,979	31,244	30,817	32,226	32,094

Figure 6.1. A summary of Ericsson's journey over a ten-year period.

Even in a longer time period, Ericsson has experienced this continuous growth - since 1961, there has been an annual growth in sales of 8 % and an annual growth of sales per employee of 5 %.

The company is divided into three business areas: (1) *Mobile Systems*; cellular systems, mobile voice and data communication systems, as well as personal pager systems, (2) *Infocom Systems*; multimedia communications solutions for transmission of voice, data and images to network operators, service providers and enterprises and (3) *Mobile Phones and Terminals*, mobile telephones and terminals and other end-user equipment for telecommunications systems.

[46] Current assets less current non interest-bearing provisions and liabilities.

The business area with the highest sales is *Mobile Systems*. This business area has undergone tremendous growth during the last years. In addition to the business units for mobile systems for analog and digital standards, this business area includes business units with responsibility for private radio systems as well as radio messaging and microwave link solutions. As of 1998, Ericsson's solutions for radio access will be included in the business area. During 1997, this was part of a combined offering of access solutions in the business area *Infocom Systems*. *Mobile Systems* had six business units in 1997: Mobile Systems for *GSM, NMT* and *TACS* standards; Mobile Systems for *D-AMPS/AMPS* standards; for the Japanese standard *PDC*; *Radio Messaging; Private Radio Systems* and *Microwave Communications.*

The *Infocom Systems* business area has four business units*: Public Networks, Business Networks, Transport Networks* and *Data Networks.* This business area has in the past year been characterized by a multitude of initiatives aimed at enhancing the efficiency of operations due to weak profitability. The guiding principle for the business area is to retain only those operations which are of major strategic significance or which cannot be carried out more efficiently by external partners.

The *Mobile Phones and Terminals* business area has three business units, one for *GSM* and European standards, one for American *(AMPS)* and Japanese *(PDC)* standards and one for data and satellite terminals. *Mobile Phones and Terminals* apply a regional organization. All operations involved directly with the end-user are combined within this new business area. In addition to mobile telephones and accessories, cordless telephones for home use, personal pagers and terminals for mobile data communications are included in the business area's products. The business area has a highly decentralized organization. The head office is in Kista outside Stockholm, but most of the management functions are based in other locations. Research and development are controlled from Raleigh, North Carolina, in the U.S. and Lund in Sweden. The marketing and sales organization is divided into three regional offices, in Lund, Raleigh and Singapore.

The basic idea behind the organization is that the business areas share a common core technology and strategy. To a great extent, they ought to cooperate closely with one another and provide each other with products and services. On the market, the local companies deal directly with the customer. The organization means that the local market responsibility is further emphasized. Concurrently, the link between the local companies and corporate management is strengthened through the appointment of so-called *corporate officers* for each of the companies, whose task is to support the local operations and protect its interests within Ericsson.

Ericsson's product development and production are distributed all over the world and the product portfolio contains a number of products for digital exchange technology, mobile telephony and defense electronics, among others: *AXE, TMOS, MiniLink* and *EriEye*.

Five of Ericsson's ten largest markets are in Europe. Including Sweden, the European market accounts for 50 percent of Ericsson's net sales, but the three largest single markets are China, the US and Brazil with 12, 9 6 %, respectively, of total sales. The company is the continued leader in switching, with 40 percent of the world market for analog systems and an even higher share for digital systems. The strongest competitors in this field are Alcatel, Lucent, Nortel and Siemens. The market share for Ericsson's mobile telephones has strengthened significantly, to about 25 percent of the world market for digital pocket phones. The strongest competitors in this field are Nokia and Motorola.

The former president summarized the situation as follows in the annual report for 1997, before he instead became chairman of the board:

> *"...Nineteen-ninety seven was a fantastically good year of operations for Ericsson, with new records for order bookings, sales, earnings and positive cash flow (...) Operations in the mobile telephony field continue to develop well - very well. The mobile systems and mobile phone units both continued to expand operations during the year. Ericsson is defending its world-leading position in the systems sector and in 1997 we also achieved a position of leadership with our digital*

mobile phones, with an increase in sales in 1997 of 87 percent (...) Despite the fact that we have experienced fantastic growth in telecommunications for a number of years, I still venture to assert that this has been only the beginning. Mobile telephony is continuing to grow. The Internet and intranet systems are growing even faster. And then we have data communications, and multimedia and many other new services that as yet we can only imagine..." [LM Ericsson, Annual Report 1997]

Ericsson formulates its strategy and focus as:

"Ericsson's mission is to understand our customers' opportunities and needs and to provide communications solutions better than any competitor. In doing this, Ericsson can offer its shareholders a competitive return on their investments." [LM Ericsson, Annual Report 1997]

Ericsson formulates its goals from three main perspectives: from a business viewpoint, from an employee viewpoint and from a structural viewpoint.

R&D Efforts at Ericsson

- SEK 22 Billion Invested 1998 in the Future and a Number of Successful Product Launches

Ericsson has always invested heavily in technical development. More than 18,000 Ericsson employees in 23 countries are active in research and development. In 1998, SEK 22 billion will be invested in trying to secure Ericsson's future position as a technological leader in the telecommunications area. Ericsson has succeeded in launching a number of commercial successes since the early 1940s;

- The cross-bar selector technology for public exchanges (1948)
- The AXE system for digital switching (1976)
- The NMT system for mobile telephony (1977)

- The GSM standard for mobile telephony (1989)
- The development and marketing of a number of mobile telephones (1990)
- The WCDMA standard for mobile telephony (1998)

But also failed in a number of important areas;

- PC (1984)
- Wide-band (1996)

Ericsson's R&D strategy in a number of important areas is to form joint ventures with other leading companies. In the field of special components, which are of strategic importance to the company, Ericsson works in a cooperative venture with Texas Instruments. This cooperation gives Ericsson access to leading microelectronics technology. Comparable joint venture programs are being conducted with Hewlett Packard with respect to the development of operating support systems. Ascom, Bang&Olufsen, Marconi, Microsoft, Novell, Intel and IBM are other examples of companies with which Ericsson is cooperating in specific areas of technology.

Ericsson conducts research and development operations at research and development centers in all parts of the world. Research and development centers are located in: Australia, Austria, Brazil, Canada, China, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Mexico, the Netherlands, Singapore, Spain, Sweden, Switzerland, and the U.K. and U.S. Through its R&D centers, Ericsson conducts worldwide programs of cooperation with international universities and colleges, for example Stanford and MIT in the U.S. and Tokyo University. Ericsson is also an active participant in about 20 EU research projects, including Acts, Esprit, Telematics and Brite Euram. The company is involved in 16 other EU projects through partly owned companies, such as MET in France, Intracom in Greece and others. Ericsson is also involved in several standardization forums in which traditional organizations like

ETSI and ITU will be replaced by highly specialized ad hoc standardization forums, for example IETF and the ATM Forum.

The Vice President for Research and Technology has a clear vision where this network-based organization is further utilized:

> *"I have a vision that all researchers in all parts of the world working in areas of interest to Ericsson should work for us. Since our focus lies primarily in recognizing the potential of new technologies, it is extremely important to identify the world's leading research groups and to establish relations with them. We need a dominant external presence to meet our goals, to communicate our visions and to convince skilled young researchers to join Ericsson."*

Overall coordination of Ericsson's R&D activities is managed by a number of advisory boards that include Ericsson System Council (ESC), Ericsson Technology Council (ETC) and Ericsson Microelectronics Council (EMEC). The focus of Ericsson technology development is: an understanding of end-users, low-cost implementation, silicon integration, software technologies, high-volume production, accessing techniques (radio, copper, fiber), switching (ATM, routers), radio networks, voice, data and video communications, transmission quality and reliability.

Beyond Mobile Switches and Mobile Phones

Ericsson has defined its future closely to the Internet Business, which is gaining speed[47], and aspires to be the leading provider of public data-communication. In parallel, convergence continues in the data, telecom and media industries to create a sector that the telecommunications world calls *infocom* and more and more people in all parts of the world will have access to voice, data, image and video communications. Ericsson's Vice

---

[47] During the year 2000 the volume of data transmission on Internet is expected to be larger than the transmission of voice world-wide via telecommunication systems. In the year 2005 a larger volume of voice traffic is expected to be transferred via internet than via the telecommunication system (Hellström *et al.* 1999).

President for Research and Technology makes the following statement about Ericsson's future:

"When we talk about infocom, we're referring to something beyond today's Internet. In order to get on the train and ride with it, Ericsson will have to be characterized by efficiency, innovation and renewal (...) Partnerships are the only alternative for Ericsson to conduct business in new areas where we have 'missed the train.' We must enter alliances with companies that have established successful operations and work in cooperation with them. Working through carefully selected alliance partners, and using our own strategic skills and experience to participate actively in the broad range of world standardization forums, Ericsson has the ability to create a future based on more than dictates handed down by Cisco and other companies."

Ericsson has formulated a goal to increase growth rate in the coming years to 20% a year and pointed out the single source of greatest potential as identifying and satisfying various user groups, including the communication needs of individual users. According to the CEO, Ericsson will gain leadership by being the first actor to master the integrated set of mobility (independence of wires), accessibility (reliability) and integration (one system being able to handle all types of information). The most important competitors in this field are Cisco and Microsoft.

SUMMARY OF PART II - THE ACT OF IDENTIFYING EMERGING PATTERNS

This part introduces the additional purpose with the thesis – to undertake an experiment in how to perform research. An experiment based on taking one step further in involving practitioners from the organizational settings into the inner processes of research – research design, data collection, analysis and validation. The elaborated research approach is called *table tennis research* to illustrate the close and frequent interactions between researcher(s) and practitioner(s). Work-shops is high-lighted as the most important method for performing the research and its typical characteristics is sketched out.

This part also introduces the specifics that follows that the thesis not is a product of one research project but an except from ten research projects, all of which have followed their own logic, although with common characteristics. Hence, that the model for investigation not is the result from rigour planning but from a large number of impressions, experiences and discussions involving both research collegues but also practitioners from the different organizational settings. And that data collection not follows the precise regulations pre-set by the investigation model.

Ericssons successful development towards a leading position in the field of telecommunications is described. The present strategy for performing complex product development is presented and a number of important historical events are revisited.

PART III – THE DOMINANT APPROACH IN COMPARISON TO NEW APPROACHES FOR MANAGING COMPLEX PRODUCT DEVELOPMENT

"Traditionally research has been considered to deal with creating objective, true knowledge by following scientific method. Through what appear, and are represented, to be data, facts, unambiguous imprints of "reality", one can acquire a competent basis for empirically founded conclusions and – in subsequent steps – generalizations and theory formation. Such has long been the belief, and probably still is among most empirically oriented researchers in social science, whether they are oriented toward studying "objective reality" (social facts) or people's subjective or intersubjective worlds of experience." [Alvesson and Sköldberg 1994, p. 7, translated from Swedish]

As described in chapter 3, this thesis is based on the assumption that perspectives on products and processes impact the set of principles for managing and organizing complex product development, which in turn impact the models used for organizing. These models then impact both principles and perspectives, which leads to a situation where perspectives, principles and application are mutually dependent on each other and develop together over time. This system of perspectives, principles and models as a whole constitutes an integrated approach, which is shown by the investigation model in Figure 5.3, p. 205. The thesis also builds upon the assumption that this integrated approach is of great significance for performance in complex product development. The formulation of new perspectives, principles and models is done, consciously in part, by one or more sway-group(s)[48] so as to fulfill new purposes and goals; but it also occurs progressively in part, through the dynamics initiated by the new perspectives, principles and models that are established and their application. The first shifts in perspective are made by a number of key actors and/or sway-group(s), but these perspectives are subsequently developed in pace with the emergence of principles and their application in organizational models.

This part of the thesis will concentrate on the application of perspectives regarding products and processes, through a set of principles and actual models used for organizing. Perspectives and principles that actors express when they talk or write represent *espoused theories* (Argyris&Schön 1974). Their deeds, or rather the researchers´ interpretations of the mechanisms that manifest themselves in these deeds represent *theories in use* (Argyris&Schön 1974). The *espoused theories* constitute an important part of the project structure while the *theories in use* are directly linked to project behavior or the actual product development process.

In the ten research projects in seven organizational settings, on which this thesis is based, there seemed to be three different approaches concerning how to perform complex product development. None of them was fully and constantly applied in any single organizational setting, although there was a clear division between those organizations that adhered generally to the first and dominant one, and those that followed the second or the third approach. Neither system was openly or consciously employed as an instrument of policy, although many beliefs and empirical methods associated with one or the other were expressed. One approach, which we called *the approach based on planning*, is the dominant one prescribed by

[48] For the development of the concept of a sway-group see Chapter 4, pp. 183-184.

leading literature (see over-view in chapter 2), and descriptions in leading companies appeared to be appropriate to handle very large projects in a stable environment. The second approach, called *the approach based on integration-driven development*, appeared to be an advanced sociotechnical system designed for its special purpose, and seemed to be required for large projects where lead-time and time of delivery were sacred. The third approach, called *the approach based on dynamic synchronization*, appeared to be an up-scaled small-company approach thriving on the edge of chaos, using sensemaking based on action to master continuous changes and seemed to be required for projects exposed to larger and continuous changes in prerequisites.

Three different perspectives on products and processes, three different sets of principles for managing and organizing complex product development projects, and three different actual models used for organizing in the organizational settings, will be introduced and analyzed. The approach *based on planning*, the approach *based on integration-driven development*, and the approach based on *dynamic synchronization*. Empirical observations will primarily be presented as refined, stylized representations for the purpose of capturing what is unique in each approach. Differences between the approaches will be focused upon, and the descriptions are made cumulatively, i.e. each description is contrasted with earlier ones. The concept *"approach"* will be used to describe the system for complex product development that prevails in the respective organizational setting, consisting of perspectives on products and processes, sets of principles for managing and organizing complex product development, and actual models used for organizing. A frame of reference to explain differences in characteristics and performance will be developed.

When we began to study how diverse development projects were organized at Ericsson, we had no fully developed *a priori* system of classification to categorize different approaches. Upon analysis of our observations, we discovered and were able to construct a pattern of three clear groupings of similarities and contrasts between the organizational settings. In order to describe and compare these similarities and contrasts, a descriptive scheme was developed. The variables in this descriptive scheme are described in chapter 5, are shown in Figure III.1 and have been used to make the description that is given below.

Variables in use	**Brief definition**
Product and Project Configuration	Perspectives, principles and actual models that are used to plan, lead and organize the configuration of products and projects. The concepts of convergence and transparency are analyzed.
Management	Focus, dominant value system, attitudes, roles of different groups of actors, and division of responsibilities.
Coordination	Perspectives on, principles and actual models for coordination, needs for coordination, use of coordination mechanisms, and how much time is spent on coordination.
System Integration	Perspectives on, principles and actual models for system integration and handling system interdependencies.
Organizational Design	Knowledge base, communication flow, task allocation, degree of projectification, dominant area of competence, dependence between projects, and dependence on specialists.
Progress Control	Focus, type, and means of progress control, as well as the view of progress control and the relevance of dependencies between subsystems.
Managing Perceived Complexity and Uncertainty	Perspectives on, principles and actual models for managing perceived complexity and uncertainty by different groups of actors and the actual perception among different groups of actors.
Performance	Projects' capacity, cost, speed and deadlines, the products' functionality and levels of quality, transparency and convergence and the conditions for learning within the organization.

Figure III.1. Dimensions in considering complex product development in each approach

Hence, the data explaining this emerging pattern originate from different research projects, but they are described, analyzed and compared according to the same variables and features, developed during and after the empirical studies[49]. The empirical data come, as earlier discussed, from ten different research projects considering various aspects of seven

[49] These variables are described in Chapter 5, pp. 204-212.

organizational settings that perform complex product development at Ericsson. The focuses of each of the ten research projects are listed in Table III.2 below[50]. Even if there not is a full overlap between organizational setting and applied approach, it has proven to be a clearly dominant approach applied in each organizational setting. Five of the organizational settings are representations of the dominant, planning-based approach; one organizational setting (*Japanese Systems*) is a representation of an emergent approach based on *integration-driven development*, and one organizational setting (*Japanese Subsystems*) is a representation of an emergent approach based on *dynamic synchronization*. *Large Switches* is used as a representation of the dominant approach based on *planning*, partly because most empirical work was conducted in this organization, and partly since this organizational setting constitutes such a pure example. Other organizational settings that apply the dominant approach based on *planning* will not be analyzed further in this chapter. Figure III.2 shows organizational settings studied in each of the ten research projects on which this thesis is based, and highlights the three organizational settings that are further analyzed and used as representations of the three different approaches.

Research project and studied aspect(s)	Organizational setting(s) under study
Key competencies for employees and companies, with a focus on understanding learning processes and the emergence of key competence.	Microwave Technology
Flows and processes in complex product development, with the aim of identifying, capturing and illustrating the process from idea/order to delivered product.	Radar Technology
Bottom-Up, with the aim of engaging many engineers in analysis and renewal of work practices.	**Large Switches**

[50] The ten research projects are further described in Appendix B.

Competence Management Process, with the aim of developing a process that helps to transform strategic goals into operative knowledge and competence management.	Increased Network Capacity
Self-Designing Design Teams, with the aim of experimenting with design teams that become responsible for their own management.	**Large Switches** **Japanese Systems**
Self-Organizing Project Organizations, with the aim of better understanding the prerequisites for product development projects in their settings.	**Large Switches** **Japanese Systems**
System dynamics in complex product development processes, with the aim of better understanding the dynamics of and interdependencies in complex product development.	Microwave Technology Radar Technology **Japanese Subsystems**
Prerequisites for convergence in complex product development, with the aim of better understanding how prerequisites for product development projects were created and the relevance of convergence and transparency.	**Large Switches** **Japanese Systems**
Best Practice Product Development, with the aim of better understanding what drives performance in complex product development	**Japanese Systems** **Japanese Subsystems**
Sustainability and dispersion of best practices, with the aim of better understanding processes of sustainability and dispersion of new work practices.	**Japanese Systems** Central Processor

Figure III.2. Performed research projects and studied organizational settings (those highlighted are the ones further described in chapters 7-9)

As described in chapter 4, the analysis is based on a *systems perspective*[51]. To obtain this *system perspective*, it is desirable to capture different relevant groups of actors' perspectives. These different perspectives are used to acquire a better system understanding. It is not the individual perspectives or how the different actors construct their reality that are in focus; these are merely used as contributions in building an integrated understanding of each approach. The focus has been upon trying to understand the processes that go on from the perspectives of several parties, both different sway-groups and actors outside these sway-groups; it is a kind of *"empathetic"* interpretive effort to achieve an improved

[51] *System* will be used throughout the thesis both to describe the perspective applied by me as a researcher (see Katz&Kahn, 1966 or Stymne 1969) and to describe the products that are being developed by the different organizational settings.

system understanding. The actors and groups of actors under study are individual engineers and four sway-groups whose significance varies between the approaches: *technical management, project management, internal project contractors, and line managers* who act in connection with the projects. Each approach, its set of principles and set of organizing models will be described in the same way. The presentations will include a brief description of context, a description and analysis of the specific characteristics according to the variables listed in Figure III.1, an integrated discussion and an overview of project performance in the respective organizational setting. Chapter 8 is based on descriptions and discussions in chapter 7, and chapter 9 is based on descriptions and discussions in both chapters 7 and 8. By way of conclusion, changes from one approach to another are discussed, and conditions for dispersion and sustainability are analyzed.

CHAPTER SEVEN

The Approach based on Planning
– Dominant Perspectives, Principles and Actual Models for Organizing in Use

"If actual performance does not meet the plan, the planning was not rigorous enough." [Line Manager at Large Switches]

This chapter will introduce and illustrate a set of perspectives, a set of principles and actual models used for organizing *based on planning*. It will discuss strengths and weaknesses of these perspectives, principles and models for organizing, and finally provide an overview of project performance in organizational settings using this approach. The chapter will focus on both project structure and project behavior.

Large Switches – The Dominant Approach in Action

The dominant approach was named on the basis of *planning* in the research project, to capture the strong and fundamental assumption that uncertainty is best managed by rigorous planning, and that the process can be compressed by carefully planning and rationalizing in each step. In this approach, activities and parts of a project are sequentially ordered and sharply separated from each other by distinct exit and entry criteria. As a result, later stages cannot start until the exit conditions from earlier ones have been fulfilled.

Large Switches is the organizational setting used as a representation of the dominant approach in action. The business unit manages a group of large projects in the process of renewing and upgrading a product range since the mid-1970s, to extend economic length of life and rationalize further customization. The product development projects have to overcome problems with the old platform as well as to manage new subsystem interdependencies and functionality. The business unit is both large and established, and the market is mature. The scope of the largest projects within the organization is 1000 to 1300 thousands of man-hours; they last approximately 24 months and involve 12-15 geographically distributed design centers and more than 1000 engineers. The projects are not tightly or clearly connected with any specific customer, but to an internal group of stakeholders. The focus of these stakeholders varies from introduction of new functionality to technical rationalization. Studies have been made of three-project generations within the same project family.

Large Switches develops systems for numerous customers in different locations, and the management strives to create resource-effective development by, as far as possible, delivering value to as many customers as possible in each individual project. To make this realistic, a set of motives and incentives are generated to develop as many common components in each customer-specific product as possible. Each project thus has two clear focus: partly to drive the development toward a standard platform based on common components, and partly toward providing sufficient differentiation to each customer in the form of specific applications adapted to that customer. The primary interest in the first focus comes from representatives of organizational units having responsibility for the different subsystems. These representatives promote, besides resource effectiveness, an effort to achieve international competitiveness for one's own subsystem. The second focus is mainly of interest to the customers who are allied with the given project; their number varies from 2 to just over 10, and was between 4 and 7 in the three projects studied. The real customer responsibility lies with the design centers which are located on the market that the customer represents, i.e. Ericsson Italy is responsible for Telecom Italia – Italy's counterpart to Sweden's Telia – and Ericsson England is responsible for British Telecom. As a result, even the local design centers allied with the given project have an important interest in the second focus – sufficient differentiation for each customer. Development resources from the local design centers which collaborate in the projects are chiefly responsible for customer-specific differentiation in the form of application development, but have come to bear an ever heavier responsibility for development of common components for the standard platform in order to achieve greater resource effectiveness.

The illustration below is based mainly on the development of the fourth product generation of telephone switches to primarily the European market, but also based on other earlier, parallel and later projects performed in the organizational setting.

Product and Project Configuration

Large Switches uses different techniques for configuring the product by breaking it down into independent subsystems based on technical suitability. Projects are configurated on the basis of existing organizational structures and an effort to minimize interdependencies. Actors from different subsystems are responsible for performing configurations and changes. The tools and support systems mainly used are *PROPS* (PROject Planning System), *PROMS* (PROject Management System), and *Lichtenberg Risk Analysis*[52] developed for the Ericsson Group in general to perform complex product development. The projects are characterized by high hierarchical convergence and transparency, but low lateral convergence and transparency.

Main Principles for Product and Project Configuration

> *"The complexity of our products is very high, far beyond the human capacity to memorize or control. As long as we deal with only hierarchical structures, it is normally possible to perceive the structures." [Senior Manager]*

[52] These tools and support systems are described in Chapter 5, p. 235.

Products are configurated by breaking down product specification into subsystem specification and breaking down subsystem specifications into sub-subsystem specification, until subsystems as manageable as possible is created. The principle is mirrored onto the line organization where each subsystem, sub-subsystem and so forth has its equivalent in an organizational subunit or sub-subunit[53].

The main principle for configuring projects in this organizational setting is to minimize dependencies between the different parts. The development process is then based on subsystem development and hierarchical integration of the subsystems when each is stable. In using this principle it is of major importance that the subsystems at every step are clean from faults; i.e. before any integration is done, each part that will be integrated must be thoroughly tested and made fault-free. The metaphor *"Clean-room development"*[54] is used to describe this stepwise cleaning process, and the metaphor *"Black-box engineering"*[55] is used to describe the sway-groups' effort at minimizing – for as long a time as possible – dependencies between individual organizational units responsible for developing a subsystem or a component. The process of configuration is defined by the subsystems, and changes are all led by different

[53] This principle is further elaborated in chapter 10.

[54] *Clean-room development* is a set of principles and practices within a process that strives for the creation of *zero-defect design* by maintaining intellectual control over all aspects of the development process. *Clean-room development* focuses on *zero-defect design* that is the prevention of defects in the development process. This focus is in contrast to traditional approaches where defects are allowed to be introduced during the process with the intention of detecting errors later in the development process. The *"right the first time"* approach of clean-room results in higher quality and productivity ultimately decreasing cycle time. The seven *clean-room* principles are team based project execution, process guided execution, specification of behavior, structured programming, step refinement, step verification and review and information-centered process. (*Cleanroom Level 1 Guidebook for Teams 1/155 01-FEABT 101 02*)

[55] The application of the concept *black-box engineering* is elaborated, in chapter 7 and in Karlsson (1998) among others, and has had an important impact on how complex product development is normally organized.

subsystems. The focus in recently performed organizational development projects has been on further strengthening subunits' responsibilities for subsystem performance. This effort is also in line with the corporate strategy:

> *"The complexity of modern technology can be mastered only through determined efforts focused on network architecture and constituent nodes. The approach helps to overcome overall problems, breaking them down into sections that can be developed individually by small teams. The team concept is particularly important in the development of software, which has assumed a growing percentage of total investment costs. That's one of the reasons why I have such high expectations of the relatively new research unit for software architecture." [Senior Manager at LME]*

Convergence within the Project(s)

The projects are all characterized by a complex goal situation. The projects also face a situation with many project clients and stakeholders in different subsystems or subunits, with different demands based on each one's situation. Priorities between demands become hard to establish, due to different perspectives among different groups of actors on both logic and language. Different perspectives on logic mean that different groups of actors relate in different ways to the logic behind goals and priorities, and that each group acts according to its own logic. Different perspectives on language mean that different actors use different words for the same thing, and the same word for different things. This lack of convergence on system level makes any attempt at comparisons between the necessity and importance of demands impossible, which leads to projects that have to aim at many goals perceived as being of equal importance. One example of this is a single project with responsibility for developing 188 subsystems (at lowest level), making 65 new subsystems robust, integrating these 253 subsystems into seven different applications to seven different customers, and simultaneously shortening lead-time from 24 to 15 months. And besides that increasing resource effectiveness by introducing a work practice based on a striving for as many common components as possible. All accomplished in an effort to move resource ownership from the periphery to the center, i.e. from major local companies to headquarters. Too much divergence also has the result that, if all groups of actors were to perform well according to the logic they pursue, the project's goals would not benefit in many cases, and in some cases would actually be disfavored by such high performance.

The scattered picture is even magnified within the project, where different actors belonging to different line organizations pursue their own development strategy at subsystem level. This leads to many different and sometimes contradictory views, in different parts and at different hierarchical levels of the projects, on what the goals are and on which of them is of greatest importance. With changing competitive conditions and emerging demands on flexibility during the development process, this divergence in terms of goal focus accumulates with each change that is being made, and the divergence on both project and subproject level increases in a dynamic context. This situation inhibits the total projects' flexibility and undermines their possibilities of navigating in real time under new conditions.

In sum, the projects at *Large Switches* are characterized by high convergence on the subproject and subsystem level, but clear divergence on the total project and system level. This manifests itself in the fact that different groups of actors have different views about goals, priorities, focus and context, with the greatest spread between subprojects and subsystems rather than between hierarchical levels – there is hierarchical convergence but lateral divergence.

Transparency within the Project(s)

The principles used for configuring products and projects create a focus on local prerequisites and the specifics of each subsystem. Main tools used to integrate between subsystems are project meetings and forums for technical coordination. When using models for organizing based on principles represented by metaphors such as *"clean room development"* and *"black-box engineering"* (c.f. Karlsson 1998), all groups of actors in each organizational subunit are mainly being evaluated according to subproject and subsystem performance – not project and system performance. The consequence is that actors are not being forced into system responsibility, or even responsibility for subsystem boundaries or certain subsystem interactions. This lack of mechanisms facilitating a shared and widespread system perspective and responsibility for the total project leads to fragmentation of goals and to few actors having a clear picture of any wholeness. Engineers in each organizational subunit become highly skilled in development of the subsystem that the subunit is responsible for. Among different groups of actors interviewed, none (even in sway-groups) could give a sufficient picture of the total project they were involved in.

The project management in this approach plays an administrative role, which means that the responsibility for technical and, to some extent, marketing matters is outside their control. Due to a strong line organization, and local design centers that in some degree pursue their own local objectives, many organizational issues also lie outside the project manager's control. Technical management focuses primarily on diverse subissues, or issues related to individual subsystems. Project contractors and line managers who are resource owners get no overview of the project as a whole. Different groups of actors in the same organizational subunit have a good picture of their own subunit and its responsibility, while the same groups of actors in different subunits have a deficient picture of each other's subunits and their responsibilities – there is high hierarchical transparency but low lateral transparency.

Management as Applied by Sway-Groups

Management in *Large Switches* is based on two major assumptions: firstly, that complexity is best managed by breaking it down into manageable units, and secondly, that uncertainty is best managed by rigorous planning. This means that management focuses on different structures, plans and deviations from plans to achieve technical performance, resource effectiveness and profitability.

Sway-group Focus

Sway-group(s) in *Large Switches* focuses on following up outcomes in relation to the plans established for a project. Decision points and scheduled meetings drive development logic, in that these represent a possibility for management to follow up, with given principles, the project's progress and any deviations from the plans. This follow-up and deviation control occur through administrative follow-up systems such as progress reports every other week and diverse project meetings. Use is made of *PROPS* and *PROMS* to create a global language and to be able to manage such large projects and act as support for new actors in the system. The use of sequential models is assumed to support control over quality, and enable mistakes to be eliminated at each hierarchical system level before the parts are integrated into more complex wholes.

> *"The objective of entry and exit criteria is to get a well-structured transition between the different activities. It can then be checked whether the different activities are ready and whether the quality is good enough to enter the next activity." [Technical Coordinator]*

Sway-groups in *Large Switches* pursues at least four goals in parallel. There is a clear effort for technical performance to be world-class, which has been the most definite focus historically. There is also a clear attempt, with increased scope and global competition, to achieve greater resource effectiveness in the development projects. With the more intense competition and the establishment of new customer groups, there is an even clearer effort to make roll-out plans in harmony with more sophisticated market assessments. In recent years, these three focus have been supplemented by striving for, and more definitely following up, profitability in individual deals, segments and regions. For the particular projects, these parallel focus mean that several dimensions are used in parallel when making judgments, priorities and decisions, and that different groups of actors emphasize the focus differently as well as interpreting each focus from their own situation. The striving for resource effectiveness is a good illustration of this phenomenon. From the perspective of top management and its staff, resource effectiveness implies that as many common components as possible are developed in the projects. Thus several customers must pay for the same development, and several projects can reuse the same development, which in turn creates conditions for competitive pricing and greater profits. The goal that was formulated in a large change effort illustrates this striving:

> *"Every block[56] that is opened must contribute to increased value for at least two customers." [Business Manager]*

From the perspective of the individual organizational subunits responsible for the development of a specific subsystem, resource effectiveness means that their engineers are occupied all the time and that this can be foreseen and planned for as long as possible in order to reduce overhead. A further dimension of resource effectiveness from the subunits' perspective is that they can obtain clear interface descriptions which remain valid, because the resources can then focus on developing a stable subsystem (with technical performance of world class) and can minimize transaction costs in the form of intense coordination. This effort is evident in the more important subsystems.

> *"If we just get a clear input of stable requirements, our products are ready in time." [Line Manager in one subsystem]*

From the perspective of a project management, resource effectiveness means that the project's goals are reached with minimal time and resources. The project's goals often represent different types of totalities in product terms, which are distinct from the goals formulated by the resource owners in the organizational subunit responsible for a specific subsystem. By the same token, the project's goals represent a time- and resource-limited effort, which is distinct from the higher management's project-spanning goals.

---

[56] A block is a term for a software package.

Dominant Value System

The projects in *Large Switches* are decision-oriented and focus on formal reports and flows of documents. Questions such as: *How can we best pass formal decision and control points? Which documents have to be finished before the next decision point? Is it possible to get a decision so that we can continue work on subsystems where not all documents are ready yet?* are given highest priority. At every decision point, a detailed plan is created for which activities are executed until the next decision point. This plan is then dominant, and deviations are minimized by control. Parallel development activities are seen as black boxes, i.e. shielded from coordination with other parallel activities. Coordination between different parallel development activities is primarily performed at the formal decision points and minimized otherwise. Stepwise breakdown of functionality and activities to optimize and execute, often sequentially together with sophisticated control mechanisms and top management attention, are applied by sway-groups. The projects focus on minimizing variations through planning and control. The projects execute a distinct strategy to minimize deviations from predefined plans, and potential changes are seen as severe problems that negatively impact the organization's capacity to optimize performance. The dominant value system is based on linear and deductive thinking. The formal organization and formally documented processes are utilized to a great extent. Any departures from plans and formal organization are usually compensated for in retrospect.

Paradoxically, this strong focus on decision-making results in few real decisions being made. Much is driven rather by non-decisions; i.e. by the fact that nobody has made a decision that hinders a given course, so that it can be pursued until such a decision is taken. The lack of clarity allows individual actors to pursue the course that best suits their unique needs and goals, until somebody reacts and takes a decision that adjusts or reorients the activity in another direction.

> *"A local manager always prioritizes the local market and his own profitability at the expense of common goals and endeavors. In*

every project all local forces act in that direction until they reach the limit when someone in Stockholm wakes up and tries to do something about it." [Business Manager]

However, the above picture is not unequivocal: competing perspectives do exist due to subsystem dominance, different sway-groups striving for different goals, and established local theories of action.

Dominant Perspectives on and Principles for Management

The foundation for management in this organizational setting consists of two main assumptions: (1) *complexity* is best managed by breaking it down into *manageable units* as independent of other manageable units as possible –

"We cannot swallow an elephant whole, but must eat it in small tractable pieces. The same is true of a complicated switch. We cannot develop it as a whole system, but must do so piece by piece and then build the parts together into a unit." [Systems Engineer]

and (2) *uncertainty* is best managed by *rigorous planning* –

"With highly complex products like ours and a changing business context, we must be masters in handling uncertainty. To be masters in handling uncertainty we must learn to be more professional and rigorous in preparing for our highly complex tasks. It is of vital importance that the early phases of a project are handled correctly and that all eventualities are analyzed in the planning." [Line Manager in a subsystem]

These two assumptions affect both espoused theories and theories used by all groups of actors in the organizational setting.

Role of Different Groups of Actors

The *project manager* or rather the *project managers* in *Large Switches* have important roles in planning and administrative coordination of the total project. This means following up plans as to functionality growth, costs and time – but above all, searching for deviations. In large and complex projects, this centralized coordination increases the administrative load on project management. Because of integration problems, project management that seeks control over a situation strives for insight into more parts, and with other outlooks, than those that the hierarchical system automatically gives. As an example, one main project manager got progress reports from more than 20 sub-projects at two-week intervals. Each report consisted of activities performed since the last report, developments in cost, subsystem functionality and time, important questions and a risk analysis. Adding this to an already heavy workload did not give project management a chance to do more than to verify that all reports arrived on time. Due to a strong subunit and subsystem focus, all inter-subproject matters fell on the project manager's desk. Avoidance of these inter-subproject matters for as long as possible increased their intensity to unmanageable levels during late project phases. One of the project managers' e-mail intensity illustrates the communication need that arose during these periods. He had a *blip-sound* indicating when an e-mail arrived and, during the three-hour period when our interview was conducted in his room, this blip-sound was continuous with only fractions of minutes between blips. In this situation the project manager has no chance to be proactive or even act in real time. All energy is focused on reactive adjustments of the worst situations or problems that have occurred.

The main project managers in this organizational setting are often seen as lightweight in Clark&Fujimoto's (1995) nomenclature, and lack formal authority to make adjustments within each subsystem. The project manager has an important role in reducing perceived uncertainty and ambiguity towards project contractors and other senior managers by administratively control deviations from plans.

The *technical coordinators* are important in setting subsystems' strategies and in configuring subsystems (which, in aggregate, are the same as the total system in this organizational setting). They pursue subsystem issues in system forums such as different product councils. The *product councils* are important in setting norms, formulating system strategy and setting the boundaries for product configuration. They also act as important advisors to line managers and subproject managers within the subsystems. Technical coordinators are seen as medium-weight to heavyweight in Clark&Fujimoto's (1995) nomenclature, and as important actors in reducing perceived uncertainty and ambiguity among project participants. Their position is strongest during early phases of a project and when major problems occur.

The *project contractors* are important in setting and changing targets and resource allocation, and in monitoring project progress. Project contractors also play an important role in reducing uncertainty and ambiguity for project management. Project contractors are seen as heavyweight and are often important line managers.

Line management is important in setting subsystem strategies that in turn affect product as well as project configurations. Line management also handles ongoing work leadership and resource development. By owning the actual resources devoted to the projects, Line management also plays an important role in inter- and intra-project priorities – it can increase pressure on engineers, and shift work between engineers within their own organizations. Line management is seen as heavyweight.

Sway-group	Role and responsibility
Line managers	Sub-system configuration Operative leadership Resource development Intra and inter project priorities
Project contractors	Project progress Setting and changing targets Resource allocation Reducing uncertainty and ambiguity Inter and intra project priorities Customer contacts
Technical coordinators	Sub-system configuration Sub-system strategies Down-ward reduction of uncertainty and ambiguity
Project Management	Project planning Coordination Monitoring project progress Taking action based on deviations from plans Up-ward reduction of uncertainty and ambiguity

Figure 7.1. Matrix of roles and responsibilities for different sway-groups

Area of Responsibilities

As projects grow larger and less work is being performed in non-projects, line management in *Large Switches* has not changed its earlier role. This has left no room for project management to successively increase its authority according to the size of the assignment. Most engineers within the projects felt a confusion regarding responsibilities in line versus project management. The differences in focus between project managers and line managers were perceived as small or unclear. This indicates an unclear role distribution, and a loss of the potential that exists in pursuing complementary focus. Line management stills own resources in terms of engineers, and the line organization is both distributed and decentralized, which means that the control of resources critical to the project's progress belongs to line managers located hundreds of miles from the project management. The actual resource owners are often local design centers, striving for local profitability and local goals. This impedes the project management in striving to meet the targets set for each project. Examples of when these two efforts do not match are the resource owner's goal of keeping people busy and the project management's goal of minimizing resource usage for a given task. Or when unforeseen problems arise in connection with a local customer so that the local actor tends to prioritize the best resources for solving this problem rather than contributing to common project goals.

The project management also has a difficult role in not being able itself to choose the persons who will collaborate in the project. As illustrated earlier, most things are established at the start of the project, and usually defined by the organizational subunits responsible for the most important subsystems.

Coordination

Large Switches uses an information-processing perspective where effectiveness is the same as efficient processing of information in the organization, i.e. giving the right person the right information at the right time. In this perspective coordination and communication are perceived as a form of transaction cost or effectiveness loss, and should be minimized. Formal mechanisms are often reactive and initiated within a subsystem.

Perspective on Coordination

In Large Switches, coordination is perceived as a non-value-adding activity that takes time from the actual development work. Time spent on coordination is seen as a *transaction cost* in the development process, and the overall coordination need is minimized as far as possible. Great need for coordination in a development project is perceived as a sign of insufficient project configuration.

> *"In periods of crisis we need to spend a lot of time on coordination, but when the crisis is solved we need to get back to our black boxes to be efficient." [Project Manager]*

Coordination is seen a process of exchanging information regarding each other's work and progress.

Coordination Need

Product and project configuration in Large Switches strives for minimizing coordination needs. A successful product and project configuration within this organizational setting creates a situation where the need for coordination is perceived as low initially in the projects, but as high during the later phases – when integration problems occur.

There is a focus at *Large Switches* to build a strictly functional project organization with clear and well-defined borders, in an effort to create an organization as simple as possible in order to develop complex products. A focus clearly based on the *espoused theories* that complexity is minimized by breakdown, but that development best occurs around independent organizational units, specialized in a specific function.

Type of Coordination Mechanisms in Use

Projects in *Large Switches* rely to a large extent on the assumption that sequential or semi-sequential pre-optimized project plans such as *Gantt schemes* will be sufficient as a main coordination mechanism. To support this planning, different generic or semi-generic development models such as *PROPS* and *PROMS* are used.

In parallel to plans and development models, hierarchies in both lines and projects are used to coordinate the work. Different hierarchical meetings for progress reporting, follow-up of plans, and problem inventory play a central role.

Projects at *Large Switches* devote much time and energy, especially in the later project phases, to reactive coordination based on rework necessary to solve problems. As an example, one large project planned for more than 200,000 man-hours to be spent in design follow-up, i.e. correcting for mistakes that were made during the actual project.

Further important mechanisms for coordination that projects in *Large Switches* use are diverse technical coordination forums, such as product councils and technical committees. A product council is responsible for all important resolutions regarding a specific subsystem; typical issues taken up at these councils involve weighing project-specific needs against subsystem strategies. Technical coordinators in ongoing projects, key persons from the subsystem concerned, and system engineers from central staffs man product councils.

Coordination activities in projects at *Large Switches* are mainly focused on hierarchical rather than lateral mechanisms, and on functional rather than cross-functional mechanisms. This means that most of the coordination mechanisms in use exist within organizational subunits responsible for individual subsystems, and between these and the higher and lower hierarchical levels. Figure 7.2 shows the most important coordination mechanisms in use.

	Internal	**External**
Formal	Project Meetings Progress Reports Sub-system Meetings Project Plan	
Informal		

Figure 7.2. Coordination mechanisms in use

Formal mechanisms are those described in manuals, project handbooks, work descriptions etc, while informal ones are not. External mechanisms have participants that are not formally engaged in the project, while internal ones do not have such participants. Mechanisms may exist in more than one position. As the figure indicates, all important coordination mechanisms are formal and internal to the sub-system or the project.

Time Spent in Coordination

The proportion of time spent in coordination is moderate for single project participants and very high for project management and technical coordinators. This follows the principle of break-down, where engineers at the bottom of the project hierarchy ends up with the responsibility for what is considered to be a well-defined independent work-task. This makes it possible for the single engineer to focus this specific task and ignore activities or aspects that not are specified to be included in this task. When specifications and independency shows to fail the hierarchical principle engage project management and technical coordinators to act in the borders and in the *"in-between"* between different tasks.

System Integration

Large Switches performs its system integration late in the process and focuses on creating organizational *"black boxes"* independent of each other. Within each black box, stable sub-systems are created through the use of *clean-room development*, i.e. doing things correctly from the beginning. Project management handles integration and interdependencies, but actual influence on the process resides in the sub-systems' line management and technical coordinators.

Dominant Perspective on System Integration

The business unit is based on low integration between different organizational sub-units and sub-systems. System integration is performed late in the project after sub-systems are stable and clean from faults, in agreement with the *clean-room development* metaphor. There is no striving for systems thinking or responsibility for the total system until the sub-systems are stable, i.e. integration remains a non-issue in the project until the sub-systems have fulfilled the demands and quality levels that are expected. Cross-functional teams do exist, but are used as artifacts where the team represents only an administrative entity, in which coordination and communication remain directed toward the organizational sub-units to which individual project participants belong. Persons responsible for tests relate primarily to other persons with the same responsibility, and especially those who work in the same sub-system. Figure 7.3 illustrates the result of mapping the flow of communication within a design team in a project at *Large Switches*.

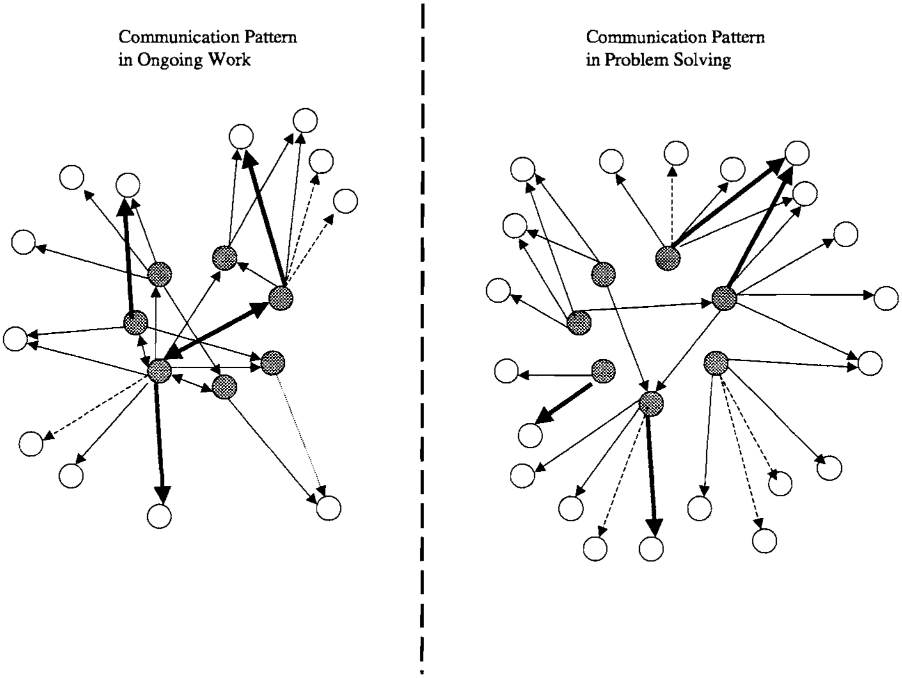


Figure 7.3. Communication pattern in a design team

The figure shows the communication pattern arising from the ongoing work (at the left) as well as the pattern arising from more complex problem solving (at the right). Types of arrows indicate intensity and direction. Dotted, lined and thick arrows indicate, respectively, communication more often than once monthly, weekly and daily. Two-way arrows indicate that both actors perceive the flows of communication as equal. The filled circles are actors in the analyzed *design team*. As the figure clearly reveals, the dependence is much greater outside the team than within it, especially for problem-related communication but also for contacts in the ongoing work. Each team member seems to have his/her own personal network, which often coincides well with the functional specialization, i.e. the evident clusters in the figure. On the whole, there is a strong functional orientation without striving for cross-functional cooperation until late in the projects.

> *"When a designer is satisfied and he feels that he has created the optimal solution, he hands it over to us testers to see if it works and works together with other optimal solutions." [Test Engineer]*

This pattern of limited integration is also repeated on other hierarchical levels. Large Switches, for a long period, has built *Design Centers* all over the world, somewhat specialized in specific sub-systems or parts of sub-systems. Most design responsibility, however, remains in at the higher hierarchical levels, and product and project management is based in Stockholm – implying distributed competence and centralized coordination.

Dominant Perspective on System Interdependencies

Through the far-reaching black-box strategy, the responsibility for interdependencies between sub-systems has been neglected.

> *"Developers take responsibility for individual components but not for the integration process." [Test Engineer]*

Naturally, the problem of integration falls upon higher hierarchical levels in the project. Due to high workload and differing focus, though, this does not become a reality until the actual integration is to be made. Moreover, project management primarily has an administratively coordinating role, and it is representatives of the sub-systems who define the actual conditions for performing the project(s). System integration and system interdependence are seen as being of less importance than sub-system progress, quality and performance. The dominant perspective is that, when sub-systems are stable, integration is a process of simple aggregation or adding up. System interdependencies are seen as controllable through clear, stable interface definitions (fixed borders rather than soft boundaries).

Organizational Design

Functional expertise is the basis of the organization. Communication is mainly hierarchical and sequential along the project flow. Actors from large sub-systems, especially from design departments, are dominant in defining prerequisites in the organization. *Large Switches* is highly dependent on technical specialists, and dependencies between project generations are high.

Knowledge Base

Large Switches is based on functional expertise organized in sub-units responsible for specific sub-systems and formally well-defined tasks. These organizational sub-units are responsible for long-term competence development, sub-system strategy and specific work packages in ongoing projects.

Large Switches has built its knowledge base on distributed competence, geographically dispersed. Organizational sub-units specialized into a specific sub-system are located all over the world. However, most sub-systems and especially the important ones are still managed by design centers located in Sweden and especially the Stockholm region.

In *Large Switches* the organizational subunits responsible for design, and particularly design of the most important sub-systems, are seen as most influential in the development process. It is evident that design drives development and that other functions are seen more as support structures.

> *"We testers always get design blocks too late and we always get the blame for projects running over time, because we are the last ones in the chain, even if it is always the designers who run over time." [Test Engineer]*

Flow of Communication

At *Large Switches* the flow of communication is mainly within sub-units responsible for specific sub-systems. Actors within the project spend most time in communication within their own sub-project. Besides intra-sub-system communication, some hierarchical flow of communication occurs through progress reports and project meetings. When all communication is considered, most communication is directed toward different types of specialists (within the same organizational sub-unit), technical management and project management. For example, project participants in a sub-project say that more than half of their communication is oriented towards searching for competence, advice and active help in finding solutions to emerging problems.

Individual project participants also hold the view that the sub-project is what they work on – not the entire project. They seldom even have any picture of other parts of the project. A sub-project manager describes his view of what happens to his own work after it is delivered to the next sub-project:

> *"It's gone to strangers, and the performance and commitment have dropped." [Sub-project Manager]*

Work Packages and Task Allocation

In Large Switches, the prevailing development organization and previous project configuration largely govern future projects and project configuration, as well as the development of particular work packages. The development of these work packages is based on functional specifications and design specifications and is focused on functional sub-systems as independently and manageably as possible. A functional specification is a document that places demands on a sub-system's performance and geometry. A typical example of a functional specification is that the central processor should be four times as fast as in earlier generations, should fit into certain dimensions, and should have a number of specified interfaces to a number of specified sub-systems. A design specification is a functional specification on a lower hierarchical level and with more details; a typical example of a design specification is that a specific component should have a specific performance and relate to other components and sub-systems in a specific way.

Degree of Projectification

Large Switches has followed the overall trend for telecommunication sketched in chapter 1, in that most value-added work is performed in different types of projects. Despite this evident development, *Large Switches* has a dominant line organization where resources are owned and primarily managed by line management. Most dominant is line management in organizational sub-units responsible for important sub-systems. These organizational sub-units manage product and project configuration.

Dominant Area of Competence

As mentioned earlier, *Large Switches* is dominated by organizational sub-units responsible for design, especially sub-units responsible for the design of important sub-systems. Design drives development and large resource owners, i.e. the large sub-systems, preside over the informal authority and power in the organization. *Upstream*[57] activities are in focus, and early phases define conditions for later phases in the projects.

Dependencies between Project Generations

Most problems with coordination and making priorities originate from design team levels, where responsibilities for earlier product generations limit and negatively affect the focus on current projects. In one studied sub-project, the design teams worked (on average) 38% of their total time with problems in old project generations and decisions in coming project generations and 9% with other matters outside the current project – which left only 53% for the project management of the current project. And the principle for making priorities is simple – *"first things first"* – which creates severe resource problems in current projects when problems occur in earlier product generations. What makes matters worse is the

[57] *Upstream* activities are in this context considered to be concept and engineering design, while implementation, test and tooling development is considered to be *downstream* activities.

continuous reinforcement of this splitting of design resources. When project management discovers that it has to finish in time with fewer resources, it naturally focuses on functionality growth at the expense of verification of functionality and consolidation, which in turn will increase the probability of problems in the delivered product generation. This will increase risks of after-work at the expense of the next project generation, which will force project management to focus all the more on functionality growth, and so forth.

Dependencies on Specialists

In Large Switches, *design teams* are often insufficient for handling ordinary workflow within the team. Intra-team communication is of minor importance, and teams work as artifacts. Figure 7.3, above on page 274, illustrated the communication pattern of sub-project participants in a large project. As Figure 7.3 indicates, dependencies on specialists are high both for ordinary workflow and for problem solving. A further analysis, regarding what type of specialists the dependencies involve, shows that system designers, special troubleshooters and block managers are the most wanted.

Progress Control

Large Switches focuses its progress control on sub-system progress and uses primarily quantitative measures of input resources such as man-hours spent or code produced. The progress control is based upon formal progress reports and hierarchical meetings focusing on deviations from plans. The structure for progress control is based on the need of decisions from senior management.

Focus of Progress Control

At *Large Switches*, both the actors within organizational sub-units responsible for a specific sub-system and the actors outside this specific sub-unit focus on sub-system progress in agreement with the *clean-room* and *black-box* metaphors. Releases to later phases of the project are not done until the design chunks are firm and stable at the sub-system level. Integration of sub-systems and sub-system interdependencies in a product is perceived as something undefined and something that will be handled when it occurs. Progress in the total system is seen and managed as the sum of progress in the sub-systems. An effect of this perspective is that system progress is always overestimated, since integration problems are insufficiently taken into account. Figure 7.4 shows a typical project in *Large Switches* and its progress over time. Sub-system progress follows the plan but, when actual progress at system level is tested, it becomes evident that total project progress does not follow the plan.

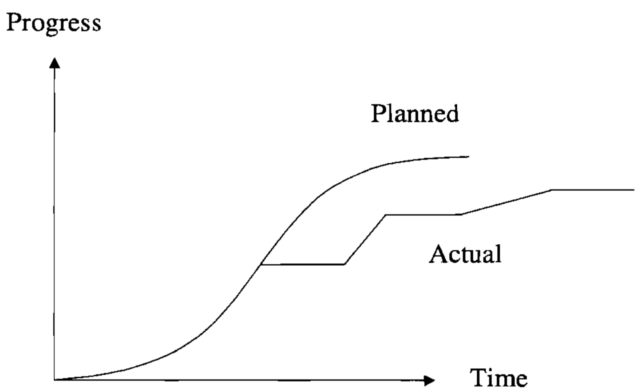


Figure 7.4. Typical project progress compared to plan over time

Figure 7.4 show the typical characteristics of perceived project progress in a project applying the approach based on *planning*; (1) late integration therefor late notice on deviations, (2) a distinct curve when perceived meets actual (i.e. when first integration is made), and (3) do take longer time and seldom deliver what was once agreed upon.

The actual progress control in use is detailed control of input resources, as man-hours and/or produced code and documents. Detailed measures of these input resources are gathered and accumulated hierarchically to project management. This accumulation of input resources in relation to planned input resources is then used as an indicator for total progress. As an example, if a project is planned to result in 100,000 lines of code, it is perceived as 70% ready if 70,000 lines of code have been produced. Or worse, if a project is planned to need 100,000 man-hours it is perceived as 70% ready if 70,000 man-hours have been spent.

> *"Management focuses on detailed control over fictive progress mainly by counting documents." [Design Engineer]*

A common characteristic of both the first focus on subsystem progress, and the second focus on input resources, is neglect or underestimation of the challenge of system integration.

Type of Progress Control and Tools for Progress Control

Large Switches uses progress reports and hierarchical project meetings as the most important tools for progress control. These reports and meetings have gradually acquired an ever more administrative significance, and several groups of actors have low respect for their correctness.

> *"We all indicate in our progress reports that progress is OK and we all show with transparencies during project meetings that progress is OK; but as soon as any subproject gives up and admits it is late, you can feel how everyone in the room takes a deep breath when they realize that they now have extra time to catch up to their plans. It's like playing Old Maid." [Subproject Manager]*

The timing and content of both progress reports and project meetings are based on *Large Switches'* decision needs and adaptation to development models such as *PROPS* in order to create bases for decision at critical points. The progress control that is carried out focuses upon deviations from plans – a form of objective measure. The follow-up concerns quantitative measures such as *number of specification items in definition phase, lines of code in software design,* and *pieces ready to be tested.*

Individual project participants see progress control in a more qualified sense as a missing link that is replaced by technical coordination in committees and administrative coordination in project meetings. When the measures being followed up have proved to be bad indicators of the actual progress, and the follow-up that is made has not proved useful for the actors in the project, accuracy and focus have gradually decreased.

As a whole, the progress indicators used at *Large Switches* have a weak validity, both due to underestimation of the challenge with system integration and due to lack of confidence in the indicators among those who provide them with content.

Managing Perceived Complexity and Uncertainty

Sway-groups play an important role in reducing complexity and uncertainty for other actors in the system and all groups of actors lack sufficient knowledge about the components in the organizational system, their critical dependencies, and the value of both components and dependencies.

Principles for Managing Perceived Complexity and Uncertainty

At *Large Switches* the sway-groups have an ambition to plan and check for reduction of perceived complexity and perceived uncertainty. The principles in use are to break down complex structures until complexity is perceived to decrease and to plan rigourly until uncertainty is perceived to decrease. Sway-groups are trying to stay in control of the situation by building and maintaining a strong bureaucracy with specialization, division of work and rigorous plans. This is based on small minority (sway-groups) defining the preconditions for the majority's perceptions of both complexity and uncertainty. History, in the form of the prevailing organization and the dominant ideas, plays a great role in the definition of preconditions for handling complexity. Perceived complexity is as discussed in chapter 5 closely related to uncertainties, where a high perceived complexity often follows a high perceived uncertainty and vice versa. *Large Switches* use several tools for reducing perceived uncertainty and thereby also reducing perceived complexity. Help is obtained from rigorous software systems for risk analysis such as the *Lichtenberg model.*

> *"If the risk in a project is too high, it is of vital importance to locate where the risk originates from and break this risk into its components until it is under control." [Subproject Manager]*

Perception of Complexity and Uncertainty

Within the projects in *Large Switches*, all groups of actors lack sufficient knowledge about the components in the organizational system, their critical dependencies, and values of both components and dependencies[58]. There are indications that actors in projects within *Large Switches* also lack sufficient knowledge about external factors such as connection with external demands or earlier, parallel and coming projects. The result is that the perceived complexity is equivalent to moderate ambiguity.

It was evident from interviews that the technical and market complexities at hand were creating less uncertainty than the organizational complexities. The first project generation in the project family under study has introduced a functionality, which well exceeded most expectations

[58]The framework to categorize technical uncertainties presented by Schrader, Riggs & Smith (1993) is used in this thesis, as described in Chapter 5, pages 214-215, to guide the interpretation of the data regarding actors' perceptions of complexity. In this context the framework is used to reflect not only technical complexity but also organizational complexity and market-related complexity. Schrader, Riggs & Smith's (1993) taxonomy will be used in the following way. Knowledge about values of components and dependencies means that an actor has not only knowledge about the existence of a component or dependency, but also knowledge about its relative importance and how it works. An example is that if actors in a system know which other actors are of importance to the system and which dependencies are of importance and to whom, there is knowledge about the system components and critical dependencies. If actors also have knowledge about the different actors' relative importance to the system and what their contribution is and how this contribution relates to other contributions and the importance of these relations, there is a knowledge about values of components and dependencies (Adler&Norrgren 1995).

and became an important issue for future technological strategies. Especially the systems designers had substantial control over the technical issues, and while not all testing and design engineers had experience from the previous projects, using the same project participants in the third-generation project as in the earlier ones transferred some learning.

In this respect one might conclude that the system components were known, but not the interdependency between the components or the values of the components and interdependencies. The most striking results were tied to the perceived organizational complexities. It was only the systems designers who had a clear picture of components and interdependencies, in the sense that they knew which they were, and how they worked. The software designers, test engineers and even the project managers had only vague ideas about interdependencies and what value different elements of their work added to the total project or the effectiveness of the process. One example was that system designers handed over specifications to testing at an early stage of the process, so that the testing engineers could start to prepare the set-up of the testing procedures. When software designers later on ran into problems with implementing the systems specifications, the changes made were not communicated to testers, who accordingly prepared testing procedures from old and wrong specifications. Neither did changes made in the overriding project, which affected the platform project, get communicated to the right persons within the platform project.

The market complexity was also perceived as high, due to major recent changes with cost and time becoming ever more important. But also due to the introduction of new customers who are not even interested in the technical solution, the introduction of new corporate strategies where platform-thinking and the share of common components between projects becomes increasingly important, and due to distance from the customer. The organizational units responsible for product provisioning, i.e. the actual product development projects, seldom had any contacts with any market people or customers.

The conclusion that can be drawn is that actors in *Large Switches* perceived complexity and uncertainty as equivalent to *moderate ambiguity*[59]. The majority of the actors did not know the interdependencies between system components or their values. Neither did the organization in terms of project and line management have an adequate understanding of the system's interdependencies and values.

Performance

Perspectives, principles and actual models for organizing in *Large Switches* support tradition, but projects seldom meet set or emerging targets. The organizational setting do accomplish very large projects but they are too late, too expensive and do not always deliver what was agreed upon. The actors in the organizational setting did not perceive performance as low, either, but rather as satisfactory if anything. Both the propensity and the capacity to change are rather low.

Project Capacity, Lead-time, Cost and Functionality

Large Switches has unique experience of performing large projects. There are many examples of projects including 1,500,000 man-hours and 1500 engineers, and some examples of projects including over 3,000,000 man-hours that actually have been completed. These endeavors are made with globally dispersed resources and in parallel to other large projects that make claims on the same resources. Projects at *Large Switches* normally run over time and take 18-24 months to perform. Large projects at *Large Switches* normally plan for a great amount of rework and design follow-up. In one project it was planned for more than 200,000 man-hours of rework. Normally, some complicated functions are transferred to later project generations due to insufficient functionality growth.

---

[59] In the framework presented in chapter 5, pp. 214-215 developed from Schrader, Riggs&Smith's (1993) original framework for categorizing technical uncertainties.

Project cost normally exceeds budget and set targets at Large Switches. Actors including sway-groups at *Large Switches* normally have limited cost-consciousness.

Conditions for Organizational Learning

The propensity for incremental and discontinuous learning is moderate and the propensity for organizational learning is low. However, the capacity for all types of learning is low. The projects are carried out in an organizational setting that historically has been very successful in terms of product innovation, i.e. it has been launching projects that have contributed a great deal to dramatically upgrading some of the core products of the AXE system. The fact that the competitive situation has changed does not seem to have penetrated the organization under study in the sense that the engineers have reconsidered their way of working. Hence, the sway-groups perceive performance as satisfying, and most of the engineers did not have any opinion or perception of total performance. *Large Switches* has an imperative need to put process innovation on the agenda, since it seems to be a non-issue. This is obviously not an easy undertaking, due to the imprinting of earlier successes with product innovation and the lack of experience and positive attitudes towards rationalization in these settings.

When the researchers fed back results of the interviews to the group of respondents, it was evident that there had been few systematic attempts to do something about the situation. Although similar problems had appeared in the earlier project generations, there existed no common codes or collective memories of past similar problems. The fact that no one really had an idea of the accumulated losses and rework caused by the lack of knowledge concerning systems interdependencies indicates that the value of interdependencies between components and how the work were not known to the project members. When this fact was fed back to the actors and an element of self-design was introduced, the actors were quite open towards, and competent to analyze and suggest necessary changes at their level in the system. Actors identified preventive factors for organizational learning and renewal of work practices such as: unpredictable change requests, insufficient hand-over both between design and test and between system design and design, reorganizations during the project, insecure resources and priorities, insufficient analysis of dependencies with other projects, and misinterpretations of the customer goals.

The strong subsystem focus also limits the preconditions for learning. Projects and sets of projects at *Large Switches* provide feedback within each subsystem, not between subsystems and seldom at system level. As discussed by Levinthal and March (1993), local learning tends to be myopic, which can lead to oversimplified and rigid mental maps, knowledge creation in already existing areas, and internally focused actions.

The dominant view on working with learning influences the organization's capacity both to identify learning need and to implement learning over time. In this organization, the line organization creates a parallel organization outside the projects, responsible for identification and implementation of improvements, which has consequences for penetration.

> *"There is probably no clever project manager who has time to spend very much energy on writing such a final report, and especially not on reading someone else's." [Subproject Manager]*

On operative level in the projects, half of the actors asked think that there is no continuous work with improvements in their organization and that they do not take any active part themselves in working with improvements. Actors in these projects at all hierarchical levels see process improvements as hard to measure and follow up, and therefore hard to motivate and implement. If actors cannot see any point in working with learning or create any feedback loops for improvement work, it is very hard to establish and implement. Responsibility for learning and improvement is separated from actual work processes in parallel organizations, as staff functions or specific projects take responsibility for learning while the ongoing work is performed in the product development projects. Moreover, all improvement projects focus on process renewal, i.e. on reconfiguring how the development process is depicted, not on how the products or the organization ought to be considered.

The Approach based on Planning – an Integrated Discussion

The approach based on *planning* as it is applied at *Large Switches* supports tradition, have accomplished very large projects, but often leads to long project lead-time, and the projects performed seldom meet set or emerging targets. The matrix below summarizes the integrated set of perspectives, principles and actual models used for organizing in terms of each variable discussed above.

Characteristics	***The Approach based on Planning in Action***
Product and Project Configuration	Product and project breakdown with minimized dependencies. Use of *"black-box engineering"* and *"clean-room development"*. Actors from sub-systems are responsible for configurating and making changes. Hierarchical convergence but lateral divergence among group of actors. High hierarchical transparency but low lateral transparency.
Management	Based on the assumptions that (1) complexity is best managed by breaking it down into ***manageable units*** as independent of other manageable units as possible and (2) uncertainty is best managed by *rigorous planning*. Focus is on following up outcomes in relation to the plans established for the given project, and decision points and scheduled meetings drive development logic. Decisions oriented and focus formal reports and flows of documents. Four main goals: (1) world-class technical performance, (2) resource effectiveness, (3) market-oriented roll-out plans and (4) profitability for individual deals, segments and regions. The organization is based on low integration between different organizational subunits and subsystems. Important sway-groups are: line management responsible for product and project configuration, resource allocation and actual work, project contractors responsible for decisions, technical coordinators responsible for subsystem performance and project management responsible for administrative coordination.

Coordination	Coordination is perceived as a non-value-adding activity that takes time from the actual development work, and time spent in coordination is seen as a *transaction cost.* Strives for independent organizational units specialized in a specific function. Large Switches uses sequential or semi-sequential pre-optimized project plans and generic or semi-generic development models together with hierarchies, in both lines and projects used to coordinate work – mainly focused towards hierarchical rather than lateral mechanisms and functional rather than cross-functional mechanisms. Sway-group members spend much time on coordination while non-sway-group members spend little time on coordination.
System Integration	*Large Switches* performs its system integration late in the process and focuses on creating organizational *"black boxes"* independent of each other. Within each black box stable subsystems are created through the use of clean-room development, i.e. doing right from the beginning. Project management handles integration and interdependencies but actual influence on the process resides in the subsystems' line management and technical coordinators.
Organizational Design	*Large Switches* is based on functional expertise organized in subunits responsible for specific subsystems and formally well-defined tasks. The base of knowledge is distributed competence, geographically dispersed. The flow of communication is mainly within subunits responsible for specific subsystems, and hierarchical towards management or different types of specialists. Prevailing development organization and earlier project configuration govern future project configuration and development of individual work packets. Most value-added work is performed in different types of projects, but a dominant line organization owns and manages resources. Design drives development and especially subunits responsible for design of important subsystems. High dependencies between project generations and on specialists.
Progress Control	Focus on subsystem progress and deviations from plans. Uses formal progress reports and hierarchical project meetings as most important tools for progress control.
Managing Perceived Complexity and Uncertainty	Plan and control for reduction of perceived complexity by breaking down complex structures until complexity decreases. Rigorous planning and deviations control for reduction of uncertainty. A small minority (sway-groups) in each sub-system defines the preconditions for the great majority's perceptions of complexity and uncertainty. Perceived complexity and uncertainty equivalent to moderate ambiguity.

Performance	Unique experience in performing large projects, 1500 to 3000 km-hours. Projects normally run over time and take 18-24 months to perform, and normally plan for large amounts of rework and design follow-up. Normally most complicated functions are transferred to later project generations due to insufficient functionality growth. Actors including sway-groups at Large Switches normally have very low cost-consciousness. Both the propensity and the capacity to change are rather low, even though no active resistance can be seen. There is no continuous work with improvements. Actors see process improvements as hard to measure and follow up, and therefore hard to motivate and implement. Responsibility for learning is separated from actual work processes in parallel organizations. Learning and renewal focus on process configuration. Problems in learning often occur due to unplanned personnel turnover and lack of arenas in use.

Figure 7.5. Summarized characteristics of the approach based on Planning

CHAPTER EIGHT

The Approach based on Integration-Driven Development – Emerging Perspectives, Principles and Models for Organizing in Use

"Processes, methods and competence can be utilized far more efficiently by seeing the total flow and increasing the communication between both processes and persons." [Project Manager at Japanese Systems]

This chapter will introduce and illustrate an alternative approach for managing and organizing complex product development introduced by an organizational unit in Ericsson, through analyzing perspectives, principles and models for organizing in use. This analysis is based on descriptions of the project organization, the functionality of the products, the seemingly impossible challenge, variables presented in Figure III.1 and the project performance – so far. The *Japanese Systems business unit* will be used as the organizational setting representing this emerging approach. The representation ends with a summarized matrix of key characteristics of this new approach based on *integration-driven development*, compared to the dominant approach based on *planning* described in chapter 7. The aim of the chapter is to describe differences between the dominant approach and this new approach in perspectives, principles, actual models used for organizing, and performance.

Japanese Systems – The Emerging Approach based on Integration-driven Development in Action

This new approach was termed *"integration-driven"* during the research project. Unlike the approach based on *planning*, the integration image aims to capture the continuous striving for systems integration. As practiced at *Japanese Systems*, the main difference is the downstream teams' early involvement in the project. In fact, the basic idea behind the approach based on *integration-driven development* was to have much of the development and design work driven by downstream phases such as integration and verification to deliver on time. In order to start all parts of the project early; all entry criteria were heavily downplayed.

> *"The traditional approach based on planning cannot help us deliver in such a short time. To radically shorten lead-times, it is a must that we start integration and verification of system functionality much earlier than we ever have done before. This will require tight cooperation between the different parts of the project." [Project Manager]*

The *Japanese Systems* business unit had a favorable starting point in building a new organization with the first thoughts starting in early 1991. The business unit was built to compensate the founders' earlier experiences with insufficient performance in their complex product development, with inspiration from leading firms, new ideas and the specific demands the initial customer had.

> *"On April 1, 1992, the new business unit was founded, and the job of creating our organization for development of base stations from scratch started at the highest possible speed." [Business Unit Manager]*

The business unit as a whole, despite its intensive growth, is among the smaller ones in Ericsson - a fact that provide actors the possibility of having an overview. The market and set of products are both expanding rapidly. The largest development projects in the organization span over 400 to 1000 thousands of man-hours, last approximately 18 months, involve five to six geographically distributed design centers, and engage approximately 600 persons during the most intensive phases. The projects are highly customer-focused, and one or a few main customers are emphasized for each project generation. Studies have been made of three project generations in the same product family, all developing and customizing mobile switches for the Japanese market. The first project generation in the family has been seen and broadly accepted as one of Ericsson's best-practice projects according to speed and punctuality of delivery. This first project generation has also constituted the foundation on which the business unit has been built.

Japanese Systems delivered the first turnkey system in the spring of 1994 to a large Japanese customer and, immediately afterward, signed for a new project that was delivered in the spring of 1995. At the end of 1996, Ericsson held 20% of the Japanese market for PDC systems[60], with some 1,700,000 users. Still, in 1998, Ericsson has maintained its role as leading foreign telecommunications company on a very fast growing market. In addition to this, Ericsson delivers base stations which are fit into Japanese mobile telephony systems. As of 1996, Ericsson was the only foreign company that had secured any strong foothold in the Japanese market for mobile phone systems. NEC is the strongest Japanese competitor, but Fuijitsu and Mitsubishi are also strong in switches and radio-base stations, respectively. Up to 1998, six project generations had been completed and a seventh was under completion.

The illustration below is based mainly on the development of the fourth product generation of a cellular system to the Japanese market, but also on other, both earlier, parallel and later projects performed in the organizational setting.

---

[60] *PDC* stands for *Personal Digital Cellular*, and is the standard for mobile telephone systems used in Japan.

The Project Organization

The business unit running the mobile systems projects for the Japanese market – *Japanese Systems* – is located in Stockholm and the projects that so far have been completed are managed from this unit. Although project management is located in the Stockholm area, much of the design work is done in other design centers in Sweden (Göteborg, Karlskrona, Linköping, Luleå and Skellefteå), in Finland, in England, in Germany and in the USA. Ericsson's local company in Japan mainly contributes marketing information, customer support and installation of the systems. The design centers are assigned full responsibility for providing one main functionality each, but the configuration of the whole system is coordinated in and managed from Stockholm. The studied projects include approximately 600 engineers each, and project members are dedicated to working primarily in one project at a time, although there are significant overlaps between starting, ongoing and finishing projects at the business unit.

Functionality of the Products

Technologically, the products for the Japanese market are derived from the Ericsson *GSM* and *AMPS* systems, which were developed for the European and American markets, respectively. By being a derivate of other *"old"* products they meet the same challenge in backward compatibility. The basic features of the system correspond well to the *GSM* system, but it is a product line of its own fitting the specific requirements of the Japanese customers as well as the standards of Japan. In terms of the system's use, there are some specific traits in the Japanese markets. The operators exploit the capacity of the systems to a much higher degree than in other countries, which puts high requirements on quality in order to avoid downtime due to overload. One illustration is that, when the full *shinkanzen trains*[61] leave the tunnel outside Tokyo central station, several hundred mobile phone users are activating their

[61] Tokyo's most crowded commuter train, primarily used by businessmen.

cellular phones at the same point of time, and in the next few seconds all connections are handed over to a new base station. This example is known as one of the toughest demands put on mobile systems worldwide. The Japanese mobile telephony systems also provide operators with the most available services and functionality due to high user demands.

The Seemingly Impossible Challenge

After the first deal with the Japanese customer was closed, key actors realized that normal ways to develop such systems were not sufficient and therefore not possible to use. History had shown that normal practice meant severe problems in coping with development lead-time and time to market. Most projects do not deliver agreed functionality in the agreed time. In this specific situation any delay of delivery would cost Ericsson both a significant fine and – more importantly – loss of further contracts and a potential market presence. Earlier attempts to dramatically shorten lead-time had resulted in severe quality problems and loss of functionality, which were not acceptable in this specific situation due to the quality-conscious customer. Hence, this emerging need to focus on speed, quality and functionality forced key actors to search for a new perspective both on products and systems (the content of development) and on the execution of development projects (the process of development).

> *"The customer told us during discussions of the details and specifications of the project that we had to come up with a better timetable. Otherwise they would consider choosing another supplier, probably one of our Japanese competitors. After some internal discussion we came to the conclusion that we must meet the challenge. We all knew that we had to be able to get the system ready and working for commercial operations by April 1, 1994." [Marketing Director]*

Product and Project Configuration

Japanese Systems configurates products according to how functionality is best realized. Projects are configurated according to how logical integration of sub-systems is best made and to a focus on important and troublesome boundaries. A few key persons are responsible for configuration and changes.

Main Principles for Product and Project Configuration

To manage the complexity in developing telecommunication systems, the dominant approach has been, as described in chapters 2, 7 and 10, to break the system down into sub-systems, sub-systems into sub-sub-systems and so forth, until a perceived control over a certain part is reached, as described in the preceding chapter. Over time, these organizations have developed specific areas of competence around their parts of the system, which become natural sub-organizations such as divisions, departments and work groups, and the organizations develop as mirror images of the functional breakdown of the systems. In the dominant approach, integration is not an issue until full stability has been reached at the sub-system level. Traditional problems with late integration, substantial rework and poor system performance lead key actors to question such an approach.

> *"By tradition, functional specifications are written on the sub-system level in AXE 10. This means that the same function may be described in a number of different functional specifications, depending on how many sub-systems are involved during implementation. Normally no coordination at all is made between these different functional specifications specifying one and only one specific function." [Systems Engineer]*

Key actors also recognized that traditional development models with a sequential logic did not support the way of working that was necessary to develop a system in the agreed time. Instead they focused on dependencies between sub-systems, an integration of sub-systems as early as possible, and continuous system thinking, i.e. that system performance is often realized in more than one sub-system and/or in the boundaries between sub-systems. They agreed that planning and project optimization in advance gave only an illusion of control, not an actual reduction of complexity or ambiguity, and did not support the actual work in the project. Deviations from plan could not be handled as exceptions or something that the process was unable to handle. Instead they searched for a development model that handled both externally and internally induced dynamics and deviations as a natural part of the actual progress in the development process.

A critical issue in the first project was how to configurate the product to be designed. The configuration was assumed to have a large impact both on conditions for project configuration in terms of activities, actors, their sequence and dependencies, and on the functional block-diagram in terms of the actual realization of product functionality. Since these two aspects of the project and the product were seen as two sides of the same coin, a new way to configurate both products and projects was implemented, using an interdependent combination of project breakdown and product build-up activities.

> *"The guiding principle for the organizational structure of the project has been the structure of the product. Therefore the structure has been stable in spite of the stormy journey. How functionality has best been realized has defined how the project best is organized to realize this functionality as soon as possible. The project is only a tool for building the product." [Project Manager]*

Project breakdown traditionally meant the process of breaking down customer requirements into prerequisites and work packages for the project and its sub-projects. This type of project breakdown has, however, led to severe difficulties in integrating the sub-systems developed by the respective sub-projects, and these difficulties have occurred rather late in the project due to traditionally late system integration. To cope with these difficulties, key actors established new perspectives on products by focusing on complete systems and interaction between sub-systems rather than on the sub-systems themselves. During the process, they developed the concept of *"least possible wholeness"* to describe the holon organization[62] they aimed to create. Key actors also established a new perspective on development processes, by focusing on the dynamics and the new knowledge created rather than the pre-optimized plan. Hereby, a process of product build-up and a process of integration and verification were created.

The process of product build-up was based on another new concept – *product anatomy*. The product anatomy is used to describe a graph of the "natural" architecture of a product, based on functionalities, sub-functionalities, their dependencies and how they are realized. The product build-up thus became a process of building up the product from zero to full system functionality in accordance with the product anatomy. Parallel to this stepwise realization of functionality, a pattern for stepwise integration of functions into system functionality and verification of the work was developed. This process was called the integration and verification plan (*I&V Plan*). A procedure which describes the natural dependencies between sub-systems, and where logistics and how to actually build the system are taken into account, is in focus. This integration and verification procedure is used as the main map for managing design activities. Instead of appointing work groups for specific design objects, the concept of least possible wholeness, as mentioned earlier, was created as an organizing principle guiding project configuration to focus continuously on natural holons.

This new way of building up instead of breaking down products differed substantially from normal practice. Historically, the project breakdown process had been a process where customer requirements were broken down to system specifications, further broken down to functional specifications, and further broken down to design specifications, directed

---

[62] The holon organization is used to describe organizational units that operate simultaneously as wholes unto themselves and as parts of many other wholes in the same time and introduced and described by Arthur Koestler (1989).

toward both software and hardware development. Based on design specifications, work packages were determined and distributed to the organizational units.

To reduce lead-time, traditionally sequential activities, such as system configuration, system design, detailed design, integration and verification, were performed in parallel. This parallelization gave more time to each activity and project phase despite the radically shortened lead-time, and made an early integration possible. The parallelization also meant a potential risk under high ambiguity by using large shares of scarce resources for short times. To cope with this concurrence, the projects, as mentioned earlier, integrated and verified functionalities as early as possible and, during the whole process, highlighted critical dependencies by giving boundary responsibilities to the sub-systems. This made actors at sub-system levels interested in progress in other sub-systems on which their work was dependent, and therefore interested in the progress of system functionality.

Convergence in the Project

The projects in this organization are clearly converging systems in comparison with projects performed using the approach based on *planning* (see Figure 8.1). The degree of convergence indicates the prerequisite for actors in a project to obtain knowledge about critical issues for the project. High convergence means that actors at all levels are connected both with the overall project mission and with the processes used, and that there is an agreement to set an overall goal priority. In a converging system, actors perceive their situation as less complex, and it supports them in identifying and implementing improvements at all hierarchical levels.

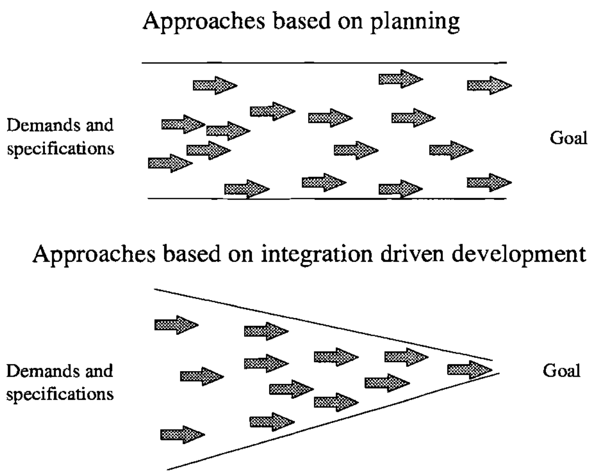


Figure 8.1. Degree of convergence in projects using different approaches

In a non-converging system, actors have insufficient knowledge about critical issues and there is room for competing views on purpose, goal and customer interests. This creates a non-interpretative complexity and a feeling of chaos among actors. A converging system supports the creation of an overall and motivating meaning through a reduction of complexity around one or a very few key issues. The projects in this organizational setting clearly give prominence to customer delivery, while projects using the approach based on *planning* usually do not give prominence to any specific factor. In our interviews, key actors in this organizational setting showed a surprisingly high convergence in perceptions on vital aspects of the project(s). Depending on whom one asks, the answer varies from technical development to effectiveness of the existing technological base or even customer delivery. However, the convergence showed to be high among key actors but only moderate among the large number of engineers.

The projects studied in this organizational setting have had the characteristics of *"turn-key"*. Hence, a total delivery of a given functionality to a given customer at a given time and place, while the projects using the approach based on *planning* have had the characteristics of a complicated supplier with many and often unknown interdependencies.

The degree of convergence is dependent both on external convergence, i.e. degree of convergence given to the project by the organization and stakeholders, and on the internal convergence, i.e. degree of convergence created within the project based on principles for managing and organizing the project itself.

> *"The functional contents and the package plan must be fully accepted by all sub-projects. It is not acceptable that one sub-project delivers a function on its level in a package and another sub-project delivers its part of the same function in a later package." [Technical Coordinator]*

By using mechanisms facilitating lateral communication clarity, couplings between goals and processes – and relatedness between individual contributions to overall purposes – are created. Members of the sway-groups in this organizational setting therefore have a relatively thorough systems overview and act to provide critical parts of the project with this overview.

> *"Each and everyone must feel responsible. Create constancy of service, pride and workmanship. In the project it was a goal that all communication should be made with clear messages, and everyone in the project should know his part in relation to the total project. Everyone then created his own goals." [Sub-project Manager]*

Transparency in the Project(s)

Projects in the organizational setting are managed to be interactive and to agree with an *interactive logic*[63]. To create a meaning and a direction in such a context there is an emerging need for internal transparency and connectedness, so that actors in an organizational system can have a sufficient knowledge about the system and their own role in relation to the system.

In the studied projects, actors perceived transparency as moderate to high and had moderate to good (but not always sufficient) knowledge about the system characteristics. The differences were between the group that was defined as key-actors and those that were not. Actors in projects using the approach based on *planning* do not have this knowledge, and there is a lack of internal transparency. One reason is that many of those projects are larger and more geographically distributed, and project management themselves have problems in defining goals and scope. However, even despite those differences, they do not use as effective mechanisms to create transparency as does *Japanese Systems*. In a complex product development project lacking transparency, actors have no clear knowledge about purposes, goals and customers. This makes it hard to estimate and judge consequences from changes and deviations and thus to make decisions about giving priorities. Thus, an organization without transparency creates worse conditions for high performance and learning.

> *"Visualize everybody's contribution to a complete system and become a part of it." [Project Manager]*

---

[63] *Interactive logic*, in contrast to *sequential logic*, is based on an acceptance of initial uncertainty and ambiguity and, instead of trying to demarcate and plan away these uncertainties, it is vital for an organization to build the capacity to cope with them. The *interactive logic* is based on ensuring that the existing base of knowledge is always tested at every real-time moment against alternative perspectives and new potential knowledge, i.e. that all possible inputs are continuously scanned and analyzed. Managing and organizing development processes ought to be based on an *interactive logic* where it is meant to optimize interdependencies and dynamic knowledge-creating and problem-solving processes (Nonaka 1990 and Lundqvist 1996).

In *Japanese Systems*, there is a large concordance and focus throughout different hierarchies in the projects. The organizations using the approach based on *planning* show another, more complex picture with missing objects and, in some cases, counteracting views. The process used to perform projects ought to be related to, and supportive of, the dominant view of business. Hence, it is unfortunate when competing perspectives flourish within a project and when actors at different levels are not synchronized or, at worst, are not aware of the business logic used and its consequences.

Projects in organizational settings using the approach based on *planning* are characterized by the absence of common meaning or consensus about what the project will achieve, and there is no distinct process perspective. On a more general level, there is no common vision of how to manage and organize projects. This means, from an actor perspective, that there is no motivating meaning with which to focus work. In this organization, there is a quite clear system thinking and system knowledge, which creates a motivating meaning at different hierarchical levels. The dominant and concordant view of the business logic creates better conditions for both high performance in the running projects and learning within and between projects.

Management as Applied by Sway-groups

Japanese Systems strives for controlled dependencies between parts of the projects and uses specialists for coordination in critical boundaries. Project management is based upon early integration and stepwise functionality growth. Sway-groups focus on time, integration and actual functionality.

Sway-group Focus

Sway-groups at *Japanese Systems* focus on project speed, time of delivery time and actual functionality growth.

> *"Our mission is to deliver products ON TIME to our customers, meaning that they will be satisfied and consequently pay... Focus is on what is important, not on what is interesting." [Senior Manager]*
>
> *"Counting documents or measuring how much work we have performed will not tell us anything about how ready we really are. The only thing that counts is functionality that is testable. Not until you have made the first call in a switch do you really know that you can make this call and that this functionality has been realized." [Test Coordinator]*

Sway-groups in this organizational setting see a danger in relying only on plans or development models. There is an evident effort at building a capacity in the project to handle emerging situations, i.e. being in control <u>in</u> different situations.

> *"It is not enough to do right the first time. The concept of right can and often will change over time (...) It is all about practicing and experimenting. We can't always be right from the beginning, but we must be prepared for not being right and cope with that without losing the time schedule." [Sub-project Manager]*

To cope with these emerging situations a group of key actors, a sway-group, acts as an extended project management team to handle challenges with system integration, sub-system interdependencies and changes in prerequisites.

To meet set targets, sway-groups focus to compress the time schedule by parallelization, continuous focus on troublesome boundaries between sub-systems, fewer hand-overs and early integration.

> *"The different stages of development have to work in parallel and build on preliminary results. Every stage has to start on time, irrespective of the completion degree of the former stage. The information missing has to be searched (...) We have changed our focus from single processes to process interaction (...) To handle the coordination need that follows such a strategy, it is of vital importance to increase contact surfaces, delegate responsibility to*

the lowest possible level, and build cross-functional teams...The project management must tell people what to do, not how to do it." [Project Manager]

By putting integration and time of delivery in focus, the process of development has become reversed. Time of delivery defines what must be available on a given occasion. This result is later broken down into what is required at different times in order to have the possibility for both system tests and integration. To further support the integration and the importance of each phase starting as early as possible, sway-groups have emphasized input as an additional criterion for evaluation. This means that actors are no longer responsible only for what they release and at what time they do so – their output – but also for their input, i.e. what they get and at what time. Thus it becomes natural to help earlier phases so as to ensure their output, i.e. one's own input.

"We are always responsible for what we do – our output – so by telling people that they are responsible for their input, they will feel responsible for both their input and their output." [Project Manager]

Dominant Value System

Projects using the approach based on *integration-driven development* are more focused upon the process of development and its progress, while the projects using the approach based on *planning* are more focused upon the formal structure and control of progress. These differences are best described by comparing focus for the two types of value systems (see Figure 8.2).

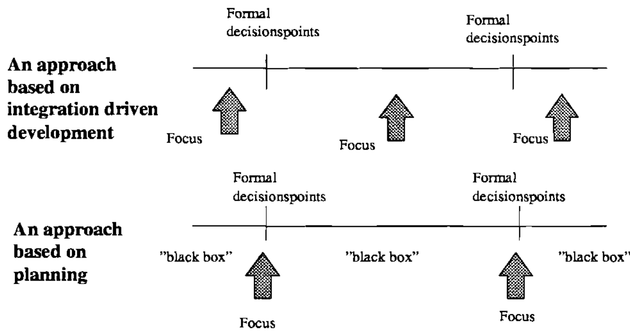


Figure 8.2. Dominant value systems and differences in focus in different approaches

The projects applying the approach based on *integration-driven development* are action-oriented and focus on the processes driving project progress. Questions such as *What kind of potential problems can we predict with existing information? How can we best avoid those problems? What can we do with the feedback from the last integration and verification?* are given priority. The organizational setting uses different forms of temporary forums and lateral coordination, driven by an explicit plan for integration and verification. In these projects the most important project management tasks provide a capacity to make all necessary decisions in the project without losing time. To do so, a special temporary forum was created, called the "*System Emergency Board*". The system emergency board was created so as always to be able to make fast decisions without losing the overall perspective or coupling to considerations at the system level. The board consisted of representatives of different interests such as managerial, technical and customer perspectives.

However, to be able to handle all decisions effectively, management also emphasizes that all are responsible for making the necessary decisions.

> *"Make decisions at the lowest possible level and make them – do not delegate upwards." [Project Manager]*

Dominant Perspectives and Principles for Management

One of the major differences from traditional approaches was that the new approach was based on the actual needs in the design process and not derived from the management needs such as decision support. This meant that the approach used mirrored actual work processes and, therefore, became an integrated part and a shared map of the actual design work and its progress. The approach in use was based primarily on the *integration and verification plan* (I&V Plan) and secondarily on the work package description derived from the product anatomy. The *I&V Plan* also differed from plans in more traditional approaches in that it was continuously changing as the system specification changed.

Another important characteristic is the ambition to build simple overviews and illustrations of the total complexity meeting the project, in order to attract more people to engage themselves holistically. To do this, a number of thoughts were aired about the project management for all to consider.

> *"Use the common sense factor. You don't have to be project manager to make decisions." [Project Manager]*

Sway-groups also try to spread a pragmatic attitude toward what is to be achieved - where the goals justify the means.

> *"It is natural to focus on high-tech problems, but many problems do occur in low-tech areas and are equally important to the time schedule." [Sub-project Manager]*

The sway-groups in the organizational setting also underlined the focus on continuous improvement, i.e. that it is always possible to do what you are doing more effectively and that it is everyone's responsibility to make improvements. There was a saying that the project was not only responsible for delivering what was agreed upon in time – the project was also responsible for making improvements during execution and for using past experiences to convey many potential improvements to the next project generation.

Role of Different Groups of Actors

The role of *project management* also differed substantially from the dominant approach. The general task for a project manager was, in the approach based on *planning*, to supply the project with expertise, resources, tools for corrections, and re-allocations responding to unforeseen events. In this organizational setting, one of the most important roles of the project managers (on every level) in these projects was to create and establish arenas for real-time coordination.

> *"Efforts to create contact networks between persons and sub-projects depending on each other are vital." [Project Manager]*

In the dominant approach, such as described in chapter 7, project management plays the role of an *"information-processing center"*. It includes gathering and evaluating detailed information related to the progress of requirements for design, system and sub-systems. Project management collects, on a routine base, detailed information from sub-project managers concerning a wide range of parameters indicating the status of the project in relation to the overall plan. A great part of their jobs is to respond to and decide about actions to solve problems, mostly in details. Information in detail about progress is needed as a consequence of product and project architecture.

In *Japanese Systems*, formal documents meant less and the actual picture is in focus.

> *"Ask! and get an answer." [Senior Line Manager]*

Project managers are seen as heavyweight in *Japanese Systems*.

The *technical coordinators* are responsible, together with project management, for making product and project configuration. The technical coordinators are also responsible for the product anatomy and the *I&V Plan*. To keep the integration and verification plan at the proper pace, they proactively focus on interdependencies and interactions between sub-systems and sub-projects. Technical coordinators are seen as heavyweight in the organization.

The *project contractors* are responsible for building necessary conditions for project management and for making inter-project priorities.

The *line management* is responsible for resource development and, together with project contractors (who often are the same people), making inter-project priorities. Line management is seen as medium-weight in the organization.

Area of Responsibilities

The approach based on *integration-driven development* has a pragmatic relation to the traditional line and project tension. There is a focus on finding a working interaction, and project management has been strengthened in comparison to a more traditional approach. The organizational setting applies a balanced matrix (in Davis&Lawrence 1977 terms) where the line management and the project management focus on different but complementary issues. The line management has a stronger focus on long-term resource development while project management has a stronger focus on meeting set and emerging project targets. Regarding resource ownership, line management is mainly responsible for recruitment, and project management can affect selection of key actors. Management in *Japanese Systems* is based on a close interaction between line and projects for a number of reasons. Such as the fact that line managers all have experience from managing large and complex projects and the importance of the large projects since the organization was originally built upon the experiences of the first project generation.

> *"Work with the line organization. Give and require information. Show and demand respect." [Project Manager]*

> *"We are a project-based organization where most work is performed in projects and where project performance is what our customers experience from working with us. Therefore the projects must be in focus, and our job is to create preconditions for numbers of projects to be performed at the same time, while we use the*

experiences gained and work performed in one project in a larger setting than the single project." [Senior Line Manager]

The long-term effect, though, is that successful project managers become line managers and carriers of the approach.

Coordination

Japanese Systems uses a proactive approach to coordination and uses earlier project experiences to focus on troublesome interfaces. The *product anatomy* and the *I&V Plan* are vital tools in coordination and in visualizing and monitoring system progress. The organizational setting experiences a controlled coordination need with known dependencies, and key actors spend a great amount of time on coordination.

Perspective on Coordination

Mechanisms for coordination used in the projects using the approach based on *planning* are systematically more reactive and focused on problem-solving than those used in this organizational setting. Approaches based on *planning* use systems for project planning and systems for control and formal reports as their most important mechanisms for coordination in their projects and have technical supervisory boards to coordinate between projects. Approaches based on *integration-driven development* apply a proactive way of working, where experiences from earlier project generations guide actors in focusing on the most troublesome parts or boundaries from the beginning, so as to avoid surprises in later phases of the projects. The approach based on *integration-driven development* also has a group of key actors who are highly knowledgeable about the total system allocated for solving integration problems. The *product anatomy*, together with continuous integration and tests of functionality, works as the main tool for coordinating the project and its parts. By using both the product anatomy and the *I&V Plan* as living documents illustrating project progress easily accessible for everyone, it was more evident that the parts belonged together and that success was dependent not only on individual contributions but rather on collective contribution.

> *"Everyone is needed for a successful project; cooperation is needed. If someone has a problem it is everyone's duty to help them." [Project Manager]*

This created a situation where the traditional focus on entry and exit criteria for each sub-system; component, sub-project and work package was replaced by a more collective focus on parallel processes and the integration and verification of larger entities.

Coordination is seen as a potentially value-adding activity, where not only information is exchanged but also new knowledge created during the coordination.

Coordination Need

The coordination need is rather high in the organization, but is controlled by a number of key actors due to a known *product anatomy* and an elaborated *I&V plan.* Some sub-systems depend more on each other than on others, and an extra effort is therefore directed toward these more troublesome interdependencies. This extra effort is mirrored in the project configuration by placing troublesome integrations as early as possible and devoting more of the key actors' time and attention to these.

The configuration with multi-skilled teams, i.e. including both designers and testers, decreases the intra team coordination need as depicted in figure 8.6, p. 326.

Type of Coordination Mechanisms in Use

As mentioned above, the two most vital instruments guiding coordination in the projects are the *product anatomy* and the *I&V Plan*. These are used for visualizations and monitoring of total project progress by giving the steps different colors depending on their status. Green represents activities completed in time and according to specification, yellow represents activities under completion and red represents activities delayed and/or not meeting specifications (see figure 8.3).

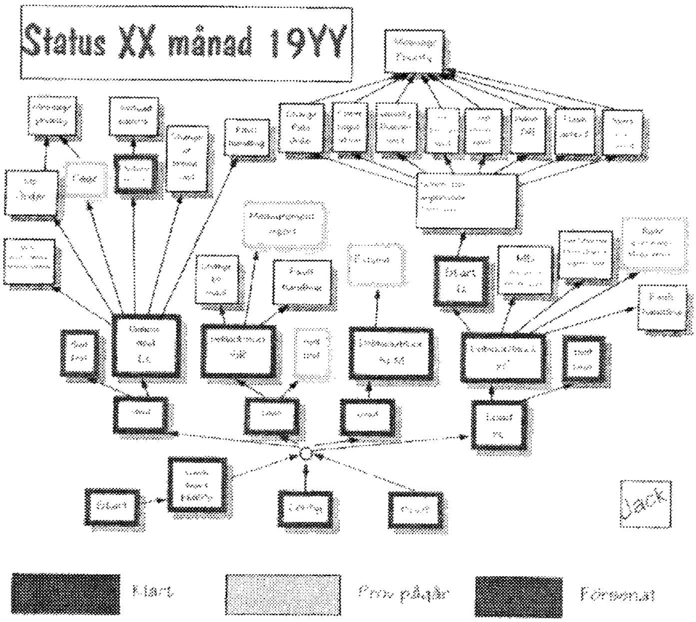


Figure 8.3. The continuous monitoring of total project progress (Järkvik&Kylberg 1994, p. 11)

By having such maps hung on all sites that participate in the projects, there will be a collective focus on the red activities. Besides these two maps, different forms of both formal and informal meetings were important to manage project coordination.

> *"The meeting followed a certain pattern. First we ensured that the mood was right, then the information from overall levels was given, and finally the wishes and demands of our own project management were stated. After this we passed round the table to catch views, and above all, the atmosphere among project members. All objects delivered weekly reports. Even if there was nothing to report, the form was to be handed in with a drawn line or similar sign showing that the situation had been considered." [Sub-project Manager]*

The air of speed in the project meant that the scheduled meetings (usually once a month) took place too seldom, which reinforced informal discussions for problem solving. If necessary, parallel teams or activities were created in order to try out different solutions for certain functionality, even though this meant that twice as many (or more) resources in terms of engineer man-hours were used to find a solution. This investment resulted in other gains and thus, from a total project perspective, they were not necessarily more expensive than forcing vital sub-projects to wait for a specific functionality. In real time this meant an intensified need of engineer man-hours, but it also reduced the time required for problem-solving and the amount of rework needed, which led to an actual decreased need for resources in realizing system functionality. There were seldom any intra-project arguments as to priorities; the solution or means of action that corresponded to the largest system progress regarding functionality was always put first. More seldom than normal were there divergent messages from the project manager, line managers (concerning e.g. resource allocation), unit manager (concerning e.g. resource allowance) etc., due to a high degree of convergence regarding goals and goal priorities. Even the customer was a convenient collaboration partner, since the close interaction resulted in mutual agreement on functionalities. The projects were all characterized by a continuous focus on actual progress and verified functionality for the whole product or system rather than processed time and sub-system progress.

To manage high speed despite a high degree of system complexity and ambiguity (due to concurrence), the project organization developed and used many different mechanisms for coordination between the different parts and actors in the project (see Figure 8.5). The project used a number of formal and informal mechanisms, some specially developed (or applied) for each project. The number and variety of mechanisms made the projects manageable despite short time limits and reciprocal activities.

Among the more extraordinary mechanisms was to use the system specification not only as input for work packages and design objects but also, and possibly more importantly, to give project participants an overview of the project and to whom and in what order they had to relate. To do this, three formal forums for system coordination were established during the development process. These forums were based on key actors (approximately 25-35 persons) getting together to sort out the total system characteristics during two-day periods at critical stages in the projects, and were named *Waxholm*, *Dalarö* and *Möja* after the first locations for the forums. Based on what the key actors agreed upon, their common view of the system architecture and known dependencies between objects, an *interwork description* – describing how and when interactions between objects should be handled – was created. These descriptions were flexible and adapted to new and previously unknown dependencies. The meetings also resulted in a *product anatomy* describing sub-systems and their natural dependencies, as well as an *integration and verification plan* describing the actual work flow in the project and in what order work packages had to be finished to ensure fluent progress. These three documents were vital for project management in performing the projects.

> *"Both our product anatomy and our integration and verification plan are vital to be able to identify critical dependencies, critical actors, critical path and slacks in real-time" [Sub-project Manager]*

Both the *product anatomy* and the *integration and verification plan* were used as main documents and roadmaps for total projects, giving participants a graphic representation of key activities, key actors, dependencies, actual progress, next steps and highlighted problems in their work. This made both the total system and the total design process more transparent to actors at all levels in the organization. The *product anatomy* and *I&V plan* were also major documents used in the interaction with the customer.

Many *temporary forums* were created during the project in order to solve specific problems or reflect on specific areas. These forums could be initiated by anyone and last for different periods of time. One of the most important forums was, as earlier mentioned, a *system emergency board* that was created when integration and verification started in the project.

The purpose was to provide an on-line decision service for different parts of the project. The project management emphasized the importance of acting immediately. As soon as a problem was discovered, something was done about it either individually or jointly. Minor problems were continuously put aside in order not to take time from solving the critical ones. This was a way of saving scarce time, and as a side effect it kept up the participants' enthusiasm for their work by providing instant feedback on all important problems.

Projects in this organizational setting used, to a large extent, dynamic and proactive mechanisms for coordination such as:

Firstly, clear and pronounced problem-solving and coordination teams – a so-called *coordination banana* – responsible for a given functionality or part in the project (see Figure 8.4). The coordination banana is a term developed for describing a specific group of actors responsible for a specific task or function that crosses geographical and cultural boundaries. The projects have developed a conscious handling of different types of potential problems, and involved actors have quite clear knowledge about how and in what way to coordinate, given a specific issue (see for example the above descriptions on how to manage complexity).

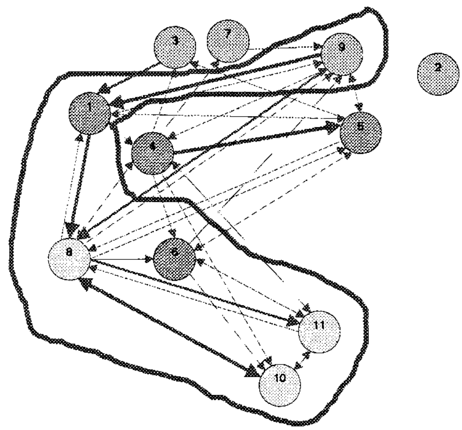


Figure 8.4. Example of a "Coordination Banana" – for delivery of a hardware part

Secondly, proactive coordination and problem solving at subproject level. Project management ensures that all actors responsible for a functionality or a critical part of the project take part in forming and structuring the total project. The development projects have formed a sequence of integration and coordination meetings on a system level to keep all parts connected with the overall purpose.

Thirdly, a dynamic project-planning system that planned with regard to continuously increased functionality. The planning system is based on a good knowledge of lateral needs for interaction and coordination, the *product anatomy*, the *inter-work description*, the *I&V Plan* and a *system emergency board.*

> *"A system emergency board was created. The main task for this forum was to handle the technical and administrative coordination between different locations. The forum was manned with the team leaders and the technical project leader. A daily meeting was held to solve all problems fast. The need of fast solutions was very high because of the very short time plan." [Technical Coordinator]*

Finally, a pronounced strategy to create autonomous and multi-skilled (including testers as well) teams was used and competence centers responsible for a functionality or part as well defined as possible, without losing a connection with the overall purpose as mentioned earlier. This is done to decrease geographically distributed high-frequency coordination needs. Figure 8.5 clearly shows the effects of such a strategy compared to the one applied in the approach based on *planning*.

	Internal	**External**
Formal	Project Meetings Progress Reports Product Anatomy I&V Plan	
Informal	System Emergency Board Product and Project Configuration (Vaxholm, Dalarö etc)	

Figure 8.5. Type of coordination mechanisms in use

Formal mechanisms are such as are described in manuals, project handbooks, work descriptions etc, while informal ones are not. External mechanisms have participants that are not formally engaged in the project, internal ones do not. Mechanisms may exist in more than one position. As the figure indicates, all important coordination mechanisms are internal to the sub-system or the project but informal mechanisms are used as a supplement to formal ones.

Time Spent on Coordination

At *Japanese Systems* there are large differences between different actors' time spent on coordination activities. Key actors spend a relatively high proportion of their time in coordinating (themselves and others), while others spend a relatively low proportion of their time in such activities.

Both groups spend more time on coordination early and late in the projects.

System Integration

Japanese Systems focuses on early system integration with internal releases once a month. The mechanisms in use for facilitating integration are the *product anatomy* (shows how life is breathed into the product), the *I&V Plan* (shows how logical integration is best done), the *workshops with key actors* (that aggregate all perspectives and get key actors to agree upon vital focus for the project), and *simulations by role-playing* (that facilitate early identification of system errors). Actors in *Japanese Systems* are responsible for both their input and their output and, through continuous live tests, there is a focus on what actually works and what does not.

Actual Tools for System Integration

The *product anatomy* and the *I&V Plan* are frequently used at *Japanese Systems* to integrate the system.

> *"The integration was based on the functional build-up in accordance with the logical plan. The deliveries from the design sub-projects were limited to match this plan. This required deliveries of parts of functions rather than complete ones. A major advantage of this method was the possibility of starting to test earlier. At the beginning only low-level functionality was tested, and it was useless to wait for development and delivery of the complete function before starting to test. The method also gave the opportunity to get used to methods and test environment gradually, and to learn about the functions step by step. Correction of failures was also simpler, since most SW and HW units already were planned to be revised." [Test Leader]*

Both the anatomy and the IV-plan is used as maps to guide actors in how much work that has been performed and to make a prognos for how much work that is still necessary to complete the project.

> *"The logical plan used for integration gives objectives in terms of what the system is capable of doing at a certain point in time. This is a much more stimulating type of objective than the number of test cases run." [Project Manager]*

The two maps also helped actors to make important priorities in the integration process.

> *"The integration tests were initially very narrow and limited to fundamental parts of the functions. The guideline was to test only those parts of the functions that enabled the execution of the next step of the logical plan. The tests were then extended to wider areas of functions." [Test Leader]*

> *"The focus was also to breathe life into new functions on a monthly basis." [Test Leader]*

As a complement, different models were built and role-plays took place, where key actors in a sub-system played their own sub-system and the project manager simulated different demands on the total system.

> *"A full-scale model of a container with a Radio Base Station mock-up was built to test installability and cabling. This was a great help and it also increased early visibility of the complete product." [Test Leader]*

These actions helped a proactive focus where up-coming troublesome phases could be prepared in advance.

> *"To find out if we were on the right track even before any lines of code were written, we tried to act as our own sub-systems. We set up a play where the scenery was making different types of calls under different circumstances and actors were all sub-systems. Our project manager defined prerequisites and then we had to improvise, based on our knowledge about our own sub-system. It*

was both a team-building activity and a learning opportunity about the total system and system interdependencies." [Subproject Manager]

Two other forums, *system emergency board* and workshops building *product anatomy* and *I&V Plan*, were also created to facilitate system integration.

"System emergency board was a new experience to me. A cluster of skilled people gathered several times a week in order to find proper and quick solutions to any trouble report written by anybody." [Test Engineer]

"We gather all key players in the project to go through the total product and create our first version of the product anatomy and the I&V Plan. The workshop was held a couple of weeks before we entered the execution phase. We then experienced a need for one new workshop a couple of weeks after execution was initiated, and finally for a last workshop with these key players before we left execution. The workshops were named after the places where we had the meetings – Waxholm, Dalarö and Möja." [Project Manager]

In the projects performed at *Japanese Systems* six increments have been established as an appropriate number of increments but when project lead-time is being reduced to less than a year no more than three to four increments are possible to perform.

Dominant Perspective on System Integration

Key actors in *Japanese Systems* focused on integrating parts and sub-systems as early as possible in the project. To find a systematic that worked and guided different actors in their system integration, internal releases once a month were set up as a rule. Each and all had to deliver their increment on time, regardless of how ready they perceived themselves to be. In essence, system integration acted as a "heartbeat" for

Knowledge Base

Japanese Systems bases its organizational knowledge on different geographically integrated competence centers responsible for separate sub-systems and/or sub-functionalities.

> *"A hardware-oriented organization must be avoided. The organization should be as functionality-oriented as possible." [Senior Manager]*

Each competence center then organized its development through teams.

> *"Teams were created. Each team was given responsibility for functions and function blocks that had something in common. They were manned with four to six designers, testers and a team leader. Besides the advantage of having the geographical locations well organized, the inexperienced designers in each team could be given assistance from the more experienced team leader." [Sub-project Manager]*

A strong project management, a strong technical leadership in each project balanced these competence centers, and trouble-shooters allocated to troublesome interdependencies. The Japanese customers are also used as a knowledge base, mainly through continuous interaction even at engineer levels.

Flow of Communication

Communication between sub-projects, design centers and design teams allowed free and effective exchange of information and knowledge. In the Japanese projects, as indicated in earlier sections, several arenas for exchanging knowledge and information had been organized. On every level, a crucial task for project management was to guarantee that there were enough formal and informal channels for communication and arenas for knowledge exchange. Project management acted as providers of arenas and infrastructure for communication.

> *"Everyone's active contribution is needed for a successful project. Not only as individuals but as teams. Without intense cooperation it*

is impossible to succeed with a complex project. If someone has a problem it is everyone's duty to help him or her. If this cooperation is to work, the flow of communication must work." [Project Manager]

Staffing

Japanese Systems has become an attractive place for young, ambitious and highly motivated engineers, so the staffing base is seen as more qualified than may normally be the case.

"At times you can get the impression that the different line organizations assign a project to those persons who are available at the time, rather than to those who would be best suited for the task. This is, of course, what first comes to mind in a stressed line organization, but in the long run it can be seen as incorrect action. The most knowledgeable personnel should be appointed to big and important projects. In our project we succeeded in creating a very good and effective project organization." [Project Manager]

Work Packages and Task Allocation

Project configuration at *Japanese Systems* is based on integration, testing and time, which drive the definition of work packages and priorities and do not result only in work packages for different design teams. System integration was also highlighted as a time-consuming activity, and resources were openly allocated to this type of work.

"When working concurrently, present process descriptions are not good enough. These descriptions are of the type 'input-process-output'. When activities are run in parallel, process interaction becomes very important. For instance, during the test period we used AD[64] *dates to synchronize test activities on various levels.*

---

[64] *AD* is used in Japanese Systems to describe each distinct time for system integration and verification.

Since process interaction is not part of present descriptions, they have to be defined in the project controlling documentation instead. This type of events becomes ever more important to monitor progress over time." [Sub-project Manager]

Degree of Projectification

This organizational setting is clearly built on a project perspective. Projects are seen as driving value-adding activities and business, and the functional line organization is primarily seen as a supporting function, responsible for resources and facilities. Actors in these projects value their project identity more highly than their functional organizational affiliation. The project organizations are highlighted in accordance with their relative weight in performing value-adding activities and business. The projects are in the center of the organization, and the line structures as well as other structures are adopted to support the projects and their logic.

"When the first project was started, the line organization was not yet founded. It is very important that a line organization is formed in a way that supports projects." [Business Unit Manager]

"A few but very helpful guiding principles for forming the line organization were set up. The line is responsible for who and how, and the project is responsible for what and when (...) We should have few and strong competence centers, with short chains of command; project and line should have equal status, close loops, make everyone accountable for their contributions and, finally, minimize hand-overs." [Business Unit Manager]

Dominant Area of Competence

As a result of earlier experience with design-driven development models, where system integration and verification are performed late in the projects (and cross-functional problems or defects in functionality realized in interaction between sub-functions are identified late and therefore lead to significant rework and delays). Key actors searched for new development models. The result of their search was an approach driven by integration and verification, i.e. going the other way around with a starting point in the exact date of delivery and then moving forward in the project. This is, as described above, realized by using the *product anatomy* and successively identifying which activities must be performed to build the product or system in steps that are possible to verify and test actual performance in. A direct effect was that actors in the development process became responsible for their *input* rather than their *output*. A responsibility for input at all levels in the projects made engineers more proactive in their approach to earlier phases. It became clearer where progress was lagging, and this was then used as a base for resource allocation.

The dominant area of competence is *project management*, followed by *technical co-ordinators* and *testers* that become important in defining the *I&V Plan*.

Dependencies between Project Generations

The projects at *Japanese Systems* strive for both a clear technical and a clear administrative consolidation after each generation, but also have organized planned hangover arenas and planned personnel turnover between the project generations.

To further strengthen the ties between the project generations and facilitate learning between projects, the main project managers for each project generation are all co-located.

Dependencies on Specialists

By building teams that are multi-skilled, i.e. include both different types of designers and testers, the team become able to solve most work-related iterations and many problems themselves. However, when it comes to solving more difficult problems and/or problems that have emerged in the boundaries between sub-systems there are a number of key-persons that are specially trained and allocated to that type of problem solving. (see figure 8.6)

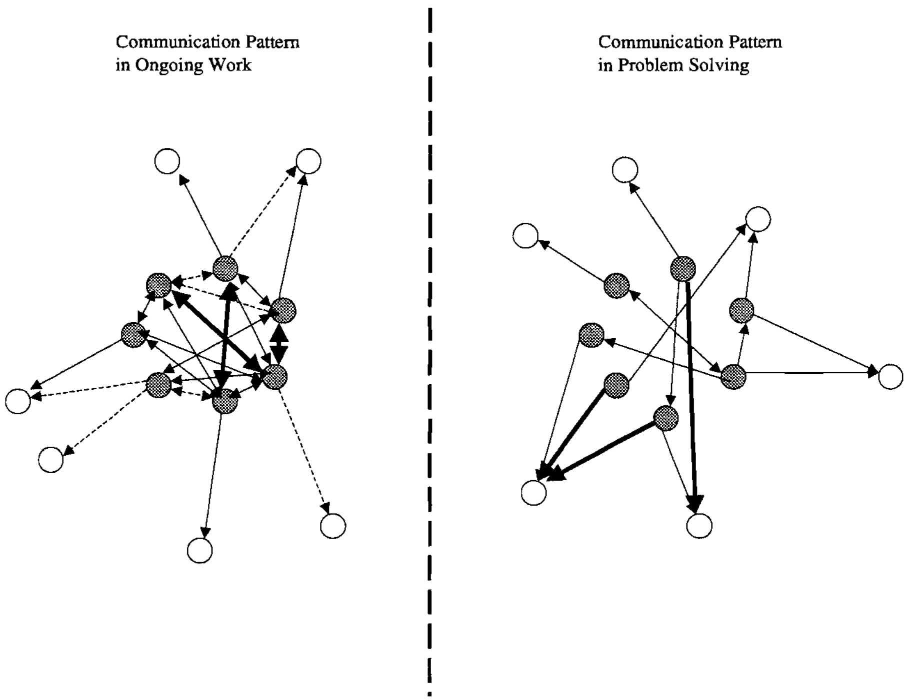


Figure 8.6. Communication pattern in a design team

The main-differences between the communication patterns in teams in *Japanese Systems* compared to teams in *Large Switches* are that the team handles most communication them-selves, especially the one related to on-going work. And also that there are fewer specialists and important communications nodes outside the team. These specialists are also more collectively used, i.e. individuals share networks.

Progress Control

Progress control at *Japanese Systems* focuses on total system progress. Perception of progress is driven by stepwise feedback about what is actually working through early system integration and testing of actual functionality. The projects use both the *product anatomy* and the *I&V Plan* to visualize project progress for all participants.

Focus of Progress Control

The progress was driven by integration, verification and test activities rather than by design activities, and qualitative rather than quantitative measures on progress were used. Project management focused on actually proven system and sub-system functionality rather than on key figures such as time worked, number of documents finalized and number of realized *kplex*[65]. This diagnostic evaluation of real progress through simulations and/or actual tests of real functionality works as a form of objective control with high validity.

> *"We are a hundred percent certain that we are ready with 20% of the system, while at Large Switches they are 20% certain that they are 100% ready with the specific sub-system." [Line Manager]*

Incremental feedback about what actually works is the focus at *Japanese Systems*, and progress is defined in relation to the final objective.

> *"Let all evaluations and decisions be influenced by the end goal." [Senior Manager]*

Moreover, the *I&V Plan* gives a packaged goal picture which, step by step, moves the project's progress toward the end goal. See the illustrated example in figure 8.3, p. 311.

> *"Create small goals throughout the complete journey." [Project Manager]*

Time serves as an engine in the project operation around which different actors, goals and efforts gather.

[65] *Kplex* is used as an indicator of quantity of lines of code in Ericsson program language produced. Kplex is the same as one-thousand lines of code.

"Time-critical projects should be run in an integration-driven way. This gives a better focus on the final goal and gives more relevant objectives for design." [Project Manager]

The progress control in the project builds upon an internal release once per month.

Figure 8.7 shows a typical project in Japanese System and its progress over time. System progress follows a predefined stepwise growth towards full functionality.

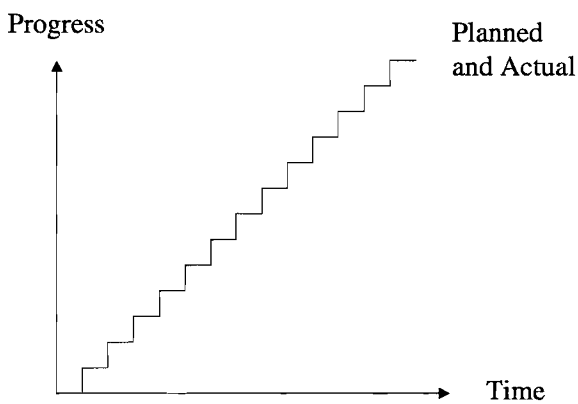


Figure 8.7. Typical project progress compared to plan over time

Figure 8.7. shows the typical characteristics of perceived project progress in a project applying the approach based on *planning*; (1) small and predefined steps, and (2) planned and actual progress are the same due to the focus on actual functionality growth.

Type of Progress Control and Tools for Progress Control

Projects using the approach based on *integration-driven development* made no use of detailed information about plan-related progress. With well-defined project goals for sub-projects, design centers and design teams, the most important signals had to be sent horizontally. Progress in relation to plan had less significance. What was important was information about real outcome in terms of functionality growth.

> *"It is of vital importance to visualize the actual progress of the system when things work and not when a milestone is reached." [Project Manager]*

Sub-projects were defined as depending on each other at the same level, and the system's integration of sub-systems was not defined as a task for project management but rather as a task for the sub-projects, design centers and/or design teams involved.

> *"The motivation among project members has been very high due to close attention from top management, goals regarded as tough but attainable, and clear and consequent priorities." [Sub-project Manager]*

Managing Perceived Complexity and Uncertainty

Actors in projects at *Japanese Systems* have good knowledge about components and interdependencies. The approach based on *integration-driven development* reduces perceived complexity and provides different actors with effective tools to handle complexity.

Principles for Managing Perceived Complexity and Uncertainty

One of the main differences between the two approaches is that the approach based on *integration-driven development* to a larger extent reduces perceived complexity[66]. And also, forces actors in projects to

---

[66] As discussed earlier, it is the subjective picture, i.e. actors' own perception of complexity, and not any objective picture of what complexity a project meets, that is of vital importance to the conditions for learning and high performance. Different organizations meet and create different types of both objective and subjective complexity, where the objective complexity is more or less given by the mission but the organization can influence the subjective complexity perceived by actors by reducing it or handling it in another way. Technical choice or interfaces do not only create

handle less complexity (by distributing it in a smarter way), and at the same time provides them with more efficient tools and organizational structures to handle the complexity that is left in a convergent way. In these projects, actors therefore perceive a moderate level of complexity and seem to have a good overview of the project they are a part of and critical dependencies to other actors and groups of actors in the project. A new project generation does not increase perceived complexity, even if the objective complexity may increase. On the contrary, the project is successful in its effort to reduce perceived complexity over time, i.e. increase organizational capacity to cope with complexity.

Uncertainty in *Japanese Systems* is managed by, based on experiences, highlighting especially troublesome and unpredictable boundaries between sub-systems and allocating special resources to those boundaries. Uncertainty is also managed by step-wise testing and verifying actual functionality-growth by integrating early and performing real tests.

Despite the fact that projects using the approach based on *planning* and projects using the approach based on *integration-driven development* both meet a high objective complexity in terms of technical dependencies, business logic and organizational structures, the complexity perceived by actors in the projects differs significantly depending on the principles used for managing the projects.

Perception of Complexity and Uncertainty

The projects in the organizational setting were studied in a top-down approach, trying to identify complexities and interdependencies that face project management. When comparing the project managers interviewed in the different organizations, there was a striking difference in how much was known about the interdependencies. The majority of project managers interviewed in *Japanese Systems* had a very clear picture of systems

---

complexity; it is also created by business logic and by organizational choice (Adler&Norrgren 1995). The way we choose can in many cases increase complexity rather than reduce it.

components as well as interdependencies. There were, however, some values of the components and the interdependencies between them that were unknown to the actors[67]. The step-wise integration and actual test of functionality growth built confidence among actors and reduced the perceived uncertainty. Hence, in this organizational setting, key-actors' perception of complexity and uncertainty can be classified as equivalent to low level of ambiguity. However, for the large number of actors the perceived complexity and uncertainty are equivalent to moderate ambiguity[68]. The actors themselves, though, could isolate the components of the system in which uncertainty resided (different perceptions concerning numbers, installations and delivery times of specified components). And in most cases also had a fairly common understanding of how problems with some interdependencies (market-product, management-design and the logistics of hardware) might negatively affect the value of the work processes. In fact, the successful reduction of lead-times as well as the ability to meet delivery times had by and large been dealt with through a very conscious handling of interdependencies between different contributors to the total project development, even if the resources involved were geographically dispersed.

[67] Knowledge about values of components and dependencies means that an actor not only has knowledge about the existence of a component or dependency, but also has knowledge about its relative importance and how it works. An example is that if actors in a system know which other actors are of importance to the system and which dependencies are of importance and to whom, there is knowledge about system components and critical dependencies. If actors also have knowledge about the different actors' relative importance to the system, what their contribution is, how this contribution relates to other contributions, and the importance of these relations, there is a knowledge about values of components and dependencies (Adler&Norrgren 1995).

[68] In the framework presented in chapter 5 and inspired by Schrader, Riggs&Smiths (1993) classification of technical uncertainties.

Performance

The approach based on *integration-driven development* as applied by projects in *Japanese Systems* supports size and speed, and projects often meet both set and emerging targets. However, the approach is limited by the capacity of the few key actors engaged in defining conditions and making necessary adjustments.

Project Capacity, Lead-time, Cost and Functionality

The approach based on *integration-driven development* has now successfully performed five large projects using a new way of working. Large projects normally comprise 700,000-1,000,000 man-hours, and there is one example of a project using 1,500,000 man-hours. One of them being Ericsson best practice, concerning low fault intensity (in both software and hardware) in system testing despite major cuts in project lead-time - from 18 to 11 months in lead-time.

Over the years, not only has the organizational setting cut lead-times dramatically; the exact delivery date has also been kept. The products delivered have reached a satisfying level[69] of *in-service performance*, despite low series and only four years of market presence. And also, despite the most demanding and extreme system load in the industry, and no trial run at site before service-in (to cope with new lead-times). Economically, the projects have yielded very high returns and, perhaps most importantly, Ericsson has acquired – as the first foreign company competing with digital mobile phone systems – a firm foothold in the Japanese market. To cope with increasing demands from Japanese customers, the projects have managed to deliver more functionality (up to an extra 20%) earlier (by up to 20%) than agreed upon at project start-up. In addition, agreed functionality has increased and agreed development time has decreased in every project generation.

---

[69] As Ericsson normal practice, which is considered highly competitive for cellular systems.

Conditions for Organizational Learning

Actors in *Japanese Systems* had, in comparison with the projects using the approach based on *planning*, a high degree of awareness about the importance of process innovations and the necessity of continuous improvement of delivery times and quality. The room for product innovation was deliberately kept well controlled, and priority was given to reusing components used in earlier project generations as well as using modules from related projects. Incentives and motivators in the project management system explicitly focused on process effectiveness. The propensity for *incremental* learning is high, while it is low for *discontinuous* and *organizational* learning. There was some uneasiness concerning the long-term effects in the motivation of design engineers to simply keep on with incremental product innovation among the most senior project management. However, the majority of project managers, who were eager to repeat and refine earlier successes, did not share this concern.

The capacity for *incremental* and *discontinuous* learning is high. Emerging problems are that designers as well as managers are reporting signs of *"burn-out"*, a feeling that it is harder to motivate a focus on long-term process effectiveness, evolving borders between design and marketing and an input-focused organization. Another question is at what point in time the members of these successful series of projects might face the situation where they will be trapped by their past and recent successes and end up with rigidity. As was described above, there are only a few senior project managers who are aware of these dangers. The question that this raises is whether it is possible to proactively create a leveraging learning mechanism that can counter the emergence of rigidity and make possible a renewal beyond existing frames of references.

The dominant view on working with improvements influences the organization's capacity both to identify and to implement improvements over time. Projects in this organization have more distinct and long-term plans on how different generations will learn from each other, and on who will carry the responsibility for improvements over project generations.

These projects integrate improvement responsibility into the project specifications as one of the major goals of the project.

In the organization using the approach based on *planning*, the line organization creates a parallel organization outside the projects responsible for identification and implementation of improvements, which has consequences for penetration. On an operative level in projects using the approach based on *integration-driven development*, all actors asked agree that there is continuous work with improvements in their organization, and only a small part think that they do not take any active part in these improvements. On an operative level in projects using the approach based on *planning*, half of the actors asked think that there is no continuous work with improvements in their organization and that they do not take any active part themselves in working with improvements. Actors in these projects at all hierarchical levels see process improvements as difficult to measure and follow up, and therefore as difficult to motivate and implement. If actors cannot see any point in working with improvements or create any feedback loops for improvement work, it is very difficult to establish and implement. Actors in projects using the approach based on *integration-driven development* emphasize the importance of identifying and implementing improvements both within the running projects and between projects. To create goals and specifications to integrate in the running projects, actors establish reference points for improvements by identifying repetitive processes or parts of processes. These projects, with their dominant view on working with improvements, do create better conditions for learning.

> *"When you see improvement areas don't wait until the final report."*
> *[Project Manager]*

The Approach based on Integration-driven Development – an Integrated Discussion

In comparison with the dominant approach based on *planning*, the important differences are the following:

Integration-driven projects have proved able to manage high speed in large and highly complex projects and to continuously shorten project lead-times and keep project deadlines. Projects applying the approach based on *planning* rely on functional expertise. The *integration-driven* project utilizes competencies and skills throughout the project organization by means of organized cross-functional dialogue.

Instead of a hierarchical, well-defined structural integration of individual experts and formally well-defined tasks in order to control complexity, the integration-driven project emphasizes flexible adjustment to emerging needs. Instead of an ambition to control and plan for reduction of complexity, the *integration-driven* project has developed communication patterns and arenas for real-time coordination in order to cope with existing complexity. Instead of a project management system aiming at detailed control of progress, the *integration-driven* project management emphasizes goal orientation and control of results and outcomes. Instead of gathering information about formal progress to the project management, information is horizontally distributed among organizational units.

In terms of requirements, the projects applying the approach based on *planning* need functional and design specifications for both hardware and software. The projects applying the approach based on *integration-driven development* require end product or systems specifications, divided into self-contained definitions of work packages (functionality on a sub-system level). An approach based on actual work emerged from the complex and dynamic reality in which the project and the project members acted. Instead of strictly following a sequential plan (as in the approach based on *planning*), certain work procedures and interaction procedures emerged informally during the project and could easily be readjusted locally according to the progress of work.

On an overarching level, the projects using the approach based on *integration-driven development* may be characterized as totally convergent regarding the overall objectives, building a firm basis for progress control. The absolute point of delivery caused a general awareness and search for speed and rapidity among project members, which in turn caused a search for *"the shortest way to reach the goal"*. The time pressure also meant that a dynamic attitude was adopted toward the system specification, i.e. specifications were allowed to change. Analogously, the work procedures as to integration and verification were affected. There was *"no time to waste"*, meaning that integration and verification of different parts started as soon as possible, i.e. without any plan as to when they were supposed to be verified. It was only the time for integration and verification that was sacred. In Figure 8.12, the projects in this organizational setting are compared with the dominant approach based on *planning*.

Characteristics	**The Approach based on Integration-driven Development in Action**	**The Approach based on Planning in Action**
Product and Project Configuration	Products are configurated according to how functionality best is realized. Projects are configurated according to how *logical integration* of subsystems is best made and guided by a focus on important and troublesome boundaries. A *few key persons* are responsible for configuration and changes. High *convergence* and *transparency* between actors in sway-groups but moderate in the total organization	Product and project breakdown with minimized dependencies. Use of *"black-box engineering"* and *"clean-room development"*. Hierarchical convergence but lateral divergence among groups of actors. High hierarchical transparency but low lateral transparency. Actors from sub-systems are responsible for configurating and making changes.
Management	Based on the assumptions that (1) *complexity* is best managed (reduced) by focusing troublesome interfaces and allocate highly skilled resources to handle situations in real-time, (2) *uncertainty* is best managed (reduced) by rigorous product and project configuration, and (3) *control* is best gained by continuos integration, step-wise functionality growth and a proactive project management. Key-actors strive for *controlled dependencies* between parts of the projects and uses *specialists* for coordination in critical boundaries.	Based on the assumptions that (1) complexity is best managed by breaking it down into manageable units as independent of other *manageable* units as possible and (2) uncertainty is best managed by *rigorous planning*. Focus is on following up outcomes in relation to the plan set up for the given project, and decision points and scheduled meetings drive development logic. Decisions orient and focus formal reports and flows of documents. Four main goals: (1) world-class technical performance, (2) resource-effectiveness, (3) market-oriented roll-out plans and (4) profitability for individual deals, segments and regions.

	Project Management is based upon *early integration* and *stepwise functionality growth.* Sway-groups focus on time, integration and actual functionality. Important sway-groups are project management, technical coordinators and testers. Important goal is keeping time.	The organization is based on low integration between different organizational subunits and subsystems. Important sway-groups are: line management responsible for product and project configuration, resource allocation and actual work, project contractors responsible for decisions, technical coordinators responsible for subsystem performance and project management responsible for administrative coordination.
Coordination	Actors apply a proactive approach to coordination and uses earlier project experiences to focus on troublesome integration. The *product anatomy* and the *I&V Plan* are vital tools in coordination and in visualizing and monitoring system progress. Highly controlled coordination with known dependencies. Key actors spend a large amount of time on coordination.	Coordination is perceived as a non-value-adding activity that takes time from the actual development work, and time spent on coordination is seen as a *transaction cost.* Strives for independent organizational units specialized in a specific function. *Large Switches* uses sequential or semi-sequential pre-optimized project plans and generic or semi-generic development models together with hierarchies in both lines and projects used to coordinate work – mainly focused towards hierarchical rather than lateral mechanisms and functional rather than cross-functional mechanisms. Sway-group members spend much time on coordination while non-sway-group members spend little time on coordination.
System Integration	Japanese Systems focus on early system integration with internal releases once a month. The mechanisms in use for facilitating integration are the *product anatomy* that shows how life is breathed into the product, the *I&V Plan* that shows how logical integration best is done, *workshops* with key actors that aggregate all perspectives and get key actors to agree upon vital focuses for the project, and *simulations by role-playing* that facilitates early identification of system errors. Actors in *Japanese Systems* are responsible for both their input and their output, and through continuous live tests there is a focus on what is actually working and what is not.	*Large Switches* performs its system integration late in the process and focuses on creating organizational *"black boxes"* independent of each other. Within each black box stable subsystems are created through the use of clean-room development, i.e. doing right from the beginning. Project management handles integration and interdependencies but actual influence on the process resides in the subsystems' line management and technical coordinators.

Organizational Design	*Japanese Systems* is organized by geographically integrated competence centers designed and based on the *product anatomy* and the *I&V Plan* and with the purpose of minimizing interdependencies. Each project then has specific resources allocated to troublesome interdependencies. The organization is highly projectified and dependent on specialists. Testing *(downstream activities)* is the dominant area of competence and defines prerequisites in terms of times of deliveries and increments for design *(upstream activities).*	*Large Switches* is based on functional expertise organized in subunits responsible for specific subsystems and formally well-defined tasks. The base of knowledge is distributed competence, geographically dispersed. The flow of communication is mainly *within subunits* responsible for specific subsystems, and hierarchical towards different types of specialists. Prevailing development organization and previous project configuration govern future project configuration and the development of individual work packages. Most value-added work is performed in different types of projects but a dominant line organization owns and manages resources. Design drives development and especially subunits responsible for design of important subsystems. High dependencies between project generations and on specialists.
Progress Control	Progress control focuses on *total system progress.* Perception of progress is driven by *stepwise feedback* from what is actually working through early system integration and testing of actual functionality. The projects use both the *product anatomy* and the *I&V Plan* to visualize project progress for all participants.	Focus on *subsystem progress* and *deviations from plans.* Uses formal *progress reports* and *hierarchical project meetings* as most important tools for progress control.
Managing Perceived Complexity and Uncertainty	A focus on total system characteristics and boundaries between sub-systems Actors in projects have good knowledge about components and interdependencies. A small group of actors defines the prerequisites for the rest. The approach based on *integration-driven development* reduces perceived complexity and provides different actors with effective tools to handle complexity. *Early integration* and actual *test of functionality* growth effectively reduces perceived uncertainty.	Plan and control for reduction of perceived complexity by breaking down complex structures until complexity decreases. Rigorous planning and deviations control for reduction of uncertainty. A small minority (sway-groups) in each sub-system defines the preconditions for the great majority's perceptions of complexity and uncertainty. Perceived complexity and uncertainty equivalent to moderate ambiguity.

	Key-actors´ perception of the complexity and uncertainty that meet them are equivalent to *low level of ambiguity*. However most actors perceive complexity and uncertainty as equivalent to *moderate ambiguity*.	
Performance	The approach based on *integration-driven development* supports size and speed, and projects often meet both set and emerging targets. Responsibility for learning and renewal is *integrated* in ordinary work. High convergence and transparency among sway-groups and moderate among other actors (high on defined key issues). Capacity for learning and renewal are high but propensity is *limited by earlier success.* The number and capacity of key-actors limit further development.	Unique experience in performing large projects; 1500 to 3000 kman-hours. Projects normally run over time and take 18-24 months to perform, and normally plan for large amounts of rework and design follow-up. Normally most complicated functions are transferred to later project generations due to insufficient functionality growth. Actors including sway-groups at *Large Switches* normally have very low cost-consciousness. Both the propensity and the capacity to change are rather low although no active resistance can be seen. There is no continuous work with improvements. Actors see process improvements as hard to measure and follow up, and therefore as hard to motivate and implement. Responsibility for learning is separated from actual work processes in parallel organizations. Learning and renewal focus on process configuration. Problems in learning often occur due to unplanned personnel turnover and lack of arenas in use.

Figure 8.8. A summarized comparison between the approach based on Planning and the approach based on Integration-driven development

The conditions for the two organizational settings differ to some extent due to age, growth, number of parallel projects; responsibility for delivered products and number of customers. *Large Switches* is older, larger, performs more projects in parallel and has more customers. *Japanese Systems* has faced an extreme growth and has a more integrated responsibility for the customer relation. Both settings use a functional line organization and base their business on exploitation of what is largely the same technology. Conditions for high performance and learning both within running projects and between projects differ markedly owing to perspectives, principles and models for organizing in use. Projects in organizational settings applying the approach based on *integration-driven development* base their product and project configuration on incremental build-up of verified functionality rather than breakdown into sub-systems and work packages. These projects also introduce more dynamic project management systems and models as complements to the more sequential ones, and continuously focus on actual progress and verified functionality for the whole system rather than processed time and sub-system progress. Actors in the projects focus on whole systems and boundaries between sub-systems rather than the sub-systems, and drive progress by integration, verification and test activities rather than design activities. The projects have introduced a number of new tools such as *product anatomies* and *I&V plans* to continuously give participants a graphic representation of the project progress. This set of changes has created a more convergent perspective on business, given priority to project logic, reduced and managed complexity more effectively, created a clearer transparency throughout the projects, a set of more effective mechanisms both for coordination and learning. The result is that these projects meet or exceed expectations as to both development time and functionality.

The track record of projects in organizational settings using the approach based on *planning* shows another picture; most projects fail in delivery on agreed time schedules and/or delivery of specified functionality. When analyzing the organizations over a longer time horizon, it is obvious that projects using the approach based on *integration-driven development* have managed complexity better by utilizing knowledge and experience over time, i.e. learning and transferring between projects. Development project performance steadily increases over generations, and mechanisms are being established to minimize risks of not utilizing existing knowledge within the organization. Even implementation of this new knowledge seems to work quite smoothly in the respective project generations. Projects in organizational setting using the approach based on *planning*, on the other hand, seem to have severe problems in utilizing knowledge and learning between projects. In that case, conditions for learning are significantly better in the organizations performing projects by applying the approach based on *integration-driven development*. This type of learning can easily be compared to *incremental learning*, i.e. to improve performance within the existing knowledge base. When comparing conditions for learning that impact or change the existing base of knowledge, i.e. comparable to *discontinuous learning*, the result is different. The inclination for this type of change is significantly higher in the organizational settings using the approach based on *planning* than in those using the approach based on *integration-driven development*. Actors in projects using the approach based on *planning* search for new solutions to manage their problems, and have come to an understanding that their existing principles for managing and organizing development processes are not sufficient. On the other hand, actors in the project using the approach based on *integration-driven development*, due to recent successes, see their converging way of managing and organizing projects as the way of doing it. Today this is no problem - rather the contrary – but what happens when the context changes? Will the organization be trapped in its success? When do the core competencies turn into *core rigidities*[70] and become a severe burden for the organization's inclination to adapt to, or impact, the environment? The projects' high degree of convergence work is an obstacle for *discontinuous learning* by defining the frameworks for focus and projects; in the organization using the approach based on *planning*, a low degree of convergence works as a support for double-loop learning in leaving space for alternative interpretations. Inclination to change outside the existing knowledge base, and therefore one type of prerequisite for *discontinuous learning*, is significantly better in the organization. But, at the same time, this organization has no capacity to implement new knowledge. Thus, even if the inclination is strong, the organization must develop an organizational capacity to cope with

---

[70] In Leonard-Barton's (1992) framework. Core rigidities are defined as *"inappropriate sets of knowledge"* (p. 118), often based on values and skills earlier developed and historically important in explaining past success.

implementing new knowledge before the conditions for *discontinuous learning* can be seen as sufficient.

Actors applying the approach based on *integration-driven development* are guided by a basic assumption of bounded rationality and provide an advanced socio-technical system to compensate this boundedness.

CHAPTER NINE

The Approach based on Dynamic Synchronization – Emerging Perspectives, Principles and Models for Organizing in Use

"Communication, interaction and cooperation are probably our most important tools for mastering global competition." [Line Manager at Japanese Subsystems]

This chapter will illustrate new principles for managing and organizing complex product development introduced by an organization in Ericsson, through describing the project organization, the functionality of the products, and the project performance so far. This will serve as a basis for further descriptions around their configurations of products and projects and leverages used in the actual design work. This chapter will only focus on contrasts not earlier discussed, i.e. when this approach differs from the one based on *integration-driven development* or when it differs in a new way from the one based on *planning*. The illustration ends with a summarized matrix of key characteristics for the emerging perspectives, principles and models for organizing in this approach, compared to a approach based on *planning* and the approach based on *integration-driven development*. The aim of the chapter is to analyze what the differences in performance consist of and originate from.

Japanese Subsystems – The Emerging Approach based on Dynamic Synchronization in Action

The identification of Japan as a new potential large market for mobile telecommunication systems made Ericsson initiate a serious effort to be one of the main players in that arena. To be able to deliver the products to the potential customers, Ericsson needed to further exploit some areas of its existing competence and technology but, most importantly, it needed to explore new ways of developing these products. The company's current competence base regarding one of the critical technologies required for one of the new products was to be found at Ericsson Microwave Systems. It belongs to a business area that previously to a dominant extent, and still to a large extent, worked with military applications. Military customers' demands deviate considerably from those of customers in the civil or commercial sector. Traditionally the military attaches secondary importance to time and cost factors, focusing primarily on performance, quality and well-documented processes. These latter priorities are mirrored in the way that products are developed in the military business area and were incorporated in a strong culture somewhat different from that of Ericsson commercial business units, especially mobile-based business units. Ericsson Microwave Systems has had satisfied customers, despite at times dramatic project over-runs in cost and time due to high product performance and high product robustness. Recent developments with severe cuts in defense budgets have, however, resulted in costs emerging as a key focus for projects developing military equipment.

Japanese Subsystems deliver an important sub-system to be integrated into the customers' cellular system for the Japanese market, which is an important competitor to the system delivered by *Japanese Systems*. The illustration below is based mainly on the development of the third product generation of an important sub-system in a cellular system to the Japanese market, as well as on other earlier, parallel and later projects performed in the organizational setting.

New Priorities

Time-related factors emerged as the most important priorities in the new and growing commercial market, in terms of both *delivery time* and *total throughput time*. Other factors seemed initially to be of secondary importance, and it was obvious that a successful market introduction would lead to large production series and new priorities in the interaction between development and production. However, competence in one critical technology was a scarce resource worldwide, and building this new competence base would be a very time-consuming process – if it could be achieved at all. Thus, taking this new market opportunity would involve creating a new business unit, including people with this critical competence from military projects as the core, together with a substantial group of newly recruited engineers and managers from other commercial business units and outside the company.

The Background of the Organization

The new business unit was located at a single site and was given great discretion to manage and organize its work as long as it satisfied customers' requirements. In 1998, the new business unit consisted, among others, of two departments responsible for developing separate sub-systems for the Japanese market. The two sub-systems compete by representing two different Ericsson boundaries to the Japanese customers. One sub-system is delivered internally to a different business unit in Ericsson, which integrates it into a total system to the customer. The other sub-system is delivered directly to the customer, and therefore this department has direct contact with the Japanese customers on all key issues. This organizational setting has delivered four product generations to the customer and is in the process of delivering the fifth and of starting to develop the sixth generation. The organizational setting manages and organizes the work in a substantially different way than other organizational settings, and hence we use this as our main example in describing the emerging approach for forming approaches based on the principle of dynamic synchronization.

The organizational setting consisted at the end of 1998 of approximately 150 development engineers (as compared to 60 persons three years ago). The growth in the size of the department is primarily limited by the availability of competent personnel. Seventy percent of the employees have a Master of Science or higher degree, and the department has a matrix organization with critical competence areas on one axis and development projects on the other axis. The majority of the staff in the department works in every project generation. The development teams consist of five to 20 persons, depending on the scope of the project, and the main projects consist of six to ten development teams depending on project configuration. The first generation product was delivered in 1992 and was the result of a substantial learning process. The project had to cope with time frames previously regarded as inconceivable. They entailed a reduction of previous standards by more than 50%. At the same time, more than half of the project engineers were recruited directly from university with little or no previous working experience and the rest, though experienced and highly skilled technically, seldom had any experience of working in a commercial environment. The department was aware that the customer had placed the same order with two other companies which both had superior experience in the product area and an established presence on the market.

Particular Assets

The new project group had, however, three main assets that such groups in Ericsson did not always possess. Firstly, they had *direct and continuous contact with a customer* that was very clear about what it wanted. Secondly, they *could operate with fewer restrictions from top management* as to how the group should manage and organize its work; and thirdly, they had *full insight into, understanding of and responsibility for business goals* relevant to the project. This enabled the project members to develop local business algorithms[71]. The development of such algorithms means that the local actors had access to knowledge regarding business dynamics and business consequences enabling them to "navigate through" customer interactions, making the necessary decisions and

[71] The term *"business algorithm"* is here used to capture the business content, context and its dynamics, and is further elaborated in Adler (1996).

priorities within the project organization, and hence to take responsibility for the necessary dynamics in purpose and context.

Product and Project Configuration

Japanese Subsystems configurates products according to how functionality is best realized. Projects are configurated by building dependencies. Every sub-system had at least two design teams working on it, and every design team was responsible for at least two sub-systems. Many actors are involved and responsible for both product and project configuration and making changes in both the product and in the process developing the product.

Main Principles for Product and Project Configuration

A central aspect of the project is the functional analysis of the system (product) to be designed. The analysis impacts both on project organizing (activities and their sequence) and on the functional block-diagram (product functionality). These two aspects of the project may be seen as two sides of the same coin, thus being reciprocally dependent upon each other.

Project breakdown is therefore, as in the approach based on *integration-driven development*, the process of breaking down customer requirements into prerequisites and work packages for the design project. In a more deductive approach, the project breakdown can be described as *customer requirements* broken down into *system specification*, further broken down into *functional specification*, further broken down into *design specifications*, directed toward both software and hardware development. Based on design specifications, work packages are determined and distributed to the organizational units. In a more inductive approach, these activities are going on in parallel and are reciprocally dependent on each other.

Product build-up is the parallel process of building up the pattern of verification and integration of the work that is or will be performed, based on design specifications into functions. It is also a process of building up the pattern of integration of functions into system functionality. This process is usually called the *verification and integration procedure* and is used as the main map for managing design activities.

> *"The spec grows during the design phase. There was substantial influence between system object and design. We had a lot of small informal meetings where we sat down together in a kind of joint interaction and mutual influence." [Software Designer]*

Project Configuration

The traditional limitations in performance for projects applying the approach based on *planning* were more evident now under the present circumstances for the teams' work, i.e. with total system responsibility, close customer interaction and the customer's demands on speed and flexibility. Instead, the work was structured according to a *coordination facilitation principle*, in contrast to the previous coordination minimization principle. This supported a new, more iterative and highly flexible development process. The second-generation project was configurated so that more than one team was responsible for each sub-system and every team worked on more than one sub-system, i.e. changing initial pooled dependencies to reciprocal dependencies[72]. By doing so, the need for coordination increased and forced the project organization to build the necessary coordination capacity. One of the factors enabling this major reconfiguration of the project was the re-distribution of responsibility from the line to the project organization after the first-generation project. Briefly stated, the motive for this change was that the parts of the organization which are responsible for value-adding work must also be responsible for decisions impacting the conditions for doing this value-adding work. This enabled the second-generation project to implement a much faster and more flexible decision process, adapted to

---

[72] For an analysis and further description of dependencies and their character, see Chapter 5, p. 225 and Thompson (1967).

the specific needs of the project and the system that should be delivered, rather than to the general needs at Ericsson Microwave Systems or specific sub-system traditions.

The second project generation used a parallel process (in line with the one described above) of breaking the project down into work packages and building the product up to an integrated and verified product which mirrored the project configuration. A central aspect of the project was the functional analysis of the system to be developed.

In a changing context, *Japanese Subsystems* has tried to find some stability on which to base its organization. One aspect that has proved to be quite stable is that of critical dependencies.

> *"Dependencies are known and do not change a lot. Find dependencies!" [Technical Coordinator]*

Convergence within the Project

The convergence within the projects is very high; i.e. most actors have the same picture of the main aspects of each project. This is at least partly explained by the fact that many are involved in system specification, product and project configuration and customer interaction.

> *"We put in a lot of time at the start of the project in order to have a project time schedule that was accepted in the whole project. When we established the time schedule we started to identify all functions and in what order they should be verified. The consequence was that we could very clearly, for all of the staff, identify even small work packages and when they should be finalized." [Project Manager]*

The project may be characterized as *totally convergent* regarding its objective. The results of the sensemaking of the project members' work and decision routines are as follows.

The very precise point of delivery caused a general *awareness and search for speed* and rapidity among project members, which in turn caused a search for "the shortest way to reach the goal". It also forced project members into close *interaction with the customer* so that time would not be lost. The time pressure also meant that a dynamic attitude was held toward the system specification, i.e. *specifications* were deliberately allowed to *change*. Likewise, the work procedures as to integration and verification were affected. There was *"no time to waste"*, meaning that *integration and verification* of different parts started as soon as possible, i.e. without any plan as to when they were supposed to be verified.

> *"Time – the finishing time and prototype delivery was clearly in focus. Functionality is a very important goal as well, but time is more important. In the prototype phase, cost is not important at all. In the production phase, cost becomes more important because of the large production volume." [Hardware Designer]*

Transparency within the Project

The transparency within projects at *Japanese Subsystems* is very high, partly since many people are involved in system specification, product and project configuration, but also because the actors worked in different parts of the projects and were invited to develop other parts as well.

> *"If, for example, I had an idea that the spec could be expressed differently, I said so and if they (the system object) thought it was a good idea they changed it." [Hardware Designer]*

Management as Applied by Sway-groups

The projects at *Japanese Subsystems* are managed by providing as many actors as possible with wholenesses. The projects strive for co-location and local participation in setting goals, analyzing context and handling the dynamics.

Sway-group Focus

Sway-groups at *Japanese Subsystems* focused on wholenesses and developed the term *"least possible wholeness"* to capture an effort at providing whole pictures for all actors involved in a project.

"The joint participation in writing the system spec has three major impacts – two good ones and a more problematic one: everyone knows both the spec as such and potential coordination points and sequence, and the communication line is shorter, but there is a shortage of resources for starting up design." [Project Manager]

The customer demanded speed, time of delivery and flexibility, and the firm had defined the customer as strategically important, so the management focus was clearly on speed, time of delivery and flexibility.

"Specs are changed due to discussions with the customer. It is a natural part of the project that everything moves all the time." [Project Manager]

"Concurrent engineering leads to several versions of the spec (specification). The main document has been revised eleven times." [Technical Project Manager]

The focus is on staying in control in situations rather than staying in control over situations. To do so, building organizational capacity to cope with changes, deviations from plans and necessary uncertainties become important. Projects at *Japanese Subsystems* focus on dynamic synchronization through creating mechanisms and arenas to handle real-time coordination and change.

"Rough spec or no spec in the beginning makes the design emerge. Continuous interaction between system object and design, and early decisions on what is the minimal start information to the next participant and phase, is all that it takes (...) The spec actually describes what has happened, and is more than 50% a historical description. Many system studies were finalized after hardware and software were finalized." [Technical Coordinator]

Dominant Value System

The most important things in projects at *Japanese Subsystems* are project progress and the customer. The customer wants projects to deliver not only according to set targets, i.e. a specified system at a certain point of time to a specified cost, but also according to emerging targets. The Japanese customers also develop their own product in parallel, which leads to changes in sub-system prerequisites. The organization responsible for delivering this sub-system must then manage to master these changes.

> *"You have to be flexible in a very fast project and you have to understand that everything does not always have to be there – only what for the moment has the highest priority." [Subproject Manager]*

The importance of the customer to the project was, among other things, manifested through specific persons devoted to customer interaction and to proactively finding out what the customer wants, potentially wants and probably will want in the future.

> *"We built our own Japan-filter with two persons allocated for daily contact with Japan and the customer." [Project Manager]*

The information from this Japan-filter guided the project in real-time decisions, and internally induced change was evaluated in the perspective of the customer.

> *"First try to find a solution. If this is not possible, then find a solution with the least negative impact on the customer." [Project Manager]*

To cope with this endeavor, resource flexibility has become an important element in building a capacity to manage both speed and flexibility. *Japanese Subsystems* has also developed a practice where many people are involved in most project activities.

> *"The person who feels a need goes to the person in charge for what can help." [Hardware Designer]*

The initiatives made by single individuals are an important aspect of the approach used at *Japanese Subsystems*.

> *"When I implemented the software I saw a need to change the spec (specification). I took an initiative to do so and then, all of a sudden; I had more responsibility, even for hardware. Nobody in the project*

was afraid to ask for what he or she wanted or needed." [Software Engineer]

Dominant Perspectives on Principles for Management

A design model based on actual work emerged from the complex and dynamic reality in which the project and the project members acted. Instead of strictly following a sequential plan (e.g. *PROPS*), certain *work procedures* and *interaction procedures* emerged. During the project, these procedures – more or less – were described in terms of a work model, thus creating a sort of *mental model* among the designers and project management. Whether this was tacit or explicit knowledge is difficult to estimate; some kind of informal model based on shared understanding, however, did develop.

"Abandoning" a strict plan to follow requires its replacement by another structure to which to relate and coordinate work progress. In one of the earlier projects, this structure came to be primarily the *I&V Plan* and, secondarily, the *work package description*. The *I&V Plan* differed from more traditional structures also in that it was *continuously changing* as the system specification plan changed.

> *"As soon as we get something we have to start working with it, and then there is a continuous update through the chain." [Technical Coordinator]*

Roles of Different Groups of Actors

The intense coordination need that follows the project configuration give the *project management* one superior mission – building coordination capacity.

> *"Interaction between people working in the different objects was quite frequent, once a week in meeting rooms and once a day less formally in someone's office..." [Test Engineer]*

The *project management* also acted as guardian of the time schedule by making everyone aware of its sacredness.

"The meetings were held at object (sub-project) level. Decisions were made on the object level. Decisions from above (project manager) were more about time schedule. If we saw that something was a problem, we had an informal meeting, calling those who had an influence on the issue." [Sub-project Manager]

The *technical coordinators* acted more as advisors and, in a way, were responsible for writing the history, i.e. what the product finally became. The large number of actors drove much of the initiative on technical solutions involved in different sub-systems, system specification, integration and verification.

The *project contractors* were not visible in the project. A special type of information was produced for the project management to show at steering-group meetings, but otherwise they had no active role in or in relation to the project.

"Project contractors do not have a lot of influence. Wee very much run the business ourselves." [Sub-project Manager]

The *line management* worked closely with the project management, especially during the first generations where the line organization was the same as the project organization.

Area of Responsibilities

The line organization was built in parallel with the first project generation starting in 1990, and the result, as mentioned above, is that the line organization and the project organization have so far cooperated with similar priorities and goals. There are less distinct borders between different groups of actors, and individual designers also perceive their possibilities of influence as good.

"You have a lot of influence as a designer on how the work is done." [Software Designer]

By appointing actors responsible for more than one sub-system, they become involved in the progress for the whole project and difficulties in other sub-systems.

"The goal was to make the prototype delivery in time. If somebody else had a problem, that was also my problem." [Software Designer]

Coordination

At *Japanese Subsystems*, the coordination need is extremely high; actors spend much time on coordination activities and coordination is seen as imperative for success. Coordination is made as often and early as possible, using a large number of both formal and informal coordination mechanisms.

Perspective on Coordination

Due to the project configuration and the changing system specification, coordination is seen throughout the organization as imperative to success. The prevailing view is that coordination must be done as often and as early as possible.

"To manage our complex projects we have to interact, interact and interact with each other. That's the only way to build a common picture and understanding of the collective achievements to be made." [Subproject Manager]

Coordination is seen as an important part of actual value-adding work, where new knowledge is created that brings the project forward.

Coordination Need

The coordination need is very high due to the use of a project configuration based on building dependencies and due to frequent changes in system specifications.

"Our need for coordinating is high. Too high, in some persons' view." [Sub-project Manager]

Type of Coordination Mechanisms in Use

To manage speed as well as flexibility, the project organization developed and used many different mechanisms for coordination between the different parts and actors in the project. The project used *formal* and *informal* mechanisms as well as *internal* and *external* ones. Formal mechanisms are those described in manuals, project handbooks, work descriptions etc, while informal ones are not. External mechanisms have participants that are not formally engaged in the project, while internal ones do not have such participants. Mechanisms may exist in more than one position. The number and variety of mechanisms made the projects manageable despite short time limits and dynamic customer demands. The mechanisms for co-ordination and integration are described below.

	Internal	**External**
Formal	Project Meetings Progress Reports System Specification work Product Anatomy I&V Plan Interwork Descriptions	System Specification work Fault Report Board Continuous Customer Contacts
Informal	System Emergency Board Temporary Forums Corridor Talk Sense-Making	Temporary Forums

Figure 9.1. Mechanisms for coordination

As the figure indicates, the projects use both formal and informal as well as internal and external coordination mechanisms.

Project meetings were held weekly primarily to handle formal progress reporting, discussion about deviations and formal decision-making.

> *"Booked meetings are for planning, status information and formal decisions; other things are solved in the corridors and actions are taken as soon as possible." [Subproject Manager]*

Every second week, formal documents called *progress reports* describing the actual status (in terms of actual workload handled, engineering hours and resources used compared to plan) of every object were spread in the project, compiled at the project level and spread outside the project to the different stakeholders. The *system specification* was used not only as input for work packages and design objects, but also to give project participants an overview of the project and whom they had to relate to and in what order.

> *"We also put a lot of effort into specifying the system and involved many hardware and software designers. The benefit was that the designers from the beginning had a deep knowledge of the requirements and how the product should be built." [Project Manager]*

The *product anatomy* was used as a tool for all engaged to develop and share a coherent view of what was necessary to accomplish and how the different tasks related to each other. The *integration and verification plan* described the actual workflow in the project and in what order work packages had to be finished to ensure smooth progress. This is one of the main documents used by designers in their work, as well as one of the main documents used in the interaction with the customer. The *interwork description* was based on an earlier and common view of the system architecture and known dependencies between objects. It described how and when interactions between objects should be handled. This description was also flexible and adapted to new and emerging dependencies.

Based on experience from *Japanese Systems*, a *system emergency board* was created when integration and verification started in the project. The purpose was to provide an on-line decision service for different parts of the project.

> *"We also established a system emergency board which made all important technical decisions. From a technical point of view the project was run by the system emergency board. Members were all object leaders, including the project manager. The system emergency board was given a very strong position in our organization and was allowed to make decisions that influenced both technology and staff." [Project Manager]*

Many *temporary forums* were created during the project in order to solve specific problems or reflect specific areas. These forums could be initiated by anyone and could last for different periods of time. In addition, *corridor talk* was used to solve problems and prepare decisions.

> *"Coordination is very much done in the corridors here (...) The corridors provide an opportunity for both quick overviews of new situations and preparations for decisions." [Sub-project Manager]*

> *"We continuously held informal meetings in the corridor or in someone's room, where decisions were made and people left and did what was agreed." [Hardware Designer]*

A *fault report board* was established to handle fault reports during successive stages of the project. The board consisted of participants from different sub-projects and from the project contractor. In addition, most engineers had *customer contact*. The main contact was coordinated by the project manager and the system object leader, but most designers participated in the contacts by working close together with the customer and discussing the frequent changes in specifications.

To continuously support progress and initiatives fast feedback was identified as important and *short feedback loops* where established as an important goal and driver for behavior in the project(s). These short feedback loops facilitated an effective process of *sensemaking* where principles and actual models for organizing emerged in continuous interaction between the actors and based on early experiences from application.

In summary, coordination is managed at *Japanese Subsystems* by co-location and local control over purpose, context and dynamics, which gives actors the opportunity to build necessary forums to handle their coordination needs.

Time Spent on Coordination

All groups of actors spend a very high proportion of their time on coordination activities.

> *"You talk so much with everyone here. When I was new I asked everyone about everything." [Hardware Designer]*

There is less of a difference in time spent on coordination between groups of actors within *Japanese Subsystems* than in the two earlier cases of *Large Switches* and *Japanese Systems*. In the earlier two cases key-persons as project managers and technical coordinators spend a lot of time in coordination while single engineers did not, while most actors act as key actors at *Japanese Subsystems*.

System Integration

System integration is perceived as vital for project progress. This integration is made continuously by the built-in dependencies through the project configuration. Special attention and resources are devoted to system integration activities.

Dominant Perspective on System Integration

System integration is achieved continuously by having engineers working in each other's sub-systems, and more than half of them is engaged in working with the system specification, integration and verification.

> *"In the I&V phase those people (the I&V team) were using my software, and if something didn't work they called me. I was there almost all the time." [Software Designer]*

By focusing on integration as a continuous activity, many people gave priority to working with system integration, and key actor time was devoted to this critical activity.

> *"When you put it together you have to interact, of course. We sit together and are well informed on what others are doing." [Subproject Manager]*

By defining system integration as a collective endeavor and a collective activity critical for reaching project goals, single engineers changed their behavior from delivering their design to *"the other guys"* to following their work along the flow and using it as a platform in a more collective design process.

> *"The first integration is between software and hardware. I deliver complete working hardware to the software group. We sit together and implement the software in the hardware; they debug their software and I debug my hardware, so we actually debug together." [Hardware Designer]*

Dominant Perspective on System Interdependencies

Both *project management* and *technical coordinators* put a great deal of effort into highlighting system interdependencies. This effort, together with a project configuration based on building dependencies, increased all actors' attention and focus on interdependencies, especially the more troublesome ones.

> *"Much of the time, people don't realize that they are dependent on something, just because they are not familiar with that particular line of code or what function their part has in the whole. In this project we have tried to work with people's attention to their dependencies." [Technical Coordinator]*

> *"Everybody has to be involved in every part of the project. Everybody participates in the system design, in the integration and verification and so on, and there are a lot of people who understand*

the whole picture. You can always get answers to your questions." [Project Manager]

Sway-groups in the organizational setting also stress accountability both for individual engineers and for actors with larger responsibilities.

"Making developers responsible for the problems they create may reduce the number of problems that are being created." [Senior Manager]

Organizational Design

Japanese Subsystems strives for co-location and building a flexible resource base through interdependent responsibilities. The flow of communication is intense and multidimensional. The organization is highly projectified, and the dependencies between project generations are high due to a limited set of actors and fast growth in size. System knowledge is highly valued and dependencies on external specialists are low due to high internal level of competence.

Knowledge Base

Japanese Subsystems is organized on the basis of one major site with co-located engineers, one production site, and one site with primary marketing responsibility. The knowledge base is cross-functional due to engineers' involvement in more than one sub-system. System knowledge is regarded highly, and integration and verification drive design activities.

"We want our engineers to feel an affiliation not to their sub-system or their part of the organization, but to the organization as a whole and to the project they participate in as a whole." [Senior Manager]

Flow of Communication

The flow of communication at *Japanese Subsystems* is intense due to the coordination need and wide range of coordination mechanisms. Many actors interact with many different types of actors, using both formal and informal, both hierarchical and lateral, arenas. The flow of communication is, as in *Japanese Systems*, a responsibility not only for the sender but also for the receiver, by being responsible for their input.

> *"We have to communicate a lot to get things going. Sometimes it feels like everyone is running around trying to communicate with everyone, but by being collectively responsible for both distributing and collecting new and relevant information I think we can manage." [Sub-project Manager]*

Work Packages and Task Allocation

The work packages come out as a natural result of the product and project configuration, the system specification and the *I&V Plan*. The specific characteristic of each work package at *Japanese Subsystems* is that it is highly dependent on other work packages.

Degree of Projectification

The degree of projectification at *Japanese Subsystems* is very high. The line organization and the project organization have historically been the same, and the cooperation between line managers and project managers is dense.

> *"The projects are our umbilical cord. It is from them that we get satisfied customers, resources and work attractive enough for the best engineers." [Senior Manager]*

Dominant Area of Competence

System knowledge is highly valued at *Japanese Subsystems*, and skills involved in system specification, system integration and system verification are seen as critical for both project and organizational success.

Dependencies between Project Generations

The dependencies between project generations at *Japanese Subsystems* are, as earlier discussed, rather high due to limited resources and high growth. Many actors are involved in more than one project generation, and some have important responsibilities in three different project generations.

Dependencies on Specialists

The dependencies on specialists outside the project organization are rather low, both because there are many specialists in the teams and because there is a high involvement in critical decisions and a high transparency.

> *"It is seldom that you can't solve a problem – no matter how complex it seems – by gathering your colleagues in the corridor." [Software Designer]*

Progress Control

Progress Control at *Japanese Subsystems* focuses on time and takes the integration challenges into serious consideration. Judgments of progress are based on actors' own subjective perceptions. Different illustrations are used to show all project participants the project's progress and major future endeavors in real-time.

Focus of Progress Control

The focus of progress control at *Japanese Subsystems* is to be on time. This means on time at the project level, i.e. so that the total endeavor is in focus; progress is measured in relation to the end goal, and sub-system progress is of subordinate importance. The project applies a more subjective perspective to progress by building the picture of project progress on different actors' perceptions of progress and goal fulfillment. The focus on total system progress further focused the integration challenge.

> *"The differences between planned progress and actual progress in a project are the same as in the integration problems." [Technical Coordinator]*

The process of achieving project progress at *Japanese Subsystems* can be described as follows. The conception of a solution represents the creation of new, potentially useful knowledge in terms of a rough outline of product characteristics. All operationalizations are continuously tested against the overall conception of a solution. Along the time dimension, the accumulated knowledge-creating loops represent a gradually enlarged picture of the product to be. This process reflects some sort of generation-growth phenomenon. In order to obtain fast and effective knowledge creation loops, they must be coordinated and integrated. Coordination in this sense will mean adjusting parts to each other and to the whole, as well as integrating the different knowledge elements into each other's and the overall system of knowledge. In order to succeed in this generation growth model, the anticipations must gradually be specified. Each system generation must be verified to check what value-adding knowledge has been achieved. In order to do so, it is proposed that two of the traditional main concepts in managing complex product development should be radically reconsidered.

Firstly, the system specification process should be seen as an ongoing activity throughout the project, rather than being frozen at an early stage. The system specification also serves the purpose of being a roadmap for integration and verification. Secondly, the testing and verification process should be initiated directly at the start, aiming to gradually assist the knowledge creators in providing feedback on how their work contributes to the emergence of a growing conception of the parts and the whole. The interplay between test, verification and design also provides possibilities for interacting with other knowledge creators in order to generate new synergetic knowledge which is instrumental in speeding up the process and providing input to the system specification process.

Figure 9.2 shows a typical project in *Japanese Subsystems* and its progress over time. System progress follows a concave line towards full functionality.

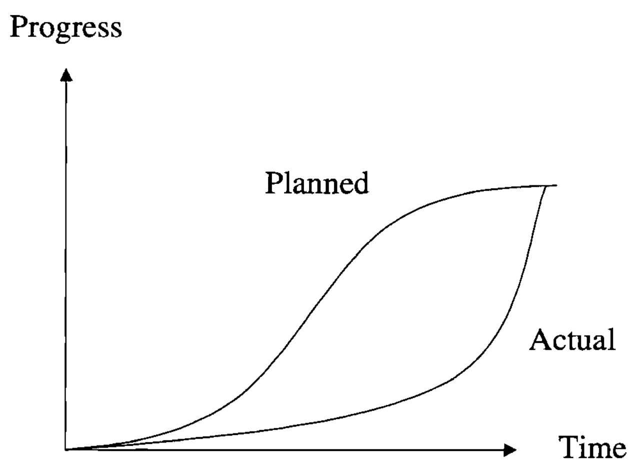


Figure 9.2. Typical project progress compared to plan over time

Figure 9.2. shows the typical characteristics of perceived project progress in a project applying the approach based on *dynamic synchronization*; (1) the curves (planned and actual) meet at the end and (2) management uncertainty is great (due to the large gap between planned and actual progress) during late phases.

Type of Progress Control and Tools for Progress Control

Customer business descriptions, customer needs and customer interaction are used as important tools to provide actors with an understanding of priorities and specific project focus and a shared mental model. To clarify the use of this mental model, actors at all levels in the project are linked as closely as possible to the customer interaction. Customer communication and system specification change documents are made available, and engineers at all levels are free to highlight questions of importance to be discussed with the customer; many of the engineers are sent to Japan to solve specific problems on site. The customers are then used as the main guideline for decisions and for both intra- and inter-project priorities during the running projects. Another guideline is time.

> *"Time is so limited that if you make a mistake it shows very quickly." [Technical Coordinator]*

> *"Because time is so limited, you seek advice. When you are new you ask all the time, and everyone has been patient. Everyone is involved in the same project, so your problems are common problems that have to be solved, even the smaller ones." [Newly recruited Software Designer]*

A strong focus on time also helps actors to prioritize and act when conditions change.

> *"The I&V Plan changed due mainly to delivery delays. When the plan changed, the first action was to recap the delay. The second was testing. The third was resource allocation within objects, to solve the problem at the expense of documentation and other such things." [Sub-project Manager]*

In summary, the notion of project progress as a collective challenge made actors take responsibility not only for their own tasks or sub-systems but also for the whole project and troublesome parts. This was made possible through a number of informal and formal meetings, as described above, to share information – and through a number of initiatives from project management on visualizing project progress to all participants in real-time.

> *"In order to make progress in the project visual for the whole staff, we established a chart of the I&V Plan, where we showed the progress in the project with different colors. The I&V Plan was located in a central place where most people passed at least once a day." [Project Manager]*

Managing Perceived Complexity and Uncertainty

Perceived complexity and uncertainty is managed by giving as many people as possible the whole picture to guide them through different potential situations that may arise. The complexity and uncertainty that actors meet in the projects is perceived as moderate.

Principles for Managing Perceived Complexity and Uncertainty

The main principle for managing perceived complexity is to avoid breaking the total complexity down into pieces, but instead to give as many actors as possible the whole picture. This principle is based upon the assumption that an overview and wholenesses reduce perceived complexity and that an arranged picture increases perceived complexity. The main principle for managing perceived uncertainty follows the same logic where rigorous plans and deviation control are changed for providing actors with the full picture about demands and actual progress in the different parts. Full knowledge about goals, conditions and important considerations provides actors with a fair chance to stay in control in different situations.

> *"By knowing and understanding the answer to the question of why, it is possible for most actors to make most decisions in real- time, instead of having to ask every time a new situation emerges." [Senior Manager]*

Perception of Complexity and Uncertainty

Actors in *Japanese Subsystems* perceive the complexity that they meet in projects as equivalent to low level of ambiguity[73]. Actors have a good knowledge of critical parties and most of their interdependencies, but a lack of knowledge of some interdependencies and their value, especially during the early phases of a project.

---

[73] In the framework presented in chapter four based on Schrader, Riggs&Smiths (1993) categorization of technical uncertainties.

"When we start a project, we know that we are highly interdependent on each other's work, but we don't know the exact interdependencies in terms of where and how important they are." [Technical Coordinator]

Actors perceive uncertainty also as equivalent to low level of ambiguity, reduced by having the whole picture.

Performance

Projects applying the approach based on *dynamic synchronization* support speed, flexibility and resource development, and often meet both set and emerging targets.

Project Capacity, Lead-time, Cost and Functionality

For a long period, the progress in the first-generation project was very discouraging: performance in developing the product was poor, and chaos seemed to reign in the project organization. However, the project managed to deliver the end product within the agreed time frame, even though its quality and performance were in some respects poorer than their competitors'. This achievement was possible due to an understanding of business logic and business algorithms, which made it possible to focus on time before functionality and costs. The first-generation project was the first attempt for the organization to work with time as a main goal parameter and in close interaction with the customer. The process of organizing and managing the development project under these circumstances involved much trial and error, and led to much learning in the organization and by the individuals in the project. This learning became possible only when actors could relate directly to the whole system and to customer needs, instead of having traditional sub-system responsibility and no customer interaction. Learning was further enhanced by the combination of experienced and new employees – together they combined a motivation and a capacity to learn. One of the main insights from the first-generation project was that the customers not only demanded speed and precision regarding delivery times; they also demanded flexibility in adapting to new specifications during project progress – an extra complicating factor due to the customers' own continuous and parallel ongoing development process.

The second project generation faced an even harder schedule (an extra 20% in time reduction). Moreover, project members had to meet the customer's demands of eliminating the shortcomings from their first project generation, in terms of a non-stable design base and a need to continuously refine delivered products. Most of the engineers who took part in the first project could participate in the second-generation project. Newly recruited and highly motivated engineers joined them. The lessons from the first-generation project – together with the newly acquired knowledge of the *product anatomy*, i.e. knowledge about critical components, critical dependencies, risks and opportunities in the product structure – led to major changes in both the support systems and the principles for managing and organizing the projects.

The two major changes introduced in the second generation were in *configuration of the project* and in *the interaction between the project organization and the line organization.* The project engineers questioned the dominant principle used to break projects down into sub-project assignments. This was derived from the basic assumption that complexity in the projects is being reduced by breaking down the envisaged final project into as many independent sub-systems as possible and then assigning different teams the responsibility for each independent sub-system. The principal aim of this approach is to decrease the need for coordination, to create a clear focus with clear limits of responsibility and to create possibilities for the development of the team's competence development in a clearly defined area.

This principle did not, however, meet the main purpose of the projects in the current situation. Its shortcomings were that (1) it focused on sub-systems instead of the system as a whole, which could create problems in integrating sub-systems and in total system performance; (2) a breakdown with the purpose of minimizing dependencies could be a dysfunctional breakdown, with respect to the natural integration of sub-systems and the build-up of the total system; and (3) it entails too great a risk that important factors may be given insufficient attention as a result of “falling between” the definitions of design team assignment responsibilities, or that opportunities arising from combinations of sub-systems may be overlooked.

The second-generation project is seen as one of the company’s best practices. The project exceeded expectations and delivered a product in 1995 well comparable with the two main competitors’ products. The main lesson drawn from using another configuration for the project and giving more responsibility to the project organization was that the project could meet the coordination needs created by developing its coordination capacity. Many new mechanisms for real-time coordination were created during the project, such as a system emergency board that formed a quorum for critical decisions or priorities 24 hours daily during the most critical phases of the project. With an increased capacity for real-time coordination, the troublesome demands on both speed and flexibility could be met. The project was one of the fastest for its size ever performed at Ericsson and, at the same time, 11 major reconfigurations were made of the system specification during the project – the last ones after production had already started. The reconfigurations were all critical to project success and customer satisfaction. Establishing real interaction with the customer at an early stage in the project yielded the flexibility. More than 25% of the project time was spent in close cooperation with technical and business representatives from the final customer, and every engineer in the project had daily access to customer representatives as the need arose.

Each of the analyzed project generations has actually managed to further shorter lead-time for both first prototyp and for service-in (se figure 9.3). This endeavor is accomplished despite larger and larger tasks in each project generation.

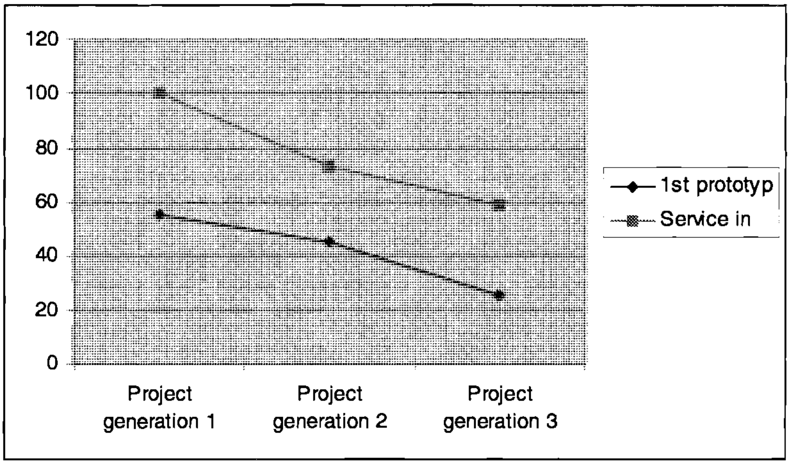


Figure 9.3. Relative lead-time for 1^{st} prototype and service in for the different project generations

There are examples of projects applying the approach based on *dynamic synchronization* with more than 100 persons involved and performing 220 kman-hours. However, when co-location is crucial for the approach to work, its capacity is limited in comparison to the other two approaches.

Project Flexibility

The projects applying the approach based on *dynamic synchronization* have shown to have an extraordinary capacity to cope with major changes during the execution phase. One of the project generations managed to cope with eleven major changes in system specifications during a twelve-month period, all initiated by the customer. The changes made by the customer were not only frequent but also late, facing stable specification first after delivery and one month before service in. Despite those both frequent and late changes the project was delivered on time. This was made possible by implementing three major changes in the integration and verification plan and three major changes in the interwork descriptions. Despite this continuous flexibility in the design process, the project managed to keep up a high speed. Normally, these two features occur separately, as flexibility slows down the process and high speed obstructs flexibility.

Conditions for Organizational Learning

Both *propensity* and *capacity* for all types of learning is high in this organizational setting. Learning is integrated as a natural part of actual work and engineers at Japanese Subsystems posses good conditions for learning.

One explanation that projects in *Japanese Subsystems* do meet set and emerging targets is that resource development is extremely fast in the organizational setting. Engineers could develop to system designers contributing to the total system progress and being able to represent the total project task towards customers in less than three years. A high-performing engineer can be developed in three to six months, and a full-fledged system designer can be developed in approximately one to two years, regardless of earlier experience. As a comparison, it normally takes five to ten years to develop a system engineer in other parts of the firm. The speedy training can be explained by early involvement in the whole project picture, a short project cycle and a focus on fast feedback.

The respondents' explanations for this type of fast resource development are close customer interaction, early involvement in the whole project picture, a short project cycle and a focus on fast feedback. The project participants at *Japanese Subsystems* also have higher education than Ericsson average and actively seek to join *Japanese Subsystems*.

Resources in the projects were highly skilled in comparison to a normal Ericsson standard. A large share (approximately 1/3) of the project members were seen as high-performing key resources competent enough to solve most problems within their area of expertise and possible to use in sub-system interactions. One of the important explanations for the large share of high-performing individuals is that resource development is fast in the organization.

Competence Development

A further positive aspect of using the coordination maximization principle was that, after a while, the engineers greatly increased their understanding of the system as a whole so that they could work with system specification, system integration and system verification as well as with their specific sub-system projects. Almost half of the engineers in the project were actually involved in working with system management along with their sub-system development. This proved to be a more effective way of developing the engineers' competence than previous methods. Newly recruited engineers could, as earlier discussed, actively contribute to the development work after approximately three to six months and acquire the competence of a system engineer in less than three years. The figures in other business units in Ericsson are at least double these.

Competence development is mainly focused on multi-phasing rather than multi-skilling, i.e. engineers developed their understanding of the system as a whole and knowledge supporting complete processes, rather than building detailed knowledge and understanding of sub-systems additional to those on which they themselves were working. This mainly opens opportunities for utilizing engineers at the same time, or in parallel, both in their particular sub-system projects and in the management of the total system, instead of simply using them in a few sub-system projects. This results in a project organization that has a capacity for dynamic synchronization rather than joint optimization, and with an increased capacity to perform parallel work processes[74]. This meant, for example, that the design teams responsible for the critical sub-projects on the critical time line in the second-generation project could start their detail design before, and in parallel with, the initial system management.

The third-generation project started in late 1995 and was able to utilize the key experienced engineers from earlier projects, together with a

[74] See for example Purser&Pasmore (1992), and their descriptions of organizing knowledge work.

considerable number of newly recruited ones. The project time frame was again reduced by 20% compared with the second-generation project. The product anatomy was known, i.e. the participants in the project were knowledgeable regarding critical components, critical dependencies, risks and opportunities in the product structure. The market conditions had also acquired a certain familiarity in the organization. The main lessons from the previous two generations were: to use a coordination facilitating project configuration and to create a team with special responsibility for integration and verification of the separate sub-systems at the outset of the project with the initial task of formulating an integration and verification plan to manage progress in the project.

In the spring of 1996 the third-generation project managed to outperform the two main competitors and was able to deliver the first working prototype of a new product generation. In 1998, the organizational setting had reached the position as a leading supplier and has successively strengthened its connection with the Japanese customer.

Without the holistic perspective, close customer interaction and new responsibilities, the capacity developed to manage both speed and flexibility at the same time would not exist. Hence, the rapid resource development would not be possible without the early introduction to the whole system or the short feedback loops provided by the close customer interaction.

The engineers also utilized their own initiative in formulating business goals for the projects by making special efforts to reduce the time in the later stages of the project. Their reasoning was that the hours worked in the project represent company capital tied up in work in progress. Reducing the number of hours in the later stages of the development work enables earlier delivery to the customer, which both leads to increased customer satisfaction (by exceeding customer expectations) and releases company capital earlier than projected: two positive business results. A result of equal or perhaps greater significance is that the engineers discussed their activities in the project not simply in technical terms but also in business terms.

The organizational capacity created has obvious risks that must be handled. By providing actors a whole system view, involving them in customer interaction, and at the same time creating an increased coordination need in an environment with continuously increasing demands and then re-utilizing key human resources in every project generation, the risks of burnout and missing the focus are clear. There are limits to how much complexity and tension a person can handle. These problems are becoming evident in the third-generation project and were also identified as the challenge of highest priority to solve in the fourth-generation project.

The Approach based on Dynamic Synchronization – an Integrated Discussion

The approach based on *dynamic synchronization* supports speed, punctuality, flexibility and resource development. Projects applying such an approach perform their product configuration based on incremental build-up of functionality, as in integration-driven development. Project configuration, however, is based not on minimizing or controlled dependencies as in the approaches described earlier, but rather on building new dependencies. Projects followed a rule that each sub-system had at least two design teams devoted to it, and that each design team worked in at least two sub-systems. Further, the projects – like those applying the approach based on *integration-driven development* – had a continuous focus on actual progress and verified functionality growth, rather than processed time and sub-system progress. Actors manage complexity by providing all participants transparency regarding wholenesses and focusing on the total system rather than specific boundaries or sub-systems. As in projects applying the approach based on *integration-driven development*, progress is driven by integration, verification and test activities rather than by design. The projects also work actively with giving participants a thorough picture by using graphic representations of key actors, key activities, dependencies, actual progress, next steps and highlighted problems. The most important difference between the approach based on *dynamic synchronization* and the approach based on *integration-driven development* is the number of actors involved in defining their own prerequisites, i.e. it is an approach involving much more self-organization.

Characteristics	**The approach based on Dynamic Synchronization in Action**	**The approach based on Integration-driven Development in Action**	**The approach based on Planning in Action**
Product and Project Configuration	Products are configurated according to how functionality is best realized. Projects are configurated by *building dependencies.* Every subsystem had at least two design teams working in it and every design team was responsible for at least two subsystems. *Many are involved* and responsible for both product and project configuration and making changes. *High* convergence and transparency.	Products are configurated according to how functionality best is realized. Projects are configurated according to how logical integration of subsystems is best made and guided by a focus on important and troublesome boundaries. A few key persons are responsible for configuration and changes. High convergence and transparency between actors in sway-groups but moderate in the total organization	Product and project breakdown with minimized dependencies. Use of *"black-box engineering"* and *"clean-room development"*. Hierarchical convergence but lateral divergence among group of actors. Actors from sub-systems are responsible for configurating and making changes. High hierarchical transparency but low lateral transparency.
Management	Based on the assumptions that (1) *complexity* is best managed by providing actors with the total picture, (2) uncertainty is best managed by distributing responsibility and providing the means for real-time handling, and (3) control is best gained by building interdependencies and distributing responsibility for meeting set targets. The projects are managed by providing as many actors as possible *wholenesses.*	Based on the assumptions that (1) *complexity* is best managed (reduced) by focusing troublesome interfaces and allocate highly skilled resources to handle situations in real-time, (2) uncertainty is best managed (reduced) by rigorous product and project configuration, and (3) control is best gained by continuos integration, step-wise functionality growth and a proactive project management. Key-actors strive for	Based on the assumptions that (1) complexity is best managed by breaking it down into *manageable units* as independent of other manageable units as possible and (2) uncertainty is best managed by *rigorous planning.* Focus is on following up outcomes in relation to the plans set up for the respective projects, and decision points and scheduled meetings drive development logic. Decisions orient and focus formal reports and flows of documents.

	The projects strive for co-location and local participation in setting goals, analyzing context and handling the dynamics. Most actors belong to the sway-group. Important goals are keep time and making a subsystem work in a customers emerging system.	*controlled dependencies* between parts of the projects and uses specialists for coordination in critical boundaries. Project Management is based upon early integration and stepwise functionality growth. Sway-groups focus on time, integration and actual functionality. Important sway-groups are project management, technical coordinators and testers. Important goal is keeping time.	Four main goals: (1) world-class technical performance, (2) resource-effectiveness, (3) market-oriented roll-out plans and (4) profitability for individual deals, segments and regions. The organization is based on low integration between different organizational subunits and subsystems. Important sway-groups are line management, project contractors and technical coordinators.
Coordination	The coordination need is extremely high. Actors spend *a lot of time* on coordination activities, and coordination is seen as imperative for success. Coordination is made as *often and early as possible*, using a large number of both formal and informal coordination mechanisms. *Build dependencies* to facilitate coordination. *Sensemaking* based on action and reflection upon action.	Actors apply a proactive approach to coordination and uses earlier project experiences to focus on troublesome integration. The *product anatomy* and the *I&V Plan* are vital tools in coordination and in visualizing and monitoring system progress. Highly controlled coordination with known dependencies. Key actors spend a large amount of time on coordination.	Coordination is perceived as a non-value-adding activity that takes time from the actual development work, and time spent on coordination is seen as a *transaction cost.* Strives for independent organizational units specialized in a specific function. *Large Switches* uses sequential or semi-sequential pre-optimized project plans and generic or semi-generic development models together with hierarchies in both lines and projects used to coordinate work – mainly focused toward hierarchical rather than lateral mechanisms and functional rather than cross-functional mechanisms. Sway-group members spend much time on coordination while non-sway-group members spend little time on coordination.

System Integration	System integration is perceived as vital for project progress. This integration is made *continuously* by the built-in dependencies through the project configuration. Special attention and resources are devoted to system integration activities.	*Japanese Systems* focus on early system integration with internal releases once a month. The mechanisms in use for facilitating integration are the *product anatomy* that shows how life is breathed into the product, the *I&V Plan* that shows how logical integration best is done, *workshops* with key actors that aggregate all perspectives and get key actors to agree upon vital focuses for the project, and *simulations by role-playing* that facilitates early identification of system errors. Actors in *Japanese Systems* are responsible for both their input and their output, and through continuous live tests there is a focus on what is actually working and what is not.	*Large Switches* performs its system integration late in the process and focuses on creating organizational *"black boxes"* independent of each other. Within each black box. Stable subsystems are created through the use of clean-room development, i.e. doing right from the beginning. Project management handles integration and interdependencies but actual influence on the process resides in the subsystems' line management and technical coordinators.
Organizational Design	*Japanese Subsystems* strives for co-location and building a flexible resource base through interdependent responsibilities. The flow of communication is *intense and multi-dimensional.* The organization is *highly projectified* and the dependencies between project generations are high due to a limited set of actors and high growth. System knowledge is highly valued and dependencies on specialists are low.	*Japanese Systems* is organized by geographically integrated competence centers designed and based on the *product anatomy* and the *I&V Plan* and with the purpose of minimizing interdependencies. Each project then has specific resources allocated to troublesome interdependencies. The organization is highly projectified and dependent on specialists. Testing *(downstream activities)* is the dominant area of competence and defines prerequisites in terms of times of deliveries and increments for design *(upstream activities).*	*Large Switches* is based on functional expertise organized in subunits responsible for specific subsystems and formally well-defined tasks. The base of knowledge on distributed competence, geographically dispersed. The flow of communication is mainly within subunits responsible for specific subsystems, and hierarchical towards different types of specialists. Prevailing development organization and earlier project configuration govern future project configuration and development of individual work packets. Most value-added work is performed in different types of projects, but a dominant line organization owns and manages resources. Design drives development and especially subunits responsible for design of important subsystems.

			High dependencies between project generations and on specialists.
Progress Control	Progress control focuses *on time* and takes the integration challenge into serious consideration. Judgments of progress are based on actors' own *subjective perceptions.* Different illustrations are used to show all project participants the project's progress and major future endeavors in real time.	Progress control focuses on *total system progress.* Perception of progress is driven by *stepwise feedback* from what is actually working through early system integration and testing of actual functionality. The projects use both the *product anatomy* and the *I&V Plan* to visualize project progress for all participants.	Focus on subsystem progress and deviations from plans. Uses formal progress reports and hierarchical project meetings as most important tools for progress control.
Managing Perceived Complexity and Uncertainty	Perceived complexity and uncertainty is managed by giving as many people as possible the *whole picture* to provide explanations and to guide them through different potential situations that can arise. The complexity and uncertainty that meets actors in the projects is perceived as equivalent to *low ambiguity.*	A focus on total system characteristics and important boundaries between sub-systems Actors in projects have good knowledge about components and interdependencies. A small group of actors defines the prerequisites for the rest. The approach based on *integration-driven development* reduces perceived complexity and provides different actors with effective tools to handle complexity. *Early integration* and actual *test of functionality* growth effectively reduces perceived uncertainty. Key-actors´ perception of the complexity and uncertainty that meet them are equivalent to *low level of ambiguity.* However most actors perceive complexity and uncertainty as equivalent to *moderate ambiguity*	Plan and control for reduction of perceived complexity by breaking down complex structures until complexity decreases. Rigorous planning and deviation control for reduction of uncertainty. A small minority (sway-groups) defines the preconditions for the great majority's perceptions of complexity. Perceived complexity and uncertainty as equivalent to moderate ambiguity.

Performance	The approach based on *dynamic synchronization* support speed, flexibility and resource development, and often meets both set and emerging targets.	The approach based on *integration-driven development* supports size and speed, and projects often meet both set and emerging targets. Responsibility for learning and renewal is integrated in ordinary work. High convergence and transparency among sway-groups and moderate among other actors (high on defined key issues). Capacity for learning and renewal are high but propensity is limited by earlier success. The number and capacity of key-actors limit further development.	The approach based on *planning* has unique experience in performing large projects, 1500 to 3000 kman-hours. Projects normally run over time and take 18-24 months to perform, and normally plan for a large amount of rework and design follow-up. Normally most complicated functions are transferred to later project generations due to insufficient functionality growth. Actors including sway-groups at *Large Switches* normally have very low cost-consciousness. Both the propensity and the capacity to change are rather low, even though no active resistance can be seen. There is no continuous work with improvements. Actors see process improvements as hard to measure and follow up and therefore hard to motivate and implement. Responsibility for learning is separated from actual work processes in parallel organizations. Learning and renewal focus on process configuration. Problems in learning often occur due to unplanned personnel turnover and lack of arenas in use.

Figure 9.4. A summarized comparison between the approach based on Planning, the approach based on Integration-driven development and the approach based on Dynamic Synchronization

CHAPTER TEN

Results and Comparative Analysis

IN this chapter the different organizational settings and applied approaches are revisited in order to consider the overall consistency of and differentiation between each approach in its organizational setting and in relation to its management. The chapter will provide an integrated discussion and analysis of the findings in the thesis and their relevance.

The Overall Consistency in Each Approach

It is not by analyzing each feature or set of features that the approaches are best understood. It is the interconnected whole of perspectives, principles and organizing models in use that constitutes each approach. Each approach is an *ideal type* constructed partly by me as a researcher. Actors in the organizational settings applying each respective approach have developed the patterns identified in the research projects into typical thinking and typical action. In this construction of ideal types it is the typical knowledge features that are relevant in terms of the researcher's guiding focus and frame of reference. This section will discuss the overall consistency of each approach and put them into the model capturing the purpose with the thesis[75] so as to analyze its *manifest* and *latent* attributes, both *functional* and *dysfunctional* ones.

---

[75] Figure 3.2, page 145 illustrates the main purpose of the thesis - to enlarge the known area (for actors in the organizational settings and for research in the area of managing complex product development) of both functional and dysfunctional latent and manifest attributes.

The Approach based on Planning

The approach based on *planning* applied by *Central Processor, Increased Network Capacity, Large Switches, Microwave Technology* and *Radar Technology* was given its name to illustrate its principal characteristic – a strong focus both on *project planning* prior to project execution and on monitoring the fulfillment of and deviations from those plans. Plans are used as the central framework around which the projects are organized and managed.

In the organizational settings applying the approach based on *planning*, most manifest and latent *functional* attributes are known while most manifest and latent *dysfunctional* attributes are not known or taken into consideration by actors.

The manifest and latent *functional* attributes are the following: a capacity to handle large and complex tasks, a simple organization to handle complex tasks, leeway for sub-system specialization, easy introduction, switching and replacement of single engineers, the use of objective and comparable indicators for progress and effectiveness, rigorous support for new actors and well-developed quality assurance to control performance. All of which are more or less known by key actors applying the approach.

The manifest and latent *dysfunctional* attributes that are taken into consideration are rigidity of the organizational system and difficulties in planning for highly dynamic contexts. Important manifest dysfunctional attributes that are not taken into consideration are slow projects without a capacity to forecast time of delivery, product and project configuration driven by sub-systems, one-sided use of reactive coordination, loss of system perspective, and excessively expensive integration. Important latent dysfunctional attributes that are not taken into consideration are non-motivated and alienated engineers, unattractive career as project manager, high dependencies on earlier practice, difficulty or impossibility of introducing new ways of working from a system perspective and the ambition to reduce complexity and uncertainty which may instead increase perceived complexity and uncertainty. (see Figure 10.1)

For a more elaborate analysis of each attribute, chapter 7 is recommended.

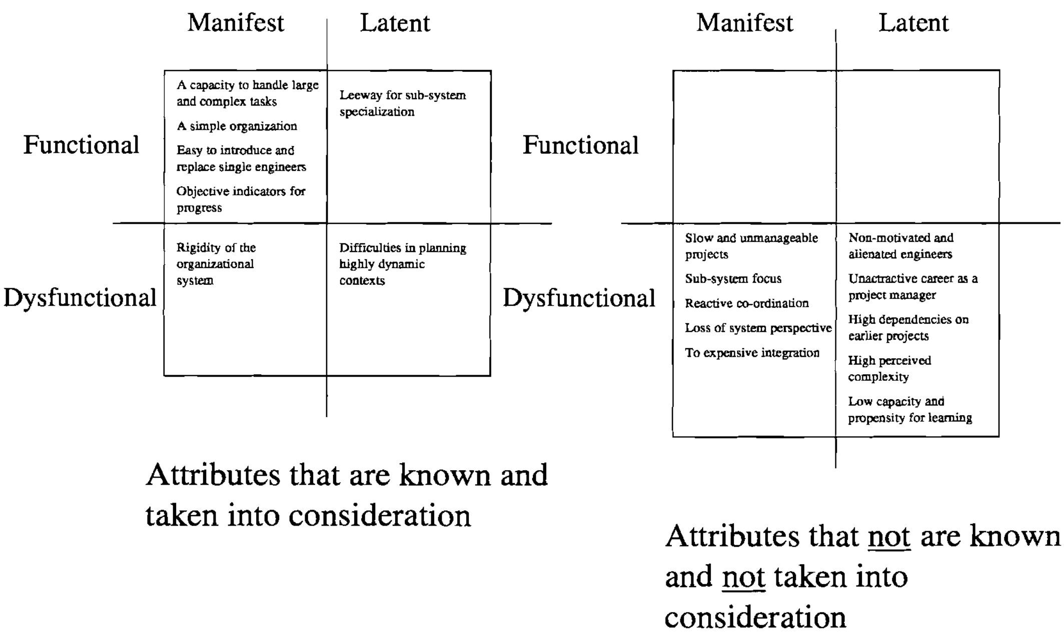


Figure 10.1. Functional and dysfunctional latent and manifest attributes in the approach based on Planning – the known and unknown areas

The overall consistency in the approach based on *planning* is high. Actors in sub-systems (especially the large and important ones) are leading figures and define dominant perspectives; principles and actual models for organizing that together constitute the integrated approach. The fundamental assumption behind the approach is a strong belief on rigorous planning as a means for reducing uncertainty and structured break-down and minimized dependencies to reduce complexity. The approach facilitates attempts toward *deductive optimizing* before project execution; i.e. searching for the optimal way of executing the project tasks supported by information that is known before projects start.

The Approach based on Integration-driven Development

The approach based on *integration-driven development* applied by *Japanese Systems* was given its name to illustrate its principal characteristic – a strong focus on *system integration*. System integration is used as the engine for project progress and functionality growth. Hence, the development is actually driven by the strongly focused system integration.

The approach based on *integration-driven development* has a large number of both manifest and latent dysfunctional attributes and some manifest functional attributes that actors in the organizational settings applying this approach do not take into consideration. However, most manifest and latent functional attributes are known to actors and are taken into consideration. The manifest and latent functional attributes that are known and taken into consideration are the following. Fast projects that meet set targets, early integration and handling of troublesome interfaces, use of proactive coordination, active leadership, attractive career as project manager and a number of key actors devoted to total system and project issues. The latent dysfunctional attributes that are taken into consideration are a limited number of key actors, a competence problem caused by fast growth. An important manifest functional attribute that is not taken into consideration is high convergence in critical issues. An important manifest dysfunctional attribute that is not taken into consideration is burnout of key actors. Important latent dysfunctional attributes that are not taken into consideration are a rigidity and low pace of renewal due to a lock in their earlier success, handling of old products and alienated engineers. (see Figure 10.2)

For a more elaborate analysis of each attribute, chapter 8 is recommended.

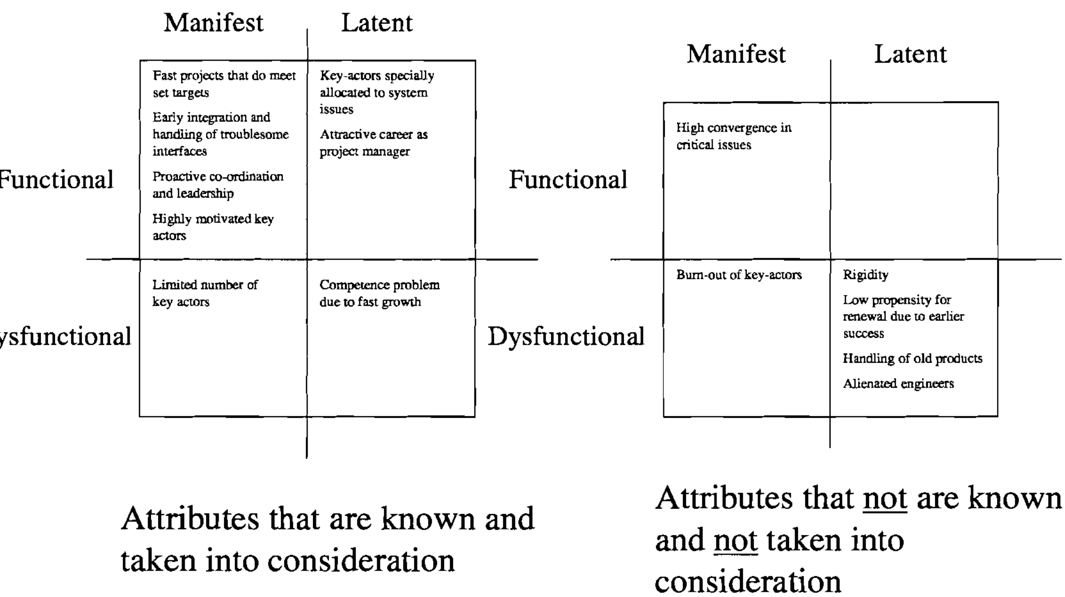


Figure 10.2. Functional and dysfunctional latent and manifest attributes in the approach based on Integration-driven development – the known and unknown areas

The overall consistency in the approach based on *integration-driven development* is high. Key actors at central positions in each project are leading figures and define dominant perspectives; principles and actual models for organizing that together constitute the integrated approach. The fundamental assumptions behind the approach are that early integration will shorten total lead-time and that products should be built up such as to facilitate a step-wise functionality growth. The approach facilitates a strong focus on a continuous striving for *effectiveness* both before and during project execution.

The Approach based on Dynamic Synchronization

The approach based on *dynamic synchronization* applied by *Japanese Subsystems* was given its name to illustrate two principal characteristics – *dynamic* and *synchronized*. It is dynamic so as to capture the ability of projects applying the approach to make fast adjustments to new conditions. And it is synchronized so as to capture the ability of projects applying the approach to refocus all actors toward a new situation while preserving high convergence and transparency by using an effective process for sensemaking based on action.

The approach based on *dynamic synchronization* has a large number of manifest and latent, dysfunctional and functional attributes that actors in the organizational settings applying this approach do not take into consideration. The manifest and latent functional attributes that are known and taken into consideration are fast projects that meet set targets and have a high coordination capacity. The manifest and latent dysfunctional attributes that are known and taken into consideration are high risk through parallel work and the use of new tools for monitoring project progress. Important manifest dysfunctional attributes that are not taken into consideration are subjective progress and effectiveness control and burnout among a number of actors. Important latent dysfunctional attributes which are not taken into consideration are the fact that project management alone stands the risk by translating actual work into prescribed work procedures and watering down sub-system knowledge. Important manifest functional attributes that are not taken into consideration are high convergence and high transparency, a high capacity for real-time coordination, highly motivated engineers, and a widely known business logic that creates better conditions both for effectiveness through *"global"* optimizations and for flexibility. An important latent functional attribute that is not taken into consideration is a way of working based on combinatorics that may become a new corporate core competence for Ericsson. (see Figure 10.3)

For a more elaborate analysis of each attribute, chapter 9 is recommended.

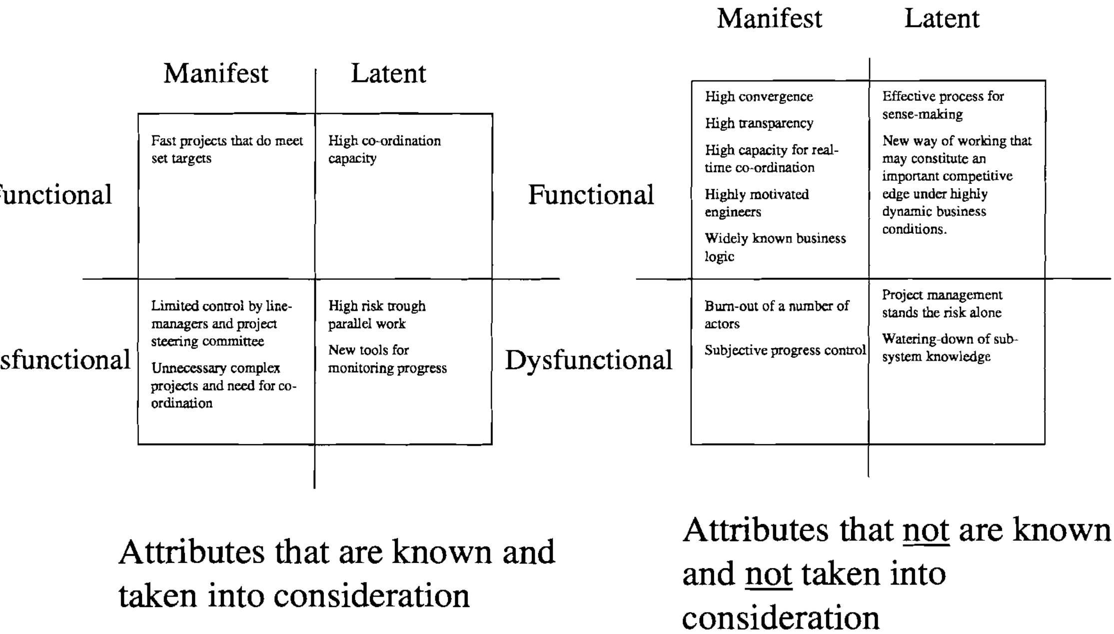


Figure 10.3. Functional and dysfunctional latent and manifest attributes in the approach based on Dynamic synchronization – the known and unknown areas

The overall consistency in the approach based on *dynamic synchronization* is high. Many actors in each project act as leading figures and define dominant perspectives, principles and actual models for organizing that together constitute the integrated approach. The fundamental assumptions behind this approach are that interdependencies build joint understanding, joint responsibility and a vital capacity for integration and that complexity is best reduced by providing actors with the full picture. The approach facilitates a continuous striving toward *inductive sensemaking* during project execution, mainly driven by action and reflecting upon action.

To sum up, all three approaches have a high internal consistency. Hence, the approach based on *planning* being an exponent for assumptions based on *full rationality* (see for example Hice *et al* 1974, Olsen 1976 or Bruzelius&Hansen 1986), the approach based on *integration-driven development* being an exponent for assumptions based on *bounded* *rationality* (see for example Galbraith 1973, Allen 1977 or Sjölander 1985) and, finally, the approach based on *dynamic synchronization* being an exponent for assumptions based on *sensemaking* (see for example Weick 1995 or Dougherty 1999)

Major Differences and their Origins

The above approaches and the organizational settings that apply them differ substantially in a number of respects, as described in chapters 7-9. This section will focus on the most relevant differences and their origins in the given context – *managing complex product development* – and will provide a summarized matrix of principal characteristics and major differences between the approaches and how they are applied. There are a large number of both important similarities and differences between the approaches. However, the areas of differences below are chosen because they are the most relevant in demarcating and capturing the uniqueness of each approach and follows from the discussions that have been made in chapters 7-9.

Product Configuration

Projects applying the approach based on *planning* configurate their products through stepwise breakdown based on technical suitability. The result is a strict hierarchical product structure with as independent sub-systems and components as possible, where the parts define the prerequisites for the whole. The product structure is often a mirror of the existing line organization, and projects implement few changes over project generations. Projects applying the approach based on *integration-driven development* configurate their products on the basis of how functionality is realized. The result is a map (a *product anatomy* and an *integration and verification plan*) guiding actors from no to full functionality, where the project management defines prerequisites for the organizations responsible for sub-systems and components. To redefine actors´ perspectives on how products are configurated, metaphors such as *product anatomy* and *breathing life into the product* are used. Projects applying the approach based on *dynamic synchronization* configurate their products in the same way as projects applying the approach based on *integration-driven development*. The difference is who does the configuration. In projects applying the approach based on *integration-driven development*, a few (approximately 20-25 out of up to 500) key actors are responsible for configuring the product. While, in projects applying the approach based on *dynamic synchronization*, many actors (often more than half of the actors involved in the project) are responsible for configuring the product.

Project Configuration

Projects applying the approach based on *planning* configurate their projects on the basis of existing organizational structures, breakdown and a striving for minimized dependencies. The result is a project organization that is a mirror of both the existing line organization and the product structure. The project configuration is driven by actors responsible for different sub-systems, and the configuration seldom changes over project generations. Projects applying the approach based on *integration-driven development* configurate their projects on the basis of how logical system integration is best achieved. The result is an integration and verification plan (*I&V Plan*) that guides action and decision further on in the project, with a project organization that supports the *I&V Plan*. The configuration is driven by a small number of key actors that strive for controlled (by the small number of key actors) dependencies between sub-projects. Projects applying the approach based on *dynamic synchronization* configurate their projects not only as projects applying the approach based *integration-driven development*, based on how logical integration is best achieved but also by building dependencies. The projects actively build dependencies into the organizational system by formulating two simple rules for project configuration: each sub-system will have at least two teams allocated to it, and each team will be allocated to at least two sub-systems. One further difference between projects applying the approach based on *integration-*

driven development and projects applying the approach based on *dynamic synchronization* is that, in the former, there are a small number of key actors responsible for the configuration and, in the latter, there are a large number of actors responsible for the configuration. The result is a highly complex organization with an intense need of coordination but with high convergence and high transparency. Prior determination of tasks (in the projects applying the approach based on *planning*), determination of task coordination requirements (in the projects applying the approach based on *integration-driven development*), or the creation of organizational structure supplemented with direct supervision (in the projects applying the approach based on *integration-driven development*) is replaced with an intense need for communication (sensemaking). And also, a striving to build a high capacity for integration and sensemaking based upon action and reflecting on action.

Actors' Roles and Responsibilities

In organizational settings applying the approach based on *planning*, the parts clearly define the prerequisites for the whole. Both formal and informal authority resides in the sub-systems, and actors from each sub-system optimize both plans and execution from their perspectives. In organizational settings applying the approach based on *integration-driven development*, key actors in the projects clearly define the prerequisites for actors responsible for the development of different sub-systems. A small group of key actors in each project plays the leading part, while other actors in the organizational setting act as supernumerary and are seen as means to reach the project goal from the group of key actors' (the sway-group) perspective. In organizational settings applying the approach based on *dynamic synchronization*, many actors in the project participate in and become collectively responsible for most important processes and decisions in the projects, while the role of the line organization and senior management is more distant. Figure 10.4 shows how different groups of actors' roles and responsibilities differ between their applied approaches.

Approach **Group of actors**	**Responsibilities in the approach based on planning**	**Responsibilities in the approach based on integration-driven development**	**Responsibilities in the approach based on dynamic synchronization**
Project participants	Component and subsystem development	Component and subsystem development Product functionality growth	Component and subsystem development Project progress Product and project configuration Co-ordination and integration Changes Customer contacts
Technical coordinators	Subsystem configuration Subsystem strategies Downward reduction of uncertainty and ambiguity	Product and project configuration Product anatomy I&V Plan Interdependencies Co-ordination and integration Changes	Product and project configuration Product anatomy and I&V Plan Project progress Co-ordination and integration Changes Customer contacts Resource development
Project management	Project planning Co-ordination Monitoring of project progress Action based on deviations from plan Upward reduction of uncertainty and ambiguity	Product and project configuration Product functionality growth Operative leadership Intra-project priorities Interdependencies Co-ordination and integration Changes	Product and project configuration Project progress Customer contacts Freedom of action for the project Operative leadership Building a sufficient capacity for co-ordination and integration Intra-project priorities Changes Translation of actual work into prescribed work

Project contractors	Project progress Setting and changing targets and resource allocation Reduction of uncertainty and ambiguity Intra- and inter-project priorities Customer contacts	Project progress Creating conditions for project management Inter-project priorities	Inter-project priorities Business decisions
Line managers	Subsystem configuration Operative leadership Resource development Subsystem strategy Intra- and inter-project priorities	Resource development Inter-project priorities	Resource development Inter-project priorities

Figure 10.4. Groups of actors and their roles in organizational settings applying different approaches

Figure 10.4 clearly shows that the approaches at the center and the right (based on *integration-driven development* and *dynamic synchronization*) move responsibilities upward in the matrix toward more operative roles in the projects. Hence, that project participants, technical coordinators and project managers have more responsibilities towards the right end of the figure, while it is the opposite for project contractors and line managers, and that new responsibilities emerge in the new approaches that develop all roles.

System Integration

In projects applying the approach based on *planning*, each sub-project responsible for a sub-system strives to make its sub-system stable and free from faults before system integration. The result is late and often troublesome integration that leads to a large amount of re-work. In projects applying the approach based on *integration-driven development*, system integration is the actual engine in the project, and integration is both early and frequent, the focus being on troublesome interfaces owing to earlier experience. The result is that the most time-consuming integration is managed first, therefore winning lead-time. Projects applying the approach based on *dynamic synchronization* perform their system integration continuously due to the built-in interdependencies both between different sub-systems (lateral dependencies) and between sub-systems, system specification, integration and verification (hierarchical dependencies – along the flow). The result is that total project and system progress is the relevant focus for all actors in the projects.

> *"Integration of sub-systems and components is very much a social phenomenon, not just a technical one - it illustrates that everyone in a project represents a vital part of the whole and that the whole never becomes better than the worst performing part" [Technical Co-ordinator, Japanese Subsystems]*

In essence, integration acted as a *"heartbeat"* for project progress, serving as both a metaphor for keeping the entire project working smoothly and as an important regulatory and pacing function where miss-matches in terms of functionality or timing in the boundaries were detected as early as possible.

Managing Interdependencies

In projects applying the approach based on *planning*, interdependencies are seen as troublesome and one important task in both product and project configuration is to minimize them. The product breakdown, together with rigorous planning, creates sequential dependencies between sub-projects and work packages. These sequential dependencies become linear in their focus on what has happened before and what will happen next according to the plan, rather than on seizing the activities, processes and conditions that are performed and arise in real-time. The perceived coordination need is low, and the projects rely on formal and internal coordination mechanisms (see diagram A in Figure 10.5) to handle this small need. The focus is on reactive coordination, where resources are allocated to the part of the project where problems have occurred.

In projects applying the approach based on *integration-driven development*, there is a focus – based upon earlier experience – on troublesome interdependencies. The perceived coordination need is moderate, and the projects use mainly formal and internal coordination mechanisms (see diagram B in Figure 10.5) together with active specialists (the group of key actors) for coordination. The focus is on a combination of reactive, problem-driven coordination, where the key actors are allocated to actual troublesome interdependencies but are also proactive on the basis of earlier experience.

In projects applying the approach based on *dynamic synchronization*, interdependencies are the engine for building a system perspective, convergence and transparency. The coordination and integration need is perceived as high, and the necessary coordination and integration capacity is primarily built using both formal and informal as well as both internal and external mechanisms (see diagram C in Figure 10.5) and by co-location. The focus is on real-time coordination and integration. One important result is that feedback on system performance comes late in the process in the approach based on planning, while it comes early in both the emerging approaches. Another important result is that the shortened integration interval improves efficiency in the testing process by focusing on relevant bugs and solutions.

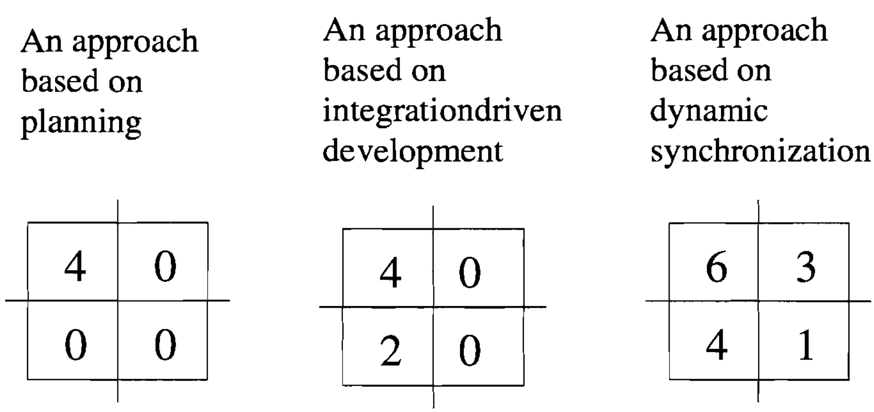


Figure 10.5. A comparison between number and type of coordination mechanisms used in projects applying different approaches

The three different approaches is based on different use of co-ordination mechanisms. Hence, the approach based on *planning* rely exclusively on formal and internal mechanisms, the approach based on *integration-driven development* on both formal and informal internal mechanisms and the approach based on *dynamic synchronization* uses all types of mechanisms to cope with the intense co-ordination need.

Progress Control

In projects applying the approach based on planning, progress is monitored against rigorous plans. Actors responsible for components systematically report their progress in relation to planned progress to actors responsible for the sub-system of which their component is a part. The actors responsible for the sub-system then report their progress in relation to planned progress to actors responsible for the sub-system of which their sub-system is a part. This process then goes on hierarchically until the project management gets a number of progress reports from the sub-systems constituting the total system. The progress is reported both in formal documents and in formal project meetings, often conducted every two weeks. The progress reports focus on input variables such as man-hours, lines of code and number of produced components or sub-systems. The assumptions behind the progress judgements are that, if 60 % of the planned sub-systems are ready, then the total system is 60 % ready. If 60 % of the planned lines of code are produced, the system is 60 % ready. And also, in some cases, if 60 % of the planned man-hours have been consumed, the system is 60 % ready. These assumptions disregard the large integration endeavor, and the result is that progress is always overestimated until the time that actual integration is performed. This gives a perceived project progress such as diagram A in Figure 10.7, where progress is perceived according to plan (due to the use of input variables as indicators) until first actual integration. The actual integration shows that there is a lot more to be done and no progress will be made until this integration endeavor has been completed. Once it has been completed, progress is again perceived as according to plan until the next actual integration is performed. This leads to slow projects that do not meet set targets.

In projects applying the approach based on *integration-driven development*, actual functionality (an output variable) is the only approved indicator of progress. By integrating early and frequently (projects often use monthly internal deliveries to be integrated) and basing work on stepwise functionality growth, it is possible to test and verify functionality both early and frequently. Actors responsible for components and sub-systems must deliver what they have to system integration at a number of set times in the project, and therefore get both early and frequent feedback on how their part works in relation to the larger whole. Some components and sub-systems (especially hardware-intensive ones) take a longer time to be ready for integration, and therefore the projects have developed a number of simulation models to compensate for those latecomers. By starting from the end and going backwards, i.e. defining which components, what sub-systems and what functions must be ready in order to meet set targets, projects define their functionality growth in a number of pre-defined steps. The result is that progress is perceived as stepwise from no to full functionality, as in diagram B in Figure 10.6.

Projects applying the approach based on *dynamic synchronization* use a collective responsibility for the total system as a principal control of progress. Different actors' perceptions and judgments of actual progress are used as a guide for project management in assessing project progress. The progress control in projects applying the approach based on *dynamic synchronization* differs from those applying the approach based on planning and those applying the approach based on *integration-driven development*. Hence, by relying on strictly subjective indicators rather than more objective indicators such as man-hours spent, lines of code produced or verification of actual functionality. The result is that perceived progress over time can differ substantially from a linear plan, as in diagram C in Figure 10.6. However, to keep senior management satisfied, project managers repackage their progress control into a more recognizable form, as in the project applying the approach based on planning (diagram A in Figure 10.6).

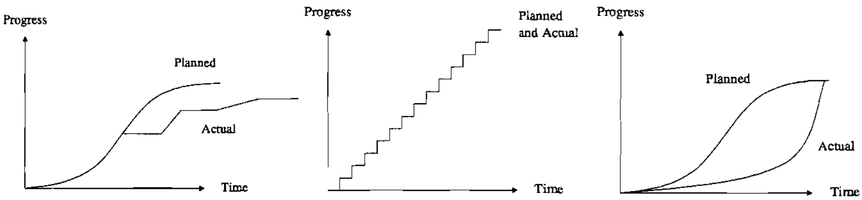


Figure 10.6. A comparison between planned and actual progress in projects applying different approaches

As figure 10.6 shows both planned and actual progress are differently characterized by the three approaches. It is only in the approach based on *integration-driven development* where the two are coherent and the planned progress in the approach based on *dynamic synchronization* only works as a political instrument in gaining resources to run the project.

Project Management Tools and Focus

Project management in projects applying the approach based on planning is based upon project plans and deviations from these. Each project is preceded by a rigorous planning phase where all activities, tasks and work packages are sketched out over time, where actors are distributed and interdependencies among them minimized and where potential project risks are analyzed and perceived as minimized. In execution, this grand plan guides behavior, decisions and priorities, and the progress reports from sub-systems are analyzed against the plan. Project management then acts on the basis of deviations from the plan and focuses attention on the parts of the project that are presented as most troublesome in the progress reports (both the formal documents and the formal project meetings). Hence, project management action becomes reactive in character. The result of using plans and deviations from plans as the engine for project management and basis for (reactive) action is that project management becomes, and is perceived as, a purely administrative function aggregating actual work in each sub-system. This situation is further strengthened by the actual power distribution, where authority resides among actors in important sub-systems.

Project management in projects applying the approach based on *integration-driven development* is based upon early integration and stepwise functionality growth. Project management, together with other key actors in the project, sets up a number of fixed dates at which system integration will be performed. These dates are based on the product anatomy and the *I&V Plan*. The dates are perceived as fixed, and actors in different sub-systems must then deliver whatever they have accomplished to system integration, test and verification. This way of working provides actors (as mentioned above) with early and frequent feedback on how their sub-system works in relation to the larger system and provides project management with an overview of both actual project progress and troublesome interfaces to which extra resources should be allocated. Project management takes action based on both troublesome integrations (reactively), experience of troublesome interfaces or project phases from earlier project generations (proactively), and a small number of key actors actively working in interfaces (proactively). The result is that project management (together with a small number of other key actors) takes responsibility for all emerging situations in the projects.

Project management in projects applying the approach based on *dynamic synchronization* is based on continuous integration, stepwise functionality growth, co-location and local control over goals, setting and dynamics. Project management uses the *product anatomy*, the *I&V Plan* and the stepwise functionality growth in the same way as they are used in the approach based on *integration-driven development*. By building interdependencies and a collective responsibility for the total project, the total system project management also uses a large number of actors in performing what are considered to be project management (or key actor) activities in the other two approaches. The result is high convergence and transparency for a large number of actors in the project, compared to the small group of key actors in the approach based on *integration-driven development*, which enables the project management to take a more external role. Thereby they can fulfill an important function in creating the necessary conditions for other actors to perform work in the necessary way in order to best meet set targets. In doing so, the project management also translates the actual work processes into the prescribed and expected ones from senior management. Project management also fulfills an important role in facilitating the development of a high communication, coordination and integration capacity.

The most distinctive character of the approach based on *dynamic synchronization* is that it clearly lets go of the Fayolian principles for command and control by allowing self-organizing as the way of handling both complexity and uncertainty. The effective process of self-organizing that has been applied is made possible by actors continuous striving for sensemaking and by sensemaking being based upon action and reflection upon action. This facilitates a speedy and experimental process of sensemaking that is the foundation for the approaches' ability to be both *dynamic* and *synchronized*.

> *"In real-world practice, problems do not present themselves to the practitioners as givens. They must be constructed from the materials of problematic situation, which are puzzling, troubling, and uncertain. In order to convert a problematic situation to a problem, a practitioner must do a certain kind of work. He must make sense of an uncertain situation that initially makes no sense" [Weick, 1995, p. 9]*

Perceived System Complexity and Performance

According to the earlier presented frame of reference[76], actors in the organizational settings applying the approach based on planning perceive the total system complexity and uncertainty that meets them as equivalent to both high and moderate ambiguity. Where most actors do not have

---

[76] For a further discussion of the frame of reference, chapter 5, page 214-215 is recommended.

complete knowledge about system components, their interdependencies or their values and where some actors have knowledge about system components but not about their value or interdependencies.

Actors in the organizational settings that apply the approach based on *integration-driven development* perceive the total system complexity and uncertainty equivalent to both low and high ambiguity. Where a small number of key actors have knowledge about system components and interdependencies but not their value and where the large number of actors do not have complete knowledge about system components, their interdependencies or their values.

In the organizational settings that apply the approach based on *dynamic synchronization*, actors perceive the total system complexity and uncertainty equivalent to low ambiguity, i.e. most actors have sufficient knowledge about system components and their interdependencies but not about their specific value.

In the organizational settings applying the approach based on planning, actors perceive their own performance as moderate to sufficient. In the organizational setting applying the approach based on *integration-driven development*, actors perceive their own performance as high. In the organizational setting applying the approach based on *dynamic synchronization*, actors perceive their own performance as moderate too high.

Propensity and Capacity for Organizational Learning

In the organizational settings applying the approach based on *planning*, the propensity for *incremental* and *discontinuous* learning is moderate, but low for *organizational* learning and renewal. The relatively high propensity for *discontinuous* learning can be explained by a number of actors' perception of performance as deficient. The capacity for *discontinuous* learning is also higher than for *incremental* and *organizational* learning, as there are no further marginal benefits in improving the existing way of working but there is a high potential for working in other ways. However, the capacity for all types of learning is limited by cybernetic thinking. Actors in organizational settings applying the approach based on *planning* focus on improvements of processes, while the product configuration is perceived as given. The leverages and mechanisms for learning that have been used are: (1) introduction of a more parallel way of planning and working, (2) introduction of clean-room development[77], (3) directed training among the large number of engineers, and (4) better incentives for top project management.

In the organizational setting applying the approach based on *integration-driven development*, past success limited actors' propensity for renewal to the refinement of earlier successful solutions, i.e. *incremental* learning, and prevented new ways to do things, i.e. *discontinuous* and *organizational* learning. The organizational setting has a high propensity for *incremental* learning and very low propensity for *discontinuous* and *organizational* learning. This was obvious even though the organization had a well-developed capacity to master primarily *incremental* but also *discontinuous* learning, owing to its ability to manage complexity and to work systematically with improvements and renewal. The organizational setting has a moderate to high capacity for all types of learning. The approach based on *integration-driven development* focus on improving both processes and product configuration. The leverages and mechanisms used for learning are: (1) *time focus*, i.e. having one very clear goal for everyone involved that is at the same time untouchable and reveals many core aspects of a project - the mechanism works as a systematic self-assessment in order to generate valid data about the process problems of recording deviations; (2) *"sufficient" personnel turnover* (30% new people in every project) to maintain experience and at the same time get new motivation and impetus; and (3) *focus on the customer boundary* (on logistics, simulated delivery and commercial consciousness).

In the organizational setting that applies the approach based on *dynamic synchronization*, the propensity for all types of learning is high, as is the capacity for all types learning. Both propensity and capacity are

[77] The concept of clean-room development is described in footnote 55, p. 259.

facilitated, but there is also a limitation imposed by the process of sensemaking based on action and reflection upon action. Actors are not aware of and thereby captured by any core competence but are instead driven by the fundamental assumption that what works is the basis on real-time theorizing and building knowledge about how complex product development is best managed. Actors in the organizational setting applying the approach based on *dynamic synchronization* focus on improvement in both processes and product configuration in order to reach high convergence and transparency. The leverages and mechanisms used for renewal and learning are: (1) *building interdependencies*, both vertical and hierarchical, (2) *facilitating transparency*, (3) *facilitating convergence* and (4) *developing responsibilities for each group of actors*.

Performance

Projects applying the approach based on planning have managed to perform very large tasks but seldom meet set or emerging targets. Projects applying the approach based on *integration-driven development* support size and speed, and most often meet set targets. Projects applying approaches based on *dynamic synchronization* support speed, flexibility and resource development, and often meet both set and emerging targets.

Fundamental Assumptions

The differences above are all differences in perspectives, principles and actual models for organizing that are applied in each respective approach. They all derive from differences in fundamental assumptions that affect how each approach is applied. The approach based on planning is derived from the following fundamental assumptions: (1) complexity is best managed (reduced) by breaking it down into its pieces and making the pieces as independent from each other as possible, (2) uncertainty is best managed (reduced) by rigorous planning before the execution of the project, and (3) control is best gained by following up deviations from plans and by hierarchical co-ordination. The approach based on *integration-driven development* is derived from the following fundamental assumptions: (1) complexity is best managed (reduced) by focusing on troublesome interfaces and allocating highly skilled resources to handle situations in real-time, (2) uncertainty is best managed (reduced) by rigorous product and project configuration, and (3) control is best gained by continuous integration, step-wise functionality growth and a pro-active project management. The approach based on *dynamic synchronization* is derived from the following fundamental assumptions: (1) complexity is best managed by providing actors with the total picture, (2) uncertainty is best managed by distributing responsibility and providing the means for real-time handling, and (3) control is best gained by building interdependencies and distributing the responsibility for meeting set targets.

Major Difference	The approach based on Planning	The approach based on Integration-driven Development	The approach based on Dynamic Synchronization
Product Configuration	Subsystems responsible for breaking the product down into its technical independent pieces. Often a mirror of the line organization, with few changes over project generations.	A few key actors in each project responsible for creating a map which guides how the product stepwise is built from no to full functionality.	Many actors in each project responsible for creating a map which guides how the product stepwise is built from no to full functionality.
Project Configuration	Subsystems responsible for organizing according to the product structure and existing line organization with an effort to minimize dependencies.	A few key actors responsible for organizing guided by the product anatomy and I&V Plan. The project organization often differs from the line organization.	Many actors responsible for organizing guided by the product anatomy, I&V Plan and by building dependencies into the project organization.
Actors' Roles and Responsibilities	Actors in the subsystems define the prerequisites for others in the projects	A small number of key actors in each project define the prerequisites for others in the projects	A large number of actors participate and become collectively responsible for the prerequisites created
System Integration	Performed when subsystems are stable – late in the project	Engine for the project progress – performed early and frequently	Continuous through built-in lateral and hierarchical interdependencies

Managing Interdependencies	Interdependencies perceived as low and use mainly reactive, formal and internal coordination mechanisms	Interdependencies perceived as moderate and use mainly key actors for coordination	Interdependencies perceived as high and use a number of different coordination mechanisms – many based on co-location
Progress Control	Comparing different input variables with plan monitors progress.	Verifying actual functionality after system integration monitors progress.	Making many actors collectively responsible for the total system and asking them for their judgment of actual progress monitors progress.
Project Management Tools and Focus	Rigorous project planning and project monitoring. Deviations from plans reactively guide action. Hierarchical control.	Actual functionality-growth, earlier experiences, and an active presence in troublesome interfaces guide action. High transparency and convergence among key actors but moderate among the large number of actors.	Collective responsibility for the total project and the total system. Focus is on building a sufficient coordination capacity. Actors' perceptions guide action. High transparency and convergence among a large number of actors.
Perceived Complexity, Uncertainty and Performance	Most actors perceive complexity and uncertainty equivalent to high ambiguity and some actors perceive complexity and uncertainty as equivalent to moderate ambiguity. Performance is perceived as moderate to sufficient.	Key actors perceive complexity and uncertainty as equivalent to low ambiguity and most actors perceive complexity and uncertainty as equivalent to high ambiguity. Performance is perceived as very high.	Most actors perceive complexity and uncertainty as equivalent to low ambiguity. Performance is perceived as high.
Propensity and Capacity for Learning	Moderate propensity for first- and second-order learning and low propensity for third-order learning Moderate capacity for second-order learning but low capacity for first- and third-order learning.	High propensity for first-order learning and very low propensity for second- and third-order learning. High capacity for first-order learning and moderate capacity for second- and third-order learning.	High propensity for all types of learning High capacity for all types of learning.
Performance	Have managed very large tasks but seldom meet set or emerging targets.	Support size and speed and often meet set targets.	Support speed, flexibility and resource development and often meet both set <u>and</u> <u>emerging</u> targets

Fundamental Assumptions	Complexity is best managed by break-down, uncertainty is best managed by rigorous planning and control is best gained by following plans.	Complexity is best managed by allocating resources to trouble some interfaces, uncertainty is best managed by rigorous product and project configuration and control is best gained by continuos integration.	Complexity is best managed by providing all actors the full picture, uncertainty is best managed by distributing responsibility and control is best gained by building dependencies.

Figure 10.7. A summary of important differences between approaches and their origin

What Do the Comparisons Tell Us?

The comparisons made above provide a set of experiences that together constitute a pattern that lends strong support to the notion that there are alternative approaches to the dominant one that are based on fundamentally different basic assumptions. These alternative approaches also have shown superior capacity to meet both set and emerging targets. Hence, dominant and fundamental assumptions about managing complex product development need to be revisited and reflected upon so that they better reflect the business conditions of today and open up to the emergence of new and alternative approaches. The discussions and analysis above also show that it is not so much the actual applied methods as the assumptions, perspectives and principles that make a difference. This section will extract the most important results from the comparisons between approaches and organizational settings.

Project Manageability

The dominant assumptions as they are applied by the approach based on planning,

- that complex product development is best managed by rigorous planning before execution,
- that it is good to build a simple organization with clear hierarchies and independent sub-groups allocated to pre-defined and independent tasks,

- that it is good not to bring any faults from lower to higher levels in the product structure or from early to later phases in the projects,
- that it is good to focus on quantifiable input variables in monitoring progress,

do not have strong support in the empirical data for being able to increase project manageability. There is, however, much data that supports alternative assumptions for how to best manage complex product development.

Experience both from projects applying the approach based on integration development and from projects applying the approach based on *dynamic synchronization* clearly shows that interdependencies can be used as a strength in accomplishing project progress. Projects applying the approach based on *integration-driven development* use interdependencies to stepwise integrate, test and verify actual functionality in the product. While projects applying the approach based on *dynamic synchronization* use interdependencies to build a collective responsibility for the total system and the total project and to facilitate transparency and convergence. Both approaches also clearly show that there are more effective means than traditional project planning to perform successful projects.

Both approaches introduce new concepts and ways of working, such as *product anatomy, I&V Plan* and *system emergency board*, in order to better adapt to the new customer demands on project speed and timeliness. Projects applying the approach based on *integration-driven development* also allocate a small number of key persons to actively take responsibility for the total system and the total project, including troublesome interdependencies between different sub-systems. Projects applying the approach based on *dynamic synchronization* distribute the responsibility among a large number of actors and introduce a large number of new, often both temporary and informal, mechanisms for coordination. Reaching manageability by rigorous planning is replaced in the first case by early integration and actual functionality growth and in the second case by collective responsibility, transparency, convergence and serendipity[78]. Achieving manageability by building a simple organization is replaced in the first case by the allocated group of key actors and in the second case by building a complex organization and providing as many actors as possible with a picture of the total complexity. Achieving manageability by eliminating faults prior to integration is in both cases replaced by system integration as early and frequently as possible, to get early and frequent feedback on how each sub-system works in relation to others rather than how it works on its own. Achieving manageability by monitoring quantifiable input variables is replaced in the first case by monitoring verifiable functionality and in the second case by collective responsibility and qualitative judgments.

This also finds support in the work of Iansiti (1995, pp. 266-267) where he show that projects that apply a system focus systematically perform better in terms of total lead-time as well as in terms of human resources used, than projects that apply an element focus.

In summary, my observations and analysis show that projects applying approaches based on fundamental assumptions that differ significantly from the dominant ones can be as manageable, if not more manageable, than projects applying the approach based on the dominant fundamental assumptions.

Actors Perspectives on Products and Processes

There seems to be two fundamentally different perspectives on how products and products are configurated; perspectives based, on the one hand, on product and work breakdown and, on the other hand, on product and work build-up. Chapter 8-10 points out that, while actors applying the dominant approach attempt to absorb uncertainty by rigorous planning in advance, actors applying any of the emerging approaches aim at building a capacity in the development organization to manage uncertainty in real-

[78] The gift of finding valuable things in unexpected places by sheer luck.

time. This is made in order to provide it with knowledge and competence broad enough to function as the unforeseeable future evolves.

A product and a project begin as a concept as part of a strategy for attracting and satisfying customers. To turn the concept into a product, designers, managers and planners must make choices about product and project content. For a firm in the telecommunications industry, the choices pertain to specific product characteristics, roll-out plans, technologies on which to focus and allocation of resources. These choices establish both *how* a firm will realize its product concept in the market place and *who* will undertake the necessary design and engineering work. Choices about product and project content, product parts and project organization have an important impact on project performance. Ultimately, effective project configuration is a matter of balance in managing trade-offs. With a given variety, the project team still has a great deal of freedom in configurating both the product and the project. Different perspectives on planning and developing new products and processes are demonstrated to imply different organizing principles. This chapter will explain how the use of different principles for organizing development work will have an impact on how actors perceive complexity and manage uncertainty.

The strength in applying an openness regarding both how products and projects are configurated find support in Ciborras (1991) work, where he discuss its positive effect on innovation.

Project Planning and Uncertainty

Product development normally includes ambiguity and uncertainty for most actors. An important focus for development organizations is to find ways to manage these ambiguities and uncertainties. Principles for reducing ambiguity and uncertainty by planning are based first on the fundamental assumption that good planning can attack uncertainty. Secondly, it is assumed that well-defined activities with clear borders mean that different types of actors will be given manageable uncertainties. The principles for planning follow a hierarchical logic in which actors on each level define the conditions for actors on lower levels. Line managers and those who commission projects define conditions for project managers and technical management, who in turn define condition for sub-project managers, who in turn define conditions for teamleaders and individual project participants. The responsibility for reducing uncertainty and ambiguity lies primarily with the one who has ordered the project, the project management and the technical management. The orderer's responsibility primarily includes defining conditions for the project and providing project management with manageable ambiguity and uncertainty. Project management and technical management are responsible for transferring these external requirements into manageable pictures of targets and manageable ambiguity and uncertainty for individual project participants. This kind of uncertainty management agrees well with principles described above for breaking down products and organizations. They are most often used together with these, i.e. actors in the respective systems or on the respective organizational levels are responsible for reducing complexity and uncertainty on their own levels by carefully planning their work packages in the sub-system or organizational unit.

The orderers of the projects, project management and technical management have a number of established tools for analyzing and reducing uncertainty in development work. The *Lichtenberg method* often used at Ericsson is a good exponent of this group of tools. The Lichtenberg method is based on breaking down each risk into its parts until it has become so small that it is manageable, and the focus is on reducing and handling risk in the management process. According to this perspective, uncertainty and ambiguity are seen as risks in a negative sense, i.e. a latent dysfunctional situation that can be thought to occur. Uncertainty and ambiguity are reformulated in these methods into possible risks that are latent in the process. Methods such as the Lichtenberg are primarily used as an aid in reducing the risks felt by decisionmakers. They are also used as support for project managers and the technical management in individual projects to reduce ambiguity and uncertainty for themselves and other project participants. These tools represent a method for relating to uncertainty and ambiguity by breaking them down until a feeling of control can be reached. Ridderstråle (1997) describes this strategy as:

"defining manageable units to reduce risk"

The focus is on configurating manageable units where the total amount of uncertainty and ambiguity is reduced by division and on thereby creating possibilities for actors to get an overview of and manage the remaining uncertainty and ambiguity – or risk – related to one's own sub-system or organizational unit. The sub-systems are thus defined according to how manageable they are. The planner strives to find sub-systems with manageable uncertainty and ambiguity that are as independent of other sub-systems as possible. Organizational units are then built around these sub-systems that have the same characteristics, i.e. units with manageable uncertainty and ambiguity that are as independent of other organizational units as possible. Figure 10.8 shows an example of a complex product development project represented through traditional project planning techniques.

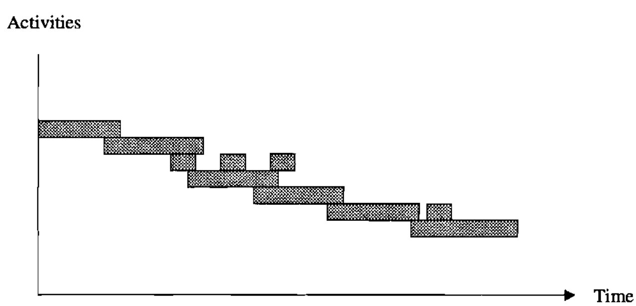


Figure 10.8. A complex product development project represented by using traditional project planning techniques

Reformulating and breaking down uncertainty and ambiguity (risk) are in the dominant approach focused toward influencing the risk that the actors perceive. The thinking is that, if the perceived risk is judged to be limited, the actors will be able to manage it. However, the problem is that these principles result primarily in that it is exactly perceived ambiguity and uncertainty and not actual ambiguity and uncertainty that are reduced. The consequence is that the actors neglect the actual uncertainties during the work process until the time at the end of the project when they become inexorably obvious.

Rigorous project planning before execution is, as discussed above, a strategy highly recommended (by both the dominant literature and practitioners) to reduce uncertainty and perform successful product development projects. The analysis of the different organizational settings and the comparisons above show a more complex picture. Strategies and procedures based on rigorous planning can, quite the contrary, decrease performance in certain settings.

The approach based on *planning* largely concerns making the extraordinary ordinary, the complex into something comprehensible, and the unusual into something routine (as described earlier, for example, by Sahlin-Andersson 1989). This approach is also based on the assumption that changes in prerequisites can be predicted and therefore planned for in advance. The approach is based upon anticipating uncertainty by planning well and configuring manageable uncertainties for diverse groups of actors. Actors on the respective system levels take responsibility for reducing complexity and uncertainty on their own system level. To handle changed conditions, new methods of planning are added whose purpose is to plan and formulate flexible systems.

The organizational settings that apply the other two approaches use a different strategy. A strategy based on the assumption that it is impossible to maintain control over all potential situations by rigorous planning but that it is possible to maintain control <u>in</u> most situations by building a capacity to handle uncertainty in real-time. The alternative approaches are based on different principles for reducing ambiguity and uncertainty. They are based on fundamental assumptions that uncertainty and ambiguity cannot be planned away – they are seen as a basic requirement in development work and are further considered to contain a number of possibilities. According to these alternative principles, a capacity must be created for real-time management of ambiguity and uncertainty. Uncertainty and ambiguity are not only seen as risks in a negative sense – they are also seen as possibilities in a positive sense, i.e. they contain not only latent dysfunctional situations but also latent functional situations. To be able to use these potential possibilities and avoid their risks, alternative approaches are focused on creating a capacity among actors to manage uncertainty and ambiguity in real time. This capacity is achieved by giving smaller or larger groups of actors the opportunity to form an understanding of the *"whole"* and to be able to see the development of the whole picture. A necessity for achieving this capacity is that actors are united around a picture of the whole that includes principles for making priorities and judgements between different types of targets and that there is an understanding of the overall business logic. Figure 10.9 shows a clear example of how the same project as is illustrated in figure 10.8 has been configurated on the basis of these principles instead of planning principles.

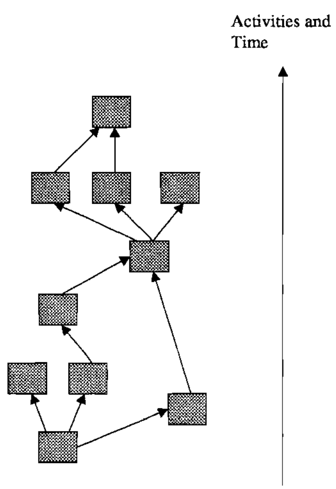


Figure 10.9. Same complex product development project represented by using an integration and verification plan

By building up a capacity to manage ambiguity and uncertainty, the effects of their characteristics in organizational settings are ameliorated applying alternative approaches. According to the dominant perspective, uncertainty is not managed other than in the actors' own minds.

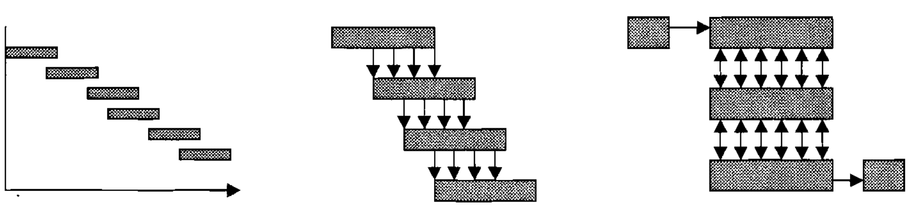
Projects applying the approach based on *integration-driven development* develop and allocate a small number of key actors that are held responsible for dealing with emerging situations. While projects applying the approach based on *dynamic synchronization* develop and allocate a large number (often more than half of the actors engaged in the project) of actors to handle emerging situations. This capacity for real-time handling of uncertainty is created by giving actors an opportunity to oversee wholenesses and their progress, in the one case with a small number of actors and in the other case with a larger group of actors. Projects applying the approach based on *integration-driven development* use arenas and forums, i.e. the application of continuous and interactive dialogues between team members in order to motivate engineers to form their own design teams. This offers possibilities both for real-time coordination and for redesigning work processes and work organization according to current status and prerequisites, and to provide valid and shared information.

Projects that apply the approach based on *dynamic synchronization* use self-designing design teams by engaging the engineers themselves in diagnosing their process problems, through giving the relevant professionals opportunities to take part in dialogue meetings. In this meetings persons who have the greatest number of interdependencies according to the analyses are asked to design temporary teams that can handle those interdependencies and share responsibility for reducing non-value-adding activities during the design process. Sensemaking is rapidly accomplished by letting action and reflection upon action be the guiding principles for the process. With a fast process for sensemaking, it is possible to continuously redefine the prerequisites for the project and the targets to be met.

My observations and analysis show what Blomberg (1995) among others have shown earlier. Rigorous planning is the same as creating rigid structures. The more developed, advanced and complex a system is, and the more planning lies behind it, the harder it is for it to change if an unexpected disturbance, some kind of unplanned event, influences the system.

> *"Planning change seems, from the figure of thought and its discursive expression, to be paradoxical." [Blomberg 1995, p. 51, translated from Swedish]*

The approach based on *planning* strives to avoid, instead of admit uncertainty by two principal strategies. First, avoiding the need for correctly predicting future events by using decision rules that emphasize nearby events and thus become determined by reactive character. And second, avoiding the need to anticipate the future by bringing about an arranged environment. In agreement with Bartlett (1958) and March (1965), the organization and its individuals do not fulfill the condition of admitting uncertainty, but simplify the internal and external environment in order to attain *"certainty"* and *"rational"* decision-making. Figure 10.10 shows the same complex product development project illustrated in the frameworks of the respective approaches.



A B C

Figure 10.10. A complex product development project illustrated by the use of three different approaches.

Projects that apply the approach based on *planning* illustrate their total task as a number of sub-tasks sequentially dependent on each other and having a fixed start and end (see diagram A in Figure 10.10). Projects applying the approach based on *integration-driven development* illustrate their total task as a number of functionalities that must be reached so as to *breath life* into the product, highlighting interdependencies (see diagram B in Figure 10.8). Projects applying the approach based on *dynamic synchronization* illustrate their total task as an integrated whole, where the different parts are reciprocal interdependent and where different project phases overlap completely without any fixed start or end (see diagram C in Figure 10.10).

In summary, my observations and analysis show that projects applying approaches based on fundamental assumptions that differ significantly from the dominant ones and do not put rigorous planning in focus can be at least as manageable as projects applying the approach based on the dominant fundamental assumptions.

Project Planning and Effectiveness

More and more people and a growing proportion of value adding activities are taking place in different development projects at the same time that successful results of these projects are becoming more and more important for the competitive ability of companies. Many key figures such as through-put times, resource use, quality levels and the performance of the product are defined as clear target parameters and are followed up to a greater and greater extent. The individual development projects are an increasingly important focus for different types of efforts toward effectiveness. The development of complex products contains a series of different types of activities and there are alternative approaches for reaching an effective use of resources. One is based on *planning* and includes an active effort to achieve processes that support a greater effectiveness, primarily of the more repetitive parts of development work. This approach is based on a fundamental assumption that important parts of the development work can be optimized by different planning efforts.

This optimization takes place deductively; i.e. the project manager uses knowledge that exists a priori to the start of the project to design an optimal action plan for its performance. Eventual deviations from this plan are seen as dysfunctional and are avoided as far as possible by rigorous control of deviations. Interaction (especially non-planned interaction) is seen as a transaction cost. This optimization is built on two primary processes: the plan is drawn logically from a model of the product and the plan is thus a result of routine experience.

The alternative approaches toward making product development more effective is based on the fundamental assumption that the development process contains a great measure of knowledge growth that is not predictable. This creates new possibilities (that it is not possible to predict or plan for) for solving problems and making innovations during the performance of the project. According to these alternative approaches, effectiveness is created not because problems are created through incorrect planning assumptions but because the organization's capacity to solve problems is utilized as problems occur. The capacity for solving problems increases in a general way because new experience is gained. The approach to *continuous effectivization* in the first case (*Japanese Systems*) and for *real-time adjustments* in the second case (*Japanese Subsystems*) is inductive or abductive. Hence, resembles more a continuous process, i.e. where people continually search for possibilities that can renew the action plan for realizing functionality which is then tuned with the prevailing action plan and its consequences. Interaction is seen as a possible transaction profit via the possibility for finding new ways to realize goals and use them. The next chapter will describe the context in which the application of both the dominant and the emerging approaches has been analyzed.

Projects that apply the approach based on *integration-driven development* build on the fact that the responsibility for defining interface relations goes from the individual parts to the whole. Hence, the focus falls on the interfaces themselves, and the work in them, rather than on defining them better in terms of the respective sub-systems' perspectives. The focus becomes a successive specialization in the level of wholeness.

The focus in projects applying the approach based on *dynamic synchronization* is on synthesis of the whole rather than analysis of the parts. Progress is seen as a process that is indescribable in quantitative terms. It can be considered as something quite mysterious. The success in projects applying this approach is manifested in the engineers' ability to deal with uncertain, unstable, unique and value-conflicting situations. Design problems and design solutions evolve over time and emerge together, becoming increasingly clearer as the process moves on, rather than following each other logically. The goal in projects applying the approach based on *dynamic synchronization* is to keep the technical window of opportunity open, i.e. to delay freezing concepts for as long as possible. The development process is pragmatic and problem and opportunity-driven, since the issues perceived as most urgent are "attacked" first and sensemaking is guided by what actually works. An increase in the understanding of wholeness through multi-phasing creates conditions for: (1) increased speed in performing activities at the sub-system level, i.e. the learning-curve effect; (2) decreased need for performing activities and/or decreased workload (content) in activities at the sub-system level; and (3) reconfigured interdependencies with the potential to decrease total workload (content) to be performed by applying a new, more updated product and project configuration.

The organization and behavior of interdependencies also differ between approaches.

> *"...when parts of the system are temporarily outside the central control and go off and do their own thing. Complexity therefore arises when there is a high degree of freedom in parts of a system, where behavior and control of the parts cannot be easily predicted based on knowledge of the system." [Flood&Carson 1993, pp. 30-31]*

The analysis of the organizational settings shows that, in projects applying the approach based on *planning*, a number of parallel sway-groups define their own interdependencies (independent of the process or focus applied by other sway-groups). This results in a strong internal focus where interdependencies external to each sub-system are ignored, at which a broken symmetry arises. Interdependencies are perceived and managed as linear and stable (which they are not), and the complexity that actors meet actually arises from the high degree of freedom in sub-systems, while the different sway-groups perceive behavior and control of the parts as predictable. Transparency and convergence in these projects are low.

In projects applying the approach based on *integration-driven development*, one sway-group (the extended project management team) defines and manages defined interdependencies that result in a partly broken symmetry. Interdependencies are perceived and managed by the sway-group as nonlinear and dynamic. The complexity that actors meet is low due to limited freedom defined by a sway-group with high internal transparency and convergence.

In projects applying the approach based on *dynamic synchronization*, many actors define and manage interdependencies through a process of sensemaking based on action that results in and unbroken symmetry. Interdependencies are managed by all as nonlinear and dynamic. The complexity that actors meet is low because there is full freedom, full convergence and full transparency.

In fine, my observations and analysis show that projects that apply approaches based on fundamental assumptions that differ significantly from the dominant ones and do not manage complexity by breaking it down into its pieces can be at least as manageable as projects applying the approach based on the dominant fundamental assumptions.

How to Manage Complexity

The dominant approach to managing complex product development is based on the fundamental assumption that complexity is best managed by breaking it down into its pieces and giving different groups of actors only the necessary amount of complexity. Each group of actors shall then also be configurated as independently of each other as possible. In doing so, complexity is perceived as reduced, and manageable organizational units and tasks are created. But the above analysis of the different organizational settings and approaches does not support this single and simple picture. Different projects applying different approaches use different principles for managing complexity. These different principles also yield different experiences for actors, even though the more objective picture may be the same.

An established and often used principle for managing great complexity in developing products and systems is (according to the dominant approach) to successively break the product down into sub-systems and divide work tasks. This is made so that the whole product is developed in work packages with specific groups of actors destined to construct their sub-systems. The goal is to create sub-systems and work packages having a complexity that is experienced by the actors in the development work as manageable. Important in this breakdown is an overview of dependencies between different sub-systems and different work packages so that the total need for coordination can be managed in the planning stage and so that individual actors are allotted a manageable span of attention. Figure 10.11 gives a typical example of how a complex product, in this case a fixed switch for telephony, is broken down by steps into its central sub-systems.

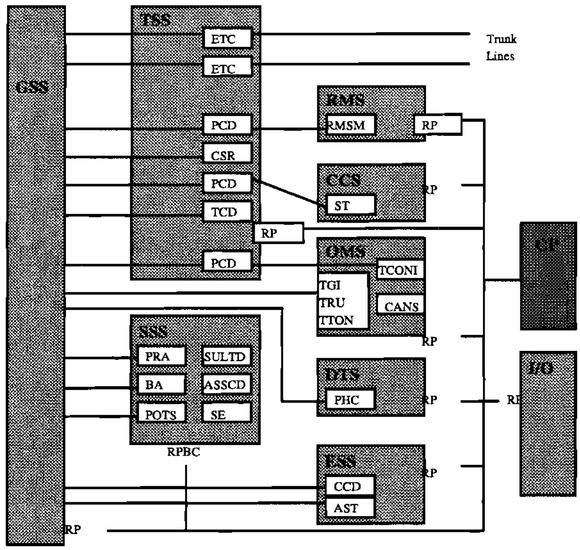


Figure 10.11. A fixed switch represented by using product-breakdown

A fixed switch for telephony consists, as the figure illustrates, of a large number of functions that together comprise the central sub-systems. Each sub-system in turn consists of a number of central sub-systems on the next system level. An example is that *Trunk and Signaling (TSS)* consist of *Exchange Terminal Circuits (ETC)* for each *Trunk Line*, an analog and two digital *Pulse Code Devices (PCD)*, a digital *Code Sender Receiver (CSR)*, a *Transceiver Control Device (TCD)* and a *Regional Processor (RP)*. These parts of a sub-system consist in turn of a number of central sub-systems. In this perspective, the product is seen as a system consisting of a large number of sub-systems on different hierarchical system levels, where the sub-systems are defined on the basis of how independent they are with respect to other parts in the total system. The better are the conditions for handling the sub-system as a separate and independent part of the whole, the better the project breakdown is considered to be. For the complexity as perceived by participants of the project to decrease, each sub-system must be able to be managed as its own "whole" upon which actors can concentrate their attention in order to make it stable. A separate sub-system such as *Trunk and Signaling (TSS)* - but also *TCD* or *CSR* on the next lower system level or the central sub-systems of which they in turn consist – are then also important areas of knowledge around which are built organizational units to ensure the existence of competent personnel in the long term.

When the company develops new products that are similar to earlier ones, there are normally both an established picture of the most important sub-systems and established organizational units with competence for managing the sub-systems. This creates a situation in which the development organization is often a mirror image of the established image of the product structure. In reverse, the product is often configurated as a mirror image of the development organization. The prevailing notion in the organization of the product as consisting of a number of sub-systems is thus a controlling one in defining the development organization and vice versa. A clear hierarchical product structure then corresponds to a clear hierarchical development organization. This is not unique for the telecommunications industry – companies that develop automobiles have organizational units that are responsible for central sub-systems, such as motors, bodies and wheel constructions. This mirror image is also represented on lower sub-system levels, where the central sub-systems in, for example, motors, such as cylinder heads, cylinder block, fans etc., are represented by organization units with specific responsibility for each of these. The line organization in the business unit that is responsible for developing switches for fixed telephony, see figure 10.12, is a pure representation (mirror image) of the product structure in figure 10.11, supplemented by a number of support roles.

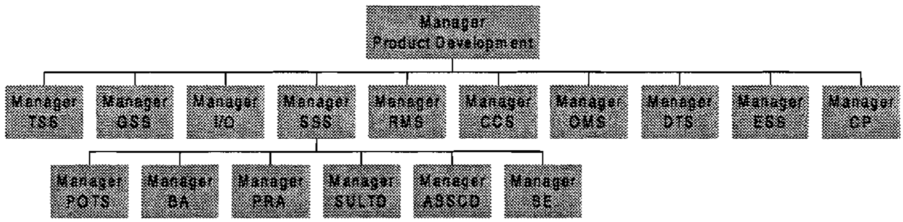


Figure 10.12. The development organization responsible for switches for fixed telephony

Each individual, new development project is placed and embedded in this established product and organization structure. Personnel responsible for the system on the highest sub-system level manage each new product and project configuration. In figures 10.11 and 10.12, for example, the organizational unit for *Product Provisioning Area Trunk and Signaling* is responsible for the sub-system of *Trunk and Signaling*. Via a detailed breakdown, the dominant portion of the development resources is allocated to units that deal with the development of sub-systems, and ideas about these sub-systems will thus determine the configuration of the product. The groups of actors that have prime responsibility for this product configuration are the technical management of each sub-system. This inherited configuration leaves little or no room to the project management to organize work in a different way.

The sub-project that is responsible for a sub-system is, according to the dominant perspective, organized to be as independent of other sub-projects as possible. Ridderstråle (1997) describes on page 221, figure 6.8, this principle as *"Divide and conquer by minimizing inter-subproject interfaces"*. The principle is also called *black box engineering*, which is a metaphor for an effort to minimize dependencies between separate sub-projects. The goal is to achieve a number of separate *black boxes* with well-defined interfaces between them. This metaphor also covers the situation in which the black box is invisible to actors outside the box and a matter of importance only for actors in the box. In reverse, that which is outside the box is invisible to actors in the box and only a matter of importance for actors outside the box. *Black box engineering* is based on creating clear and well defined borders between sub-projects, sub-systems and work packages and represents a way of making modules in the development organization and distributing responsibility for the modules. The result of principles for product breakdown, such as black box engineering, is that development projects consist of a number of independent sub-projects that are responsible for different sub-systems and work packages that are clearly divided from one another. These sub-systems and work packages are normally, according to Thompson's (1967) set of conceptions, sequentially dependent upon one another. Thus, in that tests follow designs and that all test activities are dependent upon input from designs in the different sub-systems. In an attempt to reduce lead times in development, there are examples of supplementing these sequential dependencies with more or pooled dependencies. An example of a method developed for this purpose is concurrent engineering (see for example Hartley, 1990). Concurrent engineering is based on re-configurating some sequential dependencies to pooled dependencies by initially reducing demands on input but compensates this by delivering additional input in a stepwise manner. In this product configuration, concurrent engineering would mean that those responsible for design successively deliver their development blocks (parts of work packages) that are ready to be tested without the entire sub-system (the whole work package) being completely developed.

According to the dominant approach, a detailed specialization is made on the sub-system level, where organizational units successively refine their ability to develop new versions of the sub-system for which they are primarily responsible. This organizational principle creates conditions for building competence in separate sub-systems and related work packages. New actors can be successively introduced and develop their competence in the organizational unit that is responsible for a certain sub-system and its related work package. This organizational unit then contributes, when this is necessary in a new development project, a new version of their sub-system and the necessary work package.

In summary, production configuration on the system level is given by the prevailing organizational structure and product configuration. On lower levels, technical management and line managers in organizational units that have responsibility for a given sub-system carry out the configuration. Project configuration and organization of work is thus largely fixed on the basis of this clear sub-system-motivated product configuration. Efforts in the development organization are directed toward advancing the construction of the sub-systems and seeing to it that time and cost budgets are held. Questions about integration and interfaces are considered and given priority only when deemed necessary in later phases of the projects.

Two of the organizational settings – *Japanese Systems* and *Japanese Subsystems* – apply perspectives on products and processes and use organizational principles that are different from those just described, which are more established breakdown principles. These perspectives cover different basic assumptions as to how complexity is best managed. A successful project manager describes one of these basic assumptions as:

> *"The most important thing when you are working with complex things is that you work on the basis of how things are dependent on one another." [Project Manager at Japanese Systems]*

That which will in the following be called *"principle for product and project build-up"* is in several ways in opposition to principles based on *breakdown*. Instead of concentrating on separate sub-systems and what their conditions are, the focus is on interfaces between sub-systems. The interface of interest is broader, more changeable and less well defined than in the dominant perspective. These alternative perspectives assume that the most important characteristics of the product are realized in the boundaries between sub-systems. These boundaries are called functionalities. They are different from functions in that functionalities are defined from the perspective of the purchaser and according to customer usefulness more than from the logics of the technology of the product. Examples of functionality are operational safety or being able to set up a three-party conversation. Examples of a function are *Central Processor (CP)* and *Trunk and Signaling (TSS)*. The different perspectives are expressed in the use of new concepts; one of which is product anatomy, to describe that, which is traditionally, called product structure. The concept of anatomy is used in the alternative development organizations studied to illustrate that the product is a "*whole*" that has value only when all parts cooperate and function together. Product anatomy is a map of important functionalities in a specific product and their internal relations. Product anatomy is thus a form of logical structure of the product's total functionality. Figure 10.13 gives an example of a product anatomy of a radio base station.

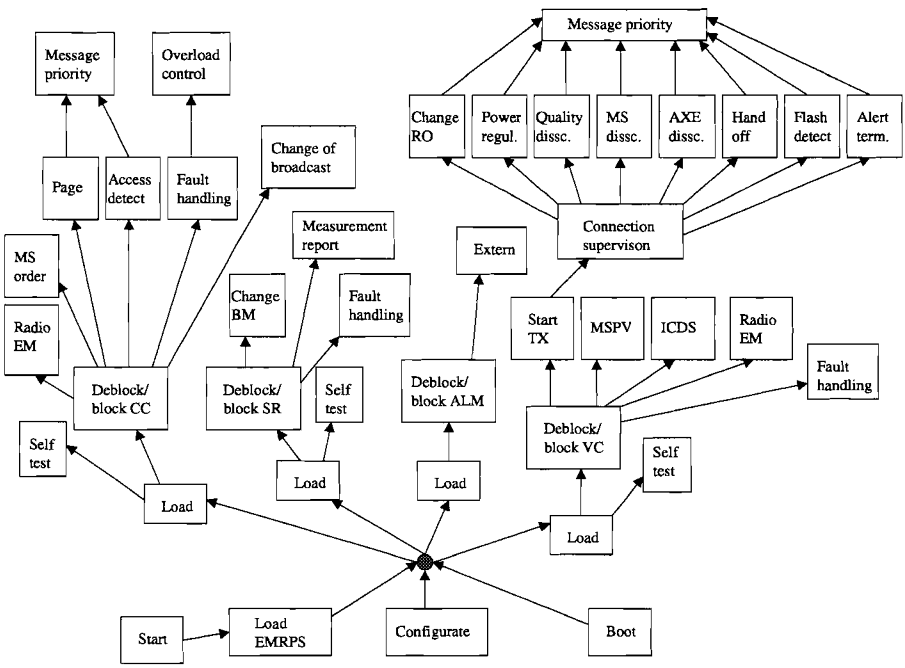


Figure 10.13. A Product Anatomy for a radio base station (from Järkvik&Kylberg 1994, p. 8)

A product anatomy (anatomical map) shows groups of functions with close and mutual dependencies as well as how these groups then relate to other groups of functions. It also shows how integration and a stepwise construction (building) of the product realize functionality. As figure 10.13 shows, there are a number of close dependencies from activating the supply of current to the switch, to making the first call and more advanced services. In these emerging perspectives, product and project configuration take place in close cooperation. The basic thought, in contrast with the dominant perspective, is that product and process are mirror images of one another and not results of different types of logic. Project management on different hierarchical levels and technical management on different system levels work closely together to configurate projects and products in the most suitable way to achieve the targets set for each individual product and project. The anatomical map is not just a logical description of the product's functionality but is directly useful for organizing work in critical activities, critical functions and critical deliveries in the project. This map is used as a tool for showing the order in which testable results must emerge. Participants in the project in different organizational units with primary responsibility for different sub-systems or sub-functionalities receive a picture of the map via the anatomy that they are able to unify themselves around, such as around a logical way for the product to achieve greater and greater functionality. The result is that the project organization must mirror competence in managing interfaces rather than being specialized in a one-sided way in one of the sub-systems.

When a time dimension is added to the anatomical map, it can be used as an integration map, that is, a construction map for how individual functionalities will be integrated to groups of functionalities and finally to functioning complete products. This integration map is called *"organic"*, to indicate the dynamics in the process. An organic integration may contain only a few exact time points. These cover times for final delivery and the integrations (attempts to make sub-systems function together) that will be made along the way. Other times are held open and are adapted during the process to the solutions that make it possible for time points for sub-deliveries and final delivery to be those initially determined. The organic integration is based on an actual growth of function, where real functionalities and sub-systems are integrated and their functions tested. A technical coordinator describes this as:

"Integration and verification are completely valid only with the real thing. Everything else is only preparation. However, under certain conditions, this can be very useful preparation." [Technical Co-ordinator, Japanese Systems]

The organization of integration does not take place once and for all but grows organically as a continuously ongoing process. As development work results in an actual growth in function, real functionalities and sub-systems can be physically integrated and their functions be tested. This means that realizing especially important functional boundaries and testing how well they function develops ideas about the product. When the ideas about the product become more precise in this way, the organization can also be adapted to become more purposeful in the rest of the development efforts.

Figure 10.14 is an example of an organic integration map for a radio base station.

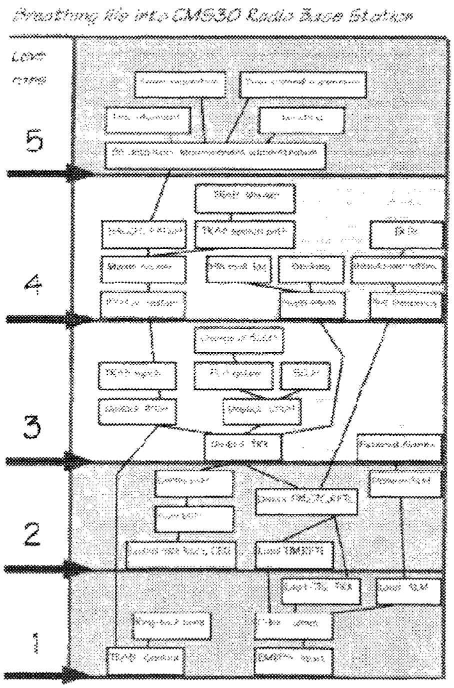


Figure 10.14. An Integration and verification plan for a radio base station (Järkvik&Kylberg 1994, p. 16)

Organic integration means striving towards shortening the total development time and the time required for integration on the sub-system level. In return, more time is given to each individual activity – especially those in the later phases of a development project, such as testing and industrialization. The focus is on the time up to the completed product and not on the time of the completion of individual activities or sub-functionalities. The integration plan is independent of general project plans or the establishment of development models through previous projects. It is instead based on the logic of specific products. Plans are, in the settings that use this alternative logic, an important tool both for the project manager and for other project members. In these plans, they receive a means to be able to develop a position toward the project as a whole. A picture is given in each given step in the integration plan of what the system can be used for as regards status, i.e. a picture of the actual growth of function. The anatomy and integration plan describes the product and the progress from the perspective of a user. The concepts that describe the status of the project are functionality-oriented, such as demonstrating an initial operation (switching on the electricity), making the first telephone call or performing a hand-over (shifting base station). In addition to the concept of anatomy, the concept of *"breathing life into the system"* is also used to describe the progress of the project and how the functionality of the product will successively be achieved. The work on anatomy and its progress is seen as an important method for achieving a common understanding of the *"whole"* among project participants of the complete project that is under development. One sub-project manager describes this as:

> *"One of the most important tasks of an anatomy plan is to get actors to agree on a picture of reality." [Sub-project Manager, Japanese Systems]*

The product is seen, according to the alternative approaches, as a system consisting of a large number of functionalties on different system levels. The central functionalities are defined on the basis of how to realize purchaser-relevant functionality. The focus for configuration is on how and through which sub-systems this functionality will be achieved. Each sub-system is then developed on the basis of the conditions of the boundaries and their development. Defining correct borders in advance has become more and more difficult, and the weaknesses in this definition are discovered relatively late in the project when it is managed according to the dominant approach. The discovery of integration needs occurs only when sub-systems have completed their work and then often lead to a chaotic situation with re-organizations and the exceeding of time and cost budgets. A technical coordinator describes this as:

> *"...throwing all of the software into a large pot and stirring and when it never makes soup we have no idea why or where it is broken. Then all kinds of people have to run around trying to fix things through the*

hallways quite a bit before we can get it on the track again..." [Technical Co-ordinator, Japanese Systems]

Instead of rigorous descriptions of borders, according to the alternative perspectives, one works with so called *"Interwork Descriptions"* that are deduced from the product anatomy. Interwork descriptions cover important dependencies and how the integration and work with boundaries will be done. Instead of an individual organizational unit working with borders' definitions that arise from those committed to the specific sub-system and from the perspective of this particular sub-system, the definition is given from the common view of the "whole". Organizational units or individuals with an especially good picture of the whole can be given great influence over interwork descriptions. While the traditional perspective works with a successively increasing specialization on the sub-system level, the alternative perspectives add to this particular specialization an ongoing, successive specialization in the other direction, on the level of the whole. Thus, over time, each unit's responsibility increases towards a greater wholeness than is represented by the tasks in its own sub-system. The borders go from being stable and carefully specified lists of demands in the dominant perspective to being living and interactive boundaries between sub-systems in the alternative perspectives, where functionality is achieved in a stepwise process.

"...and life is breathed into the product." [Test Engineer, Japanese Systems]

The product is seen in the emerging approaches as something that is built up in a stepwise manner via integration of sub-functionalities. This integration is in focus and it is a way of bridging the specialization made necessary by the increasing complexity of products. The relationship between this view of an increasingly complex product and the way of organizing development work can be understood with the help of Lawrence and Lorsch's (1967) theory on differentiation and integration. They found that the more complex problems an organization faces, the more differentiated the organization must be made. The differentiation is expressed in increasingly specialized units that work on different time perspectives, on different uncertainty levels and with different targets. Increased differentiation increases demands on increased integration. Increasing integration means that more and more different types of integration mechanisms, including special organization units with responsibility for coordination, must be created.

According to the alternative approaches for product development, integration takes place such that boundaries and groups of sub-functionalities work. Examples would be being able to turn on the electricity, make the first call and make charges for calls. These groups of sub-functionalities are described by actors in projects as the smallest possible unit and represent a group of sub-systems that together give individual project participants a *"whole"* that is sufficiently complete that they are able to relate to it in a meaningful way. According to these perspectives, integration is achieved through a successive specialization on the sub-system level in organizational units on different hierarchical levels. A specialization on a system level also means a clearer product or application orientation via special units that successively come to be responsible for the *"wholeness"* in the one case (*Japanese Systems*) and by giving a more and more differentiated picture of how the total product shall be mixed together in the other case (*Japanese Subsystems*). Hence, integration through special groups and integration through a shared framework of ideas achieved in common efforts in the boundaries.

The projects that are based on building principles work actively with representations and different types of graphic pictures of functional relations and relationships such as product anatomies and integration plans. They also use scenarios of the entire business around the product being developed in order to get actors to unite themselves around pictures of a "whole". One line manager emphasizes that:

> *"The picture can be more or less correct, but people always work and solve their part of the problem on the basis of the picture they have." [Line Manager, Japanese Systems]*

How to Manage System Integration

The dominant approach recommends that system integration be performed when sub-systems at each hierarchical level are stable and clean of faults. The result is a great deal of time allocated to testing and bug fixing at lower sub-system levels and late system integration. This approach is based on the assumption that integration is a simple task due to predictable outcomes in interfaces between sub-systems, and that the interfaces are correctly defined in the product structure. The analysis of the organizational settings above and the overall project performance discussed in chapter 1 show a quite different picture. In large and complex systems, system integration becomes a large and complex task with many unpredictable outcomes. Most functionality is realized in the interfaces, and initial system integration always gives important feedback to the sub-systems involved concerning what is not working. This feedback almost certainly leads to significant rework at the sub-system level, which will redefine the results of earlier tests and the stability reached at an earlier level. When integration takes place at a late stage, three major troublesome effects emerge: (1) the project does not meet set targets due to unpredicted rework in the late phases; (2) much of the work performed at the sub-system level is wasted due to important changes in prerequisites, as a result of the experience won in the system integration; and (3) actors do not take responsibility for activities or work performed outside their sub-system. A technical coordinator in a project applying the approach based on *integration-driven development* summarizes the integration endeavor as:

> *"Bug fixing renders many problems. Changes and solutions become meaningless if you bug-fix during too long a period, because so much else has changed in the system (...) Long intervals between integrations not only make bug-fixing more difficult - they also complicate the process of finding bugs, because it can be difficult to trace the source of a problem after numerous, interdependent changes have occurred." [Technical Coordinator at Japanese Systems]*

The analysis of the two emerging approaches that are based on *integration-driven development* and *dynamic synchronization* clearly shows that shortening the integration intervals improves the efficiency of the testing process by focusing on relevant bugs and solutions. Feedback about the whole system's performance and demands on interfaces comes very early in these two approaches. The analysis of projects applying the approach based on *integration-driven development* showed the positive motivational value of breaking a large task into a series of small successes or incremental gains, helping people to see the value of cooperation. Once actors see the value in one context – as component and sub-system integration – they become more inclined to cooperate in general. This has been demonstrated previously by, among others, Weick (1979) and Weick&Bougon (1986), who also believe that mental models can be coordinated even if people think relatively differently. The important point is that, if two or more individuals regard themselves as mutually dependent in terms of personal interests and knowledge, then they can interact in a coordinated manner independently of common norms or culture.

> *"Partners in a collective structure share space, time and energy, but they need not share visions, aspirations and intentions." [Weick 1979, p. 91]*

The analysis of projects that apply the approach based on *dynamic synchronization* also shows how system integration can work as a facilitator for showing how reciprocal interdependent groups of actors are and for building a collective responsibility for the whole system and the whole project.

> *"Integration of subsystems and components is very much a social and psychological process that illustrates that everyone in a project are parts of the same whole and that none of us gets better than the worst." [Subproject Manager at Japanese Subsystems]*

The analysis of the approach that is based on *dynamic synchronization* also clearly showed how sensemaking can be achieved in a speedy manner by using action and reflection upon action as the guiding principle.

The analysis of projects applying the approach based on *integration-driven development* and projects applying the approach based on *dynamic synchronization* clearly showed that projects are unlikely to be able to integrate the design at an early stage unless careful attention is given to architectural design, i.e. the configuration of both products and projects.

To sum up, my observations and analysis show that projects applying approaches based on fundamental assumptions that differ significantly from the dominant ones. Hence, do not manage system integration by building stable sub-systems that are integrated late in the project can be at least as manageable as projects applying the approach based on the dominant fundamental assumptions.

How to Manage Organizational Learning

In the dominant approach, learning is seen as an activity that should be separated from ordinary work, i.e. developing complex products. This strategy is based on two major assumptions: (1) a parallel and integrated focus on learning will disturb the focus on the project tasks and (2) learning is better managed by specialists. The above analysis of the different organizational settings and applied approaches points in another direction. Hence, the capacity for all kinds of learning seems to increase in organizational settings where the learning activities are integrated with ordinary work as in the organizational settings applying approaches based on *integration-driven development* or *dynamic synchronization*. And the propensity to learn seems to be more dependent on actors' perception of performance and on the extent to which actors are captured in prevalent ways of working in each organizational setting. One other important difference is that approaches based on *planning* are based on an assumption that if reality does not match up with plan the planning process was not rigorous enough. Hence, this is based on the assumption that the planning was right from the beginning but simply not rigorous enough. The learning that occurs under these circumstances is mainly focused on the planning process. Both the approach based on *integration-driven development* and the approach based on *dynamic synchronization* are based on gathering mismatches between expected and actual outcomes in order to learn how the process of managing complex product development can best be configurated and applied. In the approach based on *integration-driven development*, this learning is limited to a cumulative process in which new work practices are added to existing ones. In the approach based on *dynamic synchronization*, the process of sensemaking by letting action and results of action be the foundation for the learning process decreases limitations in both propensity and capacity for learning.

In summary, my observations and analysis show that projects applying approaches based on fundamental assumptions that differ significantly from the dominant ones. Hence, do not manage organizational learning as an activity to be handled separately from the projects and operative work, can be at least as manageable and learning-oriented as projects applying the approach based on the dominant fundamental assumptions.

How to Distribute Authority

The dominant approach prescribes that the line organization, and especially important sub-systems, shall own resources to secure technical excellence and long-term development of both engineers and the sub-system. Experience from projects applying this dominant approach clearly shows that this distribution of authority will lead to a sub-system focus at the expense of a system focus, system integration will be performed late in the projects, and resources will be allocated mainly to solve sub-system internal issues. Different sub-systems with problems that occur in interfaces will blame them on each other, and the project will have difficulty in meeting both set and emerging targets. Experience from projects applying the approach based on *integration-driven development* shows that, by strengthening the project organization, system issues, sub-system interdependencies and the total project task will be addressed and be held in focus. This has proved to support projects in meeting set targets. Experience from projects applying the approach based on *dynamic synchronization* shows that individual engineers, when confronted with the total complexity and forced to learn how the total system works, develop as engineers much more quickly than otherwise.

In summary, my observations and analysis show that projects applying approaches based on fundamental assumptions that differ significantly from the dominant ones, and do not distribute authority only to the largest sub-systems, can be at least as manageable as projects applying the approach based on the dominant fundamental assumptions.

Important Contingencies

Each approach, its perspectives, principles and actual models in use have both strengths and weaknesses that are of a contingent character. Depending on the empirical settings, the business conditions, product characteristics, coordination needs, project lead-time and complexity, and whether or not the product anatomy is known, each approach will provide different conditions for high performance.

The Organizational Settings and the Business Conditions

If the telecommunications business at present is regarded as being in a transitional stage and, for some types of products such as stationary systems for switching, moving into a specific phase[79], firms such as Ericsson will find themselves needing to adapt their operations accordingly. In manufacturing, this means innovating the processes for assembling and testing switches and radio equipment faster, more flexibly according to direct customer demands, and in a more cost-effective way, producing roughly the same product over and over again. Thus manufacturing ends up busily implementing continuous improvements, i.e. refining how you go about doing much the same thing that you are

[79] Utterback (1994) describes industries as being in different stages following a pattern of innovation curve. For a further description, see chapter 2, p. 134.

accustomed to doing (*incremental* learning) and paying attention to a theme – rationalization of work processes – which has a strong tradition in manufacturing. In the organizations responsible for product development, the change process is somewhat more complicated. Not so much in the sense that what you do is very different (*"assemble code"* and test it) but more as concerns how the legitimacy is perceived and how you understand the need for process innovation, continuous improvement, and rationalization in the way you do your work. In manufacturing, there is an imprinted tradition of considering how you work but, in design work, attention has for years been primarily on what you do, i.e. product innovation.

If the telecommunications business is considered to be in transition and converging with the computer software and internet industry, another set of business conditions will emerge where the speed of and flexibility in both the product and business development processes will grow increasingly important as a means for better competition.

In both scenarios, actors will face changes in prerequisites, and *organizational* learning must take place to master these changes. As described above, the propensity for first-order learning is higher in organizational settings that apply the emerging approaches, while the organizational settings applying the dominant approach have a higher propensity for second-order learning than any of the emerging ones. This is explained by the perception of performance among actors. The capacity for learning is higher in the emerging approaches, due to integration of those activities into the actual work processes and by having a system focus. In the approach based on *integration-driven development*, a small number of key actors are responsible for renewal, learning and system focus while, in the approach based on *dynamic synchronization*, most actors have that responsibility. The difference between the emerging and the dominant approach is that, in the former, the project organization manages such activities while, in the latter, special functions in the line organizations manage such activities.

The approach based on *planning* seems to fit best in large and old organizational settings with a few longstanding customers, where lead-time and time of delivery are subordinate to the experienced quality assurance and where targets set at the start of a project do not change over time.

> *"...there tends to be more, and more thorough, calculation in fields with projects and consequences where the future is easy to foresee. Companies in environments difficult to predict tend to rely more on the power of decision, while those who find themselves at the other end of this spectrum rely more on formalized calculation routines and bureaucracy." [Segelod 1986]*

The size and age of the organizational setting have previously been shown to influence the degree of formalization (see for example Göjeryd&Söderlund 1995). Projects applying the approach based on planning support the development of large systems where development resources are distributed, where performance in interfaces is predictable, and where all relevant interdependencies and their values are known to actors planning and configuring the projects. Another related aspect is the age and enthusiasm among engineers engaged in the project(s). Both organizational settings applying any of the emerging approaches are relatively young and have relatively young and enthusiastic engineers engaged. There seems to be a reciprocal dependency where the two emerging approaches attract young and enthusiastic engineers, while both emerging approaches also are dependent on young and enthusiastic engineers and also both emerging approaches seems to support further enthusiasm.

The approach based on *integration-driven development* seems to fit best for large and complex tasks that must be accomplished in a short time and where time of delivery is crucial. This approach also seems to be most beneficial when there is a *"temporary stability"* in customer specifications and when the number of distributed sites performing complex product development is limited.

The approach based on *dynamic synchronization* seems to fit best for highly complex tasks where performance in interfaces is not known, where all interdependencies and their values are not known beforehand, and where customers have changing demands. This approach seems to support a close customer interaction. Projects applying the approach based on *dynamic synchronization* also seem to have a large potential in a rapid development of engineers. However, at the same time place a great many demands on project participants and, therefore, seem to fit best in organizational settings where many actors are highly motivated and willing to attack the challenge.

Neither of the two organizational settings applying any of the emerging approaches have had any substantial experience of handling a large number of customers and product variants.

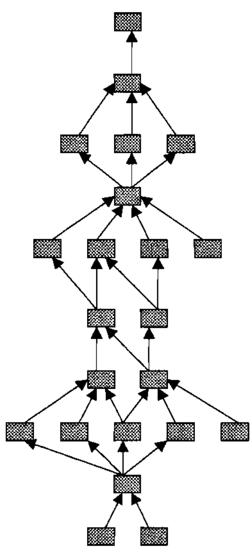
The Product Characteristics

The characteristics of the product create different preconditions for the application of different approaches, and in certain cases they limit the potential profits of applying one of the emerging approaches. The approach based on *planning* is best applied to products where sub-systems can be configurated independently of one another, where system performance can largely be predicted by monitoring sub-system performance, and where stable sub-systems are the same as a stable system, i.e. where performance in interfaces is predictable. The approach based on *planning* is also useful when there are both low uncertainty in terms of requirements and in terms of realizability.

The approach based on *integration-driven development*, on the other hand, yield high gains in both lead-time and delivery precision in *horizontally integrated systems*[80] (=software-intensive), while the large gains lie in

[80] Software intensive systems such as CMS 30 (developed by *Japanese Systems*) with 70-80 percent software components have a large potential for paralleling of a large number of work packages, that create prerequisites for product anatomies that are integrated along the vertical axis in the anatomy.

delivery precision as regards *vertically integrated systems*[81] (= hardware-intensive). The gains in reduction of perceived uncertainty is also larger in the horizontally integrated systems where more important integrations can be made and verified early in the process. Figure 10.9 shows a typical vertically integrated and a typical horizontally integrated product anatomy. The uncertainty in boundaries between sub-systems then defines conditions for the number of increments needed in the approach based on *integration-driven development*. High uncertainty renders a need for a large number of increments while low uncertainty renders a need for only a few increments.



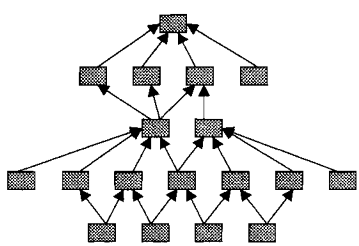


Figure 10.15. Vertically and horizontally integrated product anatomies

[81] Hardware intensive systems such as the central processor (developed by *Central Processor*) with 70-80 percent hardware components create prerequisites for product anatomies that are integrated along the horizontal axis in the anatomy.

The inherent lead-times and sequential dependencies explain these limited gains in a vertically integrated system. An *asic*[82] takes three months to produce and one month to verify, independently of how it is done. To integrate, test and verify a base station, a number of sub-systems must be in place, such as transmitter, receiver and power, and, to have a transmitter and receiver in place, a number of asics must be in place. The result is that it is possible to perform less development completely in parallel and that product anatomy becomes integrated around the vertical axis, while it is possible to develop a more software-dominated product in parallel, at which the product anatomy becomes integrated around the horizontal axis[83].

The approach based on *dynamic synchronization* follow the characteristics of the approach based on *integration-driven development*. However, but it is more motivated in products for which it is difficult (or impossible) to configurate independent sub-systems or to predict performance in interfaces and for which there are a number of unknown interdependencies and values of interdependencies.

Project Lead-time and Complexity

In the approach based on *integration-driven development* high complexity is best managed by configurating a large number of increments. However, the actual lead-time that actors have to act on limits the number of potential increments that is possible to perform. As described in chapter 9 six increments have been established as an appropriate number of increments to master complex projects applying this approach but when project lead-time is being reduced to less than a year no more than three to four increments are possible to perform. Hence, the potential benefits by

[82] *Asic* stands for *Application Specific Integrated Circuit* and is used when standard circuits not are applicable, for example in different internal boundaries in a product.

[83] Which corresponds well with Staudenmayer and Cusumano´s (1998) research, which shows that frequent integration may be more feasible in software relative to other types of products given its inherent malleability.

applying the approach based on *integration-driven development* are reduced at a certain level of possible project lead-time.

The Coordination and Integration[84] *Need*

The coordination and integration need is closely connected to the system that is developed owing to the number and unpredictability of, and complexity and uncertainty in, interdependencies in the system. Increased complexity normally leads to greater specialization, which in turn leads to an increased need of integration and coordination (as, among others, Lawrence&Lorsch 1967 have shown). Increased uncertainty and unpredictability lead to larger and more frequent changes, which in turn increase the need for coordination (as Adler (1996) among others has shown). However, it is feasible to apply different strategies for organizing that will affect both the perceived need for co-ordination and the actual capacity for co-ordination somewhat independent of the inherent complexity and uncertainty in the product to be developed and in the market that is targeted.

The application of the approach based on *planning* is motivated when the need for coordination is low – when the sub-systems can be developed independently and when the integration task is small. The application of the approach based on *integration-driven development* is motivated when the coordination need is moderate – when troublesome interdependencies are predictable and the allocation of a small number of key actors to sub-system interfaces and system integration is sufficient. The application of the approach based on *dynamic synchronization* is motivated when the coordination and integration need is large – when interdependencies and

[84] As described in chapter 5, integration is used in this thesis to capture a more active form of co-ordination, where information is exchanged between actors from different sub-systems at predefined hierarchically organized project meetings, and where new knowledge is created during interaction and responsibilities are shared over sub-systems, thus turning borders into boundaries.

performance in interfaces are unknown and when changes in prerequisites are frequent.

The Familiarity of the Product

The familiarity of the product, the product structure, its sub-systems and their interdependencies provide different conditions for product and project configuration and the process of managing the actual projects. The approach based on *integration-driven development* presupposes that a number of key actors can together depict a sufficiently correct illustration of the product anatomy, i.e. how different pieces work together and how functionality is realized in the product being developed. The approach based on *planning* can handle low familiarity of the product that is to be developed, but this will have a strongly negative effect on both lead-time and precision due to the unpredictable integration challenge. The approach based on *dynamic synchronization* is motivated when the familiarity of the product is low.

The Three Approaches – Different Species or Types?

The approach based on *integration-driven development* and the one based on *dynamic synchronization* are termed emerging approaches, implying a movement from the dominant approach toward these newer ones. Both of the organizational settings that apply these emerging approaches have their history in projects applying the approach based on *planning*. To cope with more intense competition and increased demands from the customer(s), key actors had to introduce new perspectives, new principles and new actual models for organization in their product development projects based on fundamentally different basic assumptions. Both organizational settings in which the emerging approaches are applied faced tough demands on lead-time and a fixed time of delivery. The organizational setting applying the approach based on *dynamic synchronization* also faced tough demands on flexibility and response time. The role of market forces as effective facilitators for introducing new ways of working has earlier been elaborated by Kelly (1982), among others, and, without the demanding customer(s) and tough competition, these new approaches would probably never have been introduced. This section will discuss support for and obstacles to changes from one approach to another to elaborate on the differentiation between them.

An important dimension to be reflected in analyzing conditions for changes from one approach to another is that of potential gains and potential losses. What are the potential gains and losses, when do they potentially occur and who will get the credit or be blamed? In organizational settings applying the approach based on *planning*, a movement toward applying the approach based on *integration-driven development* will increase performance in terms of lead-time and precision. Such a movement will also increase project management authority and system focus at the expense of sub-system management authority and sub-system focus. The potential gains are at the system level, and the potential losses are to actors at the sub-system level. In organizational settings applying the approach based on *planning*, actors at the sub-system level are (as discussed earlier) those who are most powerful. This means that, to initiate a movement from applying the approach based on *planning* toward applying the approach based on *integration-driven development*, top management must believe so strongly in the necessity of a movement that they take the necessary action, i.e. completely alter the current power structure. This limits such a movement to customer- or market-driven ones where no other alternatives exist.

A movement away from applying the approach based on *planning* toward applying the approach based on *dynamic synchronization* will, as in the approach based on *integration-driven development*, increase potential project performance in terms of lead-time and precision. And will also increase the potential flexibility in the projects and the speed of development of human resources engaged in the projects. Such a movement will also engage many actors in one another's sub-systems and into the wholeness, but at the same time lose the previous quantitative overview of project progress and increase the coordination need. The total authority will be more distributed than earlier, and convergence and transparency will increase. The potential gains are for actors at the system level (many engaged in the wholeness, not limited by the capacity of the very few, the actors from the important sub-systems are equal players, increased convergence, shortened lead-time, higher precision and project flexibility) and actors at the sub-system level (many engaged in one another's sub-systems, increased transparency and speed of development of human resources). The potential losses are for top management by a loss of perceived control over progress, for all by the loss of effectiveness through increased coordination, and for actors not interested in learning or facing the total picture and afraid of the seeming loss of control over details. The movement is facilitated by non-hierarchic organizing and by a large number of actors with a high propensity and capacity to develop their roles. A major obstacle to such a movement arises if single actors must take all the risk while still only being one of many who will share the potential gains, as when the project manager must translate actual work into prescribed work to the project steering committee.

A movement away from applying the approach based on *integration-driven development* toward applying the approach based on *dynamic synchronization* will increase the potential project flexibility and the number of actors that take responsibility for the whole. The major obstacles to such a movement is both that key actors will lose relative influence and that some of the other actors might not be interested in gaining influence and responsibility. Therefore such a movement will not be initiated internally; it is most probable that it would be driven from management outside each project. A movement from applying the approach based on *dynamic synchronization* toward applying the approach based on *integration-driven development* will gather power in a smaller group, decrease its coordination need, and provide a more objective progress control. However, it will also decrease flexibility and the potential speed of development of human resources. The potential gains are primarily directed toward the small number of prospective key actors, and will probably be possible only if demands on flexibility are significantly decreased. Any movement between sub-systems must also, besides the specific demands, be supported by the incentive system applied by the organizational setting.

Another important dimension to be considered in the movement between approaches is how well the attributes of each approach are known and how well they can be described. As discussed above, the approach based on *planning* has the most manifest and latent functional attributes known to actors in different organizational settings, while most of the manifest and latent dysfunctional attributes are unknown to actors in the different organizational settings. For the other two approaches, and especially the one based on *dynamic synchronization*, the picture is the other way around, i.e. manifest and latent dysfunctional attributes are fairly known to actors while manifest and latent functional attributes are unknown to the majority of the actors. This is partly a result of their newness – whereas the approach based on *planning* have behind them a huge literature with both academic and practical descriptions of how they are best applied, the emergent approaches lack rigorous description. However, is also a result of the difficulties in capturing the new approaches. In both organizational settings, a number of attempts have been made to illustrate how work has been performed and how this differs from the earlier approach. Each illustration has failed when it has attempted to be rigorous in the description.

> *"...I do not recognize myself in this description (...) If you ask me I would say that in this description everything is represented as most important and at the same time it has not captured what was really important..." [Senior Manager at Japanese Subsystems]*

Yet the illustrations must be rigorous in some sense to be able to transmit a sufficient picture of what the new approach is about.

The concept of *core rigidity* (from Leonard-Barton 1992, 1995) also plays an important role in the changes from one approach to another. Core rigidity was introduced by Dorothy Leonard-Barton (1992) to capture the process in an organization when its major strength and base for competitiveness becomes its major weakness and obstacle to competitiveness.

> *"... Some such problems are idiosyncratic to the particular project, unlikely to occur again in the same form and hence not easily predicted. Others, however, occur repeatedly in multiple projects. These recurring shortfalls in the process are often traceable to the gap between current environmental requirements and a corporation's core capabilities. Values, skills, managerial systems, and technical systems that served the company well in the past and may still be wholly appropriate for some project or parts of projects, are experienced by others as core rigidities – inappropriate sets of knowledge..." [Leonard-Barton 1992, p. 118]*

Actors in all three approaches focus primarily on doing more of the same. In organizational settings applying the approach based on *planning*, actors do what they have always done and managers defining the prerequisites have come to those positions by doing well within that particular approach. The former core competence – a distributed set of competencies and sub-systems configurated to be easily integrated – has become their major obstacle to taking integrated initiatives that may result in changes from one approach to another. In the organizational setting applying the approach based on *integration-driven development*, actors can become stuck in their own success. By repeatedly succeeding in meeting tough project targets, actors have successively become more and more sure that the way they are doing things is the right, and probably the only right, way to do things. The core competence – a strong and highly convergent group of key actors who take active responsibility for the whole project – can easily become their own main obstacle to further renewal. In the organizational settings that apply the approach based on *dynamic synchronization*, actors had not at the time of study become aware of what they were doing. They had also experienced an unexpected success that lead them to believe that what they were doing was probably right.

Finally, the parallel presence of the three approaches ought to be considered in an analysis of changes from one to another. According to a number of actors, the different models seem to fit more or less into different project phases. The approach based on *dynamic synchronization* is recognized as a possible way of working at a very early stage in a project. The approach based on *integration-driven development* is then recognized as a possible way of working in the early phases and during execution, while the approach based on *planning* is recognized as a possible way of working in late execution and production. Although these considerations are important, the approaches as depicted in this thesis are not project phase-dependent, but rather dependent on project prerequisites due to fundamental differences in basic assumptions. In many projects, prerequisites can be seen as changing over phases, and discussing the overall prerequisites rather than the phase prerequisites probably supports changes from one approach to another.

In summary, do the approaches differ in species or only in degree or type? The recurring discussions above, all ending in the conclusion that all three are based on different fundamental assumptions and that the application of a given principle or model in each would lead to three quite different results strongly support the former, i.e. that they actually represent three different species. This is further strengthen by their high internal consistency, their discriminant characteristics and the fact that there are more similarities between the approaches in operative practices than in principles, perspectives or basic assumptions. Despite similarities in work practices, changes from one approach to another also seem very painful for the actors involved.

The approach based on *integration-driven development* seems to be an important bridge between the other two by sharing some important characteristics with both, while the other two share very few. The approaches based on *planning* and *integration-driven development* both create a perceived control for management, rely on *"objective"* and quantitative means, believe in design theory and the use of single heroes and are limited by very few key actors´ capacities. The approaches based on *integration-driven development* and *dynamic synchronization* both focus on early system integration, build up their own product anatomy, work with strong and real-time graphic illustrations, such as the *I&V plan*, and put strong effort into developing a capacity for real-time handling of uncertainties.

Sustainability of the Emerging Approaches

The organizational settings studied have had up to seven years of experience in applying the emerging approaches. Both settings have changed single elements in or aspects of how to apply each approach, but both have also kept the same original, fundamental assumptions on which each approach is based. Today, projects applying both of the two new approaches have stabilized their performance on a high level of effectiveness and efficiency. Compared to normal practice, we find a set of institutions and patterns that enable the projects to meet set targets and, to some extent, to continuously improve themselves. In considering and understanding the sustainability of the emerging approaches, their origin is important, as is another set of factors as well. These factors can provide plausible explanations for why it has been possible to avoid stagnation in effectiveness and efficiency over project generations, while also providing plausible explanations for the tendencies toward stagnation – with decreasing rates of improvement or increasing costs for keeping improvement rates at the same level. This section will introduce a number of issues and discuss their enabling and disabling effects.

Customer Interaction

Both organizational settings performing projects that apply new approaches have a visible customer, with a highlighted, continuous customer interaction that involves more than project management. A small number of key actors in the approach based on *integration-driven development*, and a large number of actors in the approach based on *dynamic synchronization*, are directly involved in discussions with representatives from the end-user or local market organization. For each project generation, these personal contacts add to a refined network and add to the organizational knowledge about the counterpart's value system and priorities. In the early phases of every project, specifications are defined in a close dialogue with the customer. In the approach based on *integration-driven development* they are perceived as fixed, and in the approach based on *dynamic synchronization* they are perceived as preliminary. The end user has, in both approaches, possibilities to control and audit the outcome before the whole system is released to him, but the one based on *dynamic synchronization* also has the capacity to handle changes during the project. Recent projects can take advantage of personal relations established in earlier project generations and they provide a network for dialogue, which enables quick and unified solutions (sensemaking) to unforeseen problems. These mechanisms presuppose both an efficient and a demanding customer. The close customer interaction has also resulted in continuously rising expectations. In the eyes of the customers, good performance in earlier projects leads to rising expectations. The conditions tend to be harder for every new contract, because customers learn a great deal about what is possible and how further pressure is best brought to bear.

To sum up, close and frequent customer interaction enables sustainability of the two emerging approaches, while distant and rare customer interactions are probably disabling. If the organizational settings do not receive continuous input and demands from the customer, they will more easily develop an internal focus and apply the approach based on *planning*.

System Focus

Both emerging approaches apply a strong emphasis on early (or continuous) integration and testing at the system level. As described earlier, the product and process configuration in both approaches focuses on early integration and verification to secure a stepwise growth in actual system functionality. This *"innovation"* is, as discussed earlier, one important factor explaining improvements in efficiency. Integrating different tasks in this way enables a different role of the testing function.

Test procedures add to the overall understanding of what should be achieved in the project, even if tasks are distributed among design centers and design teams. Once established, these new test procedures also add to the problem-solving processes. Real tests of components and sub-systems as early as possible help the project to identify errors and weaknesses in design, and thus provide a continuously updated list of problems and shortcomings. Early testing procedures also add to the overall understanding of the general objectives of the project. From the point of view of a sub-project or a design team, the whole project becomes more transparent and one's own activities can continuously be evaluated in terms of their contributions to the whole project.

In summary, sustainability for the emerging approaches is enabled by a strong system focus and also facilitates such a strong focus, while a strong sub-system focus disables the sustainability of the emerging approaches.

Improvement Activities

Much time, effort and resources are spent on improvement activities in the emerging approaches and also, to a large extent, on those carried out by the development projects. A set of institutions and arenas has been developed to systematically absorb and evaluate ideas and suggestions for improvement in the approach based on *integration-driven development*, while it has become a natural way of working in the approach based on *dynamic synchronization*. The concurrence between project generations is also used as an opportunity for learning between project generations. Concurrence means on the team level that a design team, as a team, is involved in more than one project generation. The previously described improvement conferences provide every new project generation with experience gained in earlier generations.

In summary, integrating and focusing on improvement activities in actual work enables a sustainability of the emerging approaches, while separating and managing improvements as special projects disables sustainability.

Frameworks and Development Models

For the approach to be sustainable, it must be possible to describe, and the description of the approach must give sufficient security to management and customers so that control of the process will not be lost. The approach based on *integration-driven development* bases its process control on actual and validated functionality growth, illustrates the project as the *I&V Plan*, and describes its progress through distinct controllable steps toward full functionality. This approach also has a distinct group of key actors that are responsible for progress control. Actors in the approach based on *dynamic synchronization* have come to the conclusion that this description is not a valid one in their setting and have therefore tried to find others. They have not been successful in this endeavor, and they base their freedom in action on confidence from local management and high performance. If performance weakens in one project generation, sustainability will be threatened.

In summary, a communicable development model that provides necessary security for the actors outside the organizational setting enables sustainability, while the lack of this security disables sustainability. High performance also enables sustainability, while poor performance will disable it.

Location of Actors in the Projects

The emerging approaches have used fewer distributed actors in their projects than a project of that size normally uses within the firm. At each site the emerging approaches – especially the one based on *dynamic synchronization* – have co-located actors working in the same project. This has facilitated the building of local theories and common responsibilities.

Co-location and closeness of actors involved in the project seem to support a system focus that is important for both emerging approaches, and strengthen a path that has been initiated – i.e. leads to the building of structures around a given solution. This means that co-location will help preserve and develop a way of working and work as an obstacle to the introduction of new ways of working.

To sum up, co-location and closeness enable sustainability while distribution and separation of actors disable sustainability of the emerging approaches.

The Known Area

Most of the manifest and latent functional attributes in the emerging approaches (especially the approach based on *dynamic synchronization*) are not known to and/or considered by most actors. While, most of the manifest and latent dysfunctional attributes in the dominant approach based on *planning* are not known to and/or considered by most actors. This leads to a situation in which the approach based on *planning* is perceived as better in comparison with the emerging approaches, owing to a lack of knowledge. An enlargement of the known area will therefore enable sustainability, while a preserved known area such as the present one will disable sustainability.

	An approach based on planning		An approach based on integrationdriven development		An approach based on dynamic synchronization	
Known and taken into consideration	4	1	4	2	1	1
	1	1	1	1	2	2
Not known or taken into consideration	0	0	1	0	5	2
	5	5	1	4	2	2

Figure 10.16. The known area in each approach

In the approach based on *planning* all functional attributes are known and taken into consideration, while most dysfunctional attributes are not known or taken into consideration. Hence, the approach is perceived as more attractive than it actually is by the actors applying it. In the approach based on *integration-driven development* most functional attributes are also known while most latent dysfunctional attributes not either are known or taken into consideration. However, in the approach based on *dynamic synchronization* it is to a large extent the other way around, i.e. most functional attributes are not known or taken into consideration while many of the dysfunctional attributes are known and taken into consideration.

Garbage Cans and Sediments

Both March&Olsen (1986) and Danielsson (1983) emphasize the time of the idea's breakthrough, i.e. the connection between problem and solution, which is the important event at which problems and solutions that may long have existed individually but undergo a successful coupling to create a lasting sediment. To understand the emergence of a sediment we require, as mentioned earlier, an analysis of (1) the perceived problems, (2) the perceived available solutions, (3) the actors involved and (4) the time of the connection between the problem and the solution. Sustainability for the approach in action is the opposite of new ideas' breakthrough: as long as the present approach is perceived by the dominant actors in the organizational setting as a solution to the perceived problem, sustainability will be enabled, and if it is not, sustainability will be disabled.

Models for Managing and Making Decisions

Planning procedures and organizational solutions have traditionally been rigid and are designed around stable goals and sub-goals with the purpose of providing an important foundation for high autonomy of tasks and work groups. The approach based on *integration-driven development* is a step from autonomy and separation toward integration and interdependencies, and the approach based on *dynamic synchronization* is one step further from rigid to dynamic. To enable the sustainability of these steps, other strategies, incentive systems and decisions must be based on the same fundamental assumptions. If the organizational setting applies other (more traditional) aspects in the overall strategy formulation, in the rewards to actors or in priorities, sustainability will be disabled.

Dispersion of the Emerging Approaches

Each of the two emerging approaches is based on studies of only one organizational setting that applies it – even if there are a number of other examples outside the firm that has been discussed in work shops with actors outside the company. The analysis and discussions conducted in this thesis have shown that there are other organizational settings performing complex product development and facing increased demands on speed, punctuality and flexibility. Even if new knowledge and experiences are generated, collected, shared and used by individuals, organizations play a critical role in triggering and enlarging the knowledge and experiences, and in enabling or disabling dispersion of new work practices. This section will discuss some of the enabling and disabling attributes for dispersion of the two emerging approaches.

Customer Requirements

A very important customer that demands specific behavior that can not be achieved with the present way of working will, if this becomes evident to actors, be an important engine and enabling factor in introducing new ways of working. This was what made possible the introduction and application of the two emerging approaches at *Japanese Systems* and *Japanese Subsystems*. If, on the other hand, the customer lets the supplier on his own have a significant impact upon defining the process, or the customer requirements never face the organizational settings performing the actual work, this will have an important disabling effect for introducing new ways of working.

Knowledge about Attributes in each Approach

As in the discussion of sustainability above, the superior knowledge and experience in the approach based on *planning* leads to a perception of this dominant approach as relatively better than the emerging, more unknown approaches. Increased knowledge about attributes in each approach will enable dispersion of the emerging approaches, while arresting the search for more knowledge about these attributes will disable dispersion. As figure 10.10 shows this is especially so with the approach based on *dynamic synchronization* where most both latent and manifest functional attributes are unknown and not taken in consideration by actors in the organizational setting applying it.

The Perception of the Process of Dispersion

Adler&Docherty (1995) introduced a model for transfer of practices and organizational learning in knowledge-based organizations that divides the process of dispersion into four main transformation processes. The model argues that conceptualizing and extracting the fundamental assumptions behind the identified practice enables an effective transformation of work practices and implement these fundamental assumptions in its specific organizational setting where it is supposed to be applied. The model also argues that an effective transformation of work practices is disabled by only trying to blue-print the work practices into a new organizational setting.

The Difference in Application due to Different Basic Assumptions

As discussed in the section above, dispersion of the emerging approaches is not only dependent on a full understanding of the concrete work practices or actual models for organizing. Successful dispersion is also dependent on both a full understanding of the basic assumptions, the perspectives and the principles that work practices and organizing models are derived from and on the application of these basic assumptions, perspectives and principles. An application of a set of work practices and organizing models will lead to something other than what was expected or desires as a result of differences in basic assumptions, perspectives and principles underlying and guiding the application. Some early examples are in the endeavors to diffuse the approach based on *integration-driven development* at *Central Processor.* Actors in this new organizational setting are interested in applying a set of work practices and models for organizing to increase manageability and introduce new complementary tools to master the demands on their new and large project. However, these actors have not accepted that a successful dispersion will demand that basic assumptions, perspectives and guiding principles be reconsidered. This makes dispersion more difficult and the potential outcome more uncertain.

The Number of Actors Involved in the Process of Dispersion

As discussed in the section above, enlarging the known area among actors in the organizational setting in which the new approach is meant to be applied enables dispersion. Involving as many actors as possible in the dispersion process also enables dispersion.

> *"It is, however, not only the generation, or production, of these artifacts that consists of social construction processes. Even artifacts must be reconstructed socially in order to have any significance at all for human action. Unless artifacts are actively recreated by individuals' thought processes (unconsciously, consciously in practice, or consciously in discourse) they can be said to cease to exist." [Blomberg 1995, p. 65]*

This means that the approach is best diffused if it is understood, accepted and validated by the potential users. This is further supported by recent research on change strategies (see for example Ingelgård 1998) where *broad change strategies* involving many actors have proved to be more effective in producing change. Hence, using only specialists in the process of dispersion disables dispersion of the emerging approaches, while engaging many actors in the process enables dispersion.

What Parts of an Organization are Responsible for New Ways of Working

The two preceding sections showed that a large number of actors engaged in truly understanding the specifics of both the new approach to be applied and the organizational setting that is meant to apply it enable dispersion. While, engaging few specialists in implementing a blueprint of a best-practice solution disables dispersion. If the organizational setting itself and actors performing actual work are responsible for introducing new ways of working, dispersion will be enabled; while if another organization is responsible for introducing new ways of working to the organizational setting performing actual work, dispersion will be disabled.

Beyond the Emerging Approaches

Organizational settings performing complex product development already face, and will probably face to an even greater extent in the future, high demands for fast and dynamic development. Demands, where many potential courses of action coexist, where new circumstances are continuously introduced that change the validity of basic assumptions, where unforeseen problems will continuously occur, and where the final products may be evaluated across a number of criteria by potential customers. The emerging approaches illustrated and discussed above constitute a movement and transition in the following aspects:

- from sub-system focus to a stronger system focus,
- from no one to a small group or to most actors involved in synthesis of the whole system and interdependencies between sub-systems,
- from rigorous planning to building a capacity for a small group in one approach,
- and from many in the other approach and from being right from the beginning toward letting solutions evolve over time and emerge together and become increasingly clearer as the process moves on.

These two emerging approaches (which differ significantly from the dominant one) have been identified by working together with one firm for five years. Other approaches in terms of nuances, or perhaps even in terms of fundamental assumptions, would probably have been found by working together with other firms in other industries facing different prerequisites and in other time frames. Both emerging approaches are results of having faced the demands of a Japanese customer, and each is high performing under its respective preconditions. What will the next approach be that differs significantly from both the dominant and the emerging ones described in this thesis? A number of trends can be discerned – both from this particular study and from the presentation of the preliminary results to a large number of actors from different firms – which may constitute the building blocks for a fourth approach that reaches beyond the two emerging ones.

Firstly, to master competition, project-based firms must raise themselves from having the single project, or even the single project family, as the unit of analysis. Multi-project management will be an important issue in managing short-term effectiveness as well as in managing learning in a sufficient way. The approach based on *integration-driven development* lacks sufficient propensity and capacity for learning, and both emerging approaches manage projects in a way detached from the larger purpose of the organizational setting.

Secondly, to truly develop the project organizations as self-organizing entities with the capacity to handle most emerging situations, they must be given a more distinct business responsibility and thus be forced to develop a more advanced understanding of the business logic. Both the approach based on *integration-driven development* and the approach based on *dynamic synchronization* lack sufficient knowledge about the inherent complexity in the business logic around the product or system for which they are responsible.

Thirdly, the role of line managers must be developed toward something else than less powerful images of their colleagues in organizational settings applying the approach based on *planning*.

Finally, the increasing demands, together with increasing opportunities for actors in organizational settings applying one of the emerging approaches, raise the question of stress and burnout. Actors in the organizational settings that have been studied possess only seven to eight years of experience in the emerging approaches, and the organizational settings already face more burn-outs than in organizational settings applying the approach based on *planning*. To build long-term competitiveness for knowledge-based organizations, it is of vital importance to build conditions for a healthy long-term development of actors in these organizations.

Toward a Model for Explaining Performance in Complex Product Development

As described in chapters 1 and 2, the dominant set of knowledge (applied into the approach based on *planning*) is based on a distinct set of basic assumptions and suggests a set of perspectives, principles and models for organizing to perform complex product development. The results presented and discussions performed in this thesis provide strong support for the view that this is not sufficient to explain performance in complex product development facing current competitive conditions. Vital elements that ought to be considered in order to explain performance are the dynamics of organization, the notion of *"soft specifications"* such as boundaries and emerging prerequisites, the process of managing complexity by providing actors with wholenesses, the process of distributing responsibility for the complex whole to specially allocated or many actors, the process of managing learning and renewal as an integrated task, and new perspectives on planning and control.

The Dynamics of Organizing

The three approaches regarding how to manage complex product development presented in this thesis represent a movement from project organizations in the approach based on *planning*, to project organizing and *"advanced socio-technical"* design in the approach based on *integration-driven development*, to self-organizing projects and sensemaking in the approach based on *dynamic synchronization*. This means that the traditional project organization, which has a clear specification that limits the projects' scope, prior determination of tasks, an organizational structure supplemented with direct supervision, specific and independent areas of responsibilities, and a clear hierarchy that governs reporting and decision-making, is replaced by less clear areas of responsibility, paths of reporting, and structures for decisions, where a few key actors in one case and most actors in the other emerging approach are responsible for continuously updating the formal and informal structures and actual work to the emerging prerequisites. New organizational concepts such as task-specific forums[85], handshaking[86], sensemaking[87] and arenas for learning[88] become relevant and a complement to sub-projects and management groups.

Since the process of organizing and self-organizing action is to be guided by the way the whole task is defined, there is reason to spend some time questioning and balancing knowledge about action-outcome relationships. If this is not done, there is a risk that many performance potentials will remain undiscovered, or that it will be unrealistic to accomplish the overall task – at least within given frames of time, cost and functionality (Lundqvist 1996). Purser and Pasmore (1992) believe that this

---

[85] A *task-specific forum* is a specially established task-actor relationship, determined by actors interacting with one another in order to accomplish a time-limited task (Lundqvist 1996, p. 21)

[86] *Handshaking* is the process of ensuring that persons establishing and/or committed to a new task-specific forum have the same perception about the task associated with the new forum, and about how the new task relates to the original task and to the overall performance standard (Lundqvist 1996, p. 22)

[87] The concept of *sensemaking* is elaborated by Weick (1995) among others and its application in the approach based on *dynamic synchronization* is described in chapter 9.

[88] "*Lärande och spridningsmekanismer inom produktutveckling*" [in Swedish] by Westling (1998)

presupposes a balance between order and disorder, where order provides the systemic coherence necessary for the technical and social sub-systems to be able to focus on current task requirements, but where too much order can reduce creative fluctuations. Thus, disorder is beneficial to the extent that ambiguity and fluctuations trigger opportunities for creative learning, adaptability and self-renewal. The approach based on *dynamic synchronization* means that the social and technical sub-systems must continually learn and unlearn in order to maintain a dynamic, flexible balance between order and disorder, to enable organizations to dynamically synchronize various phases, activities, and value orientations within the knowledge development process.

In summary, it is not certain that uncertainty is best managed by rigorous planning, i.e. staying in control over all potential situations. Rather, uncertainty can be managed by providing actors with tools and a capacity to handle uncertainty in real-time and, by doing so, to stay in control in most possible situations.

The Notion of Soft Specifications

As organizational settings performing complex product development are subject to increasing environmental turbulence and more complex technology, the greater the need becomes for differentiation and specialization within different knowledge domains. The need for requisite variety in knowledge work is critical. The effective utilization of professional expertise in knowledge work systems, when and where it is most required, also demands an extraordinarily high level of organizational flexibility. This endeavor has been resolved, in the approach based on *planning*, by clearly specified and independent assignments with clearly defined borders to other tasks and groups of actors. In the approach based on *integration-driven development*, by defining functional chains and critical interdependencies and allocating a small number of key actors to management of the whole; and, finally, in the approach based on *dynamic synchronization*, by making most actors responsible for both interdependencies and the wholeness. In the latter two approaches, distinct borders have been replaced by softer boundaries where project phases tasks and sub-systems overlap and in some cases emerge. In knowledge-based work, the flow of knowledge is highly uncertain and unit boundaries are often unclear. Multi-skilling is not a viable alternative, considering the extensive learning required to master individual specialist competencies. The multi-skilling in routine work may be replaced by multi-phasing in knowledge work, in which highly differentiated technical groups plan and solve problems in parallel. The groups together engage in creating and reaching agreement on a set of shared criteria, which allows their members to interpret and implement procedures for coordinating action across functional lines. This even reduces possible tendencies toward sub-optimization by helping to focus commitment on joint product goals. Different actors think about the work of designing in different ways, neither fully sharing the same representation of the design process, nor of the product that is being designed. Sometimes they work alone, within their own object worlds, and sometimes they participate in collective efforts in formal or informal groups. Designing becomes a social process, where the participants negotiate their different interests and, hopefully, agree on the final design of the product. Coordination between participants in different functions becomes crucial if a focus on integration and wholeness is to be possible. The approach based on *dynamic synchronization* has solved this problem with the rule that each team must work in at least two sub-systems and that each sub-system must have at least two teams engaged in it. This has proved to get actors involved in the whole system. Hence, based on the reasoning that to understand two or more sub-systems, it is better to understand the whole system.

To sum up, it is not certain that effectiveness is best reached by minimizing dependencies between work packages and work groups; rather, effectiveness can be reached by early integration and a continuous focus on the total system.

Managing Complexity by Providing Wholenesses

It is clear that different actors' perceptions of complexities and performance have an impact on the organization's propensity and capacity for organizational learning and renewal. The differences in necessary learning and renewal concern type, content and prerequisites, depending on what complexity actors meet in different organizational settings. Actors in organizational settings applying the approach based on *planning* have traditionally tried to reduce and handle complexity by breaking down the envisaged product into sub-systems and components that are as independent as possible, so as to set aside directed resources for the respective sub-systems and components. The basic idea is to create clean borders between the parts and to minimize the coordination need so that these can optimize their own time plans, resource usage and technological decisions. The problem has often been that these clean interfaces could not be created and the strategy has only delayed necessary interaction, and in several cases has created extra work through considerable rework. In numerous cases, the interaction between the parts is more important for the system's properties than are the individual parts' own properties. Both emerging approaches have instead focused on integration and on providing actors with wholenesses. One result of this change in perspective is that actors (a small number of key actors in the approach based on *integration-driven development*, and a large number of actors in the approach based on *dynamic synchronization*) build an ability to alternate between the whole and the parts. Hence, that these (the whole and the parts) are perceived as emerging in parallel rather than having the whole follow the parts. In summary, it is not certain that complexity is best managed by breaking it down into its pieces; rather, complexity can be managed by providing all actors with the total complexity and giving them a wholeness.

Managing Renewal and Learning as an Integrated Task

Specialists in organizations separated from the product development projects traditionally manage renewal and learning. In the two emerging approaches, these activities instead have been integrated into the project work. The leverage in doing so has proved to be the organizational ability to identify learning and renewal needs – and learning and renewal conditions to match them with the use of the most effective learning and renewal mechanisms and tools.

In summary, it is not certain that specialists separated from actual work best manage renewal and learning; rather, renewal and learning can be managed as an integrated task in which most actors participate.

New Perspectives on Planning and Control

Actors in organizational settings applying the approach based on *planning* normally put a great deal of emphasis and energy into, and also rely on, rigorous planning before project execution. Then the main task of project management becomes that of monitoring progress and deviations in relation to plan. These deviations guide project management actions. In contrast to the identification and measurement of deviations from plans in routine work, these deviations are hidden in complex product development, mainly in the heads of the actors. Incorrect assumptions, mistakes, misinformation and misunderstandings are regarded as natural elements of activities such as product development, and may even be difficult to identify in retrospect. In fact, several authors have come to question the relevance of the production concept of variance and deviations in the context of knowledge work, as there is no norm, modal case or average from which the deviations can be identified (Purser&Pasmore 1992 and Taylor&Felten 1993). The former authors also point out that knowledge work is embedded in open systems that are in a state of disequilibrium and can often entail the conduct of experiments that aim to introduce uncertainty in the system. The two emerging approaches use other tools and means for planning and control. The traditional project planning is reduced in emphasis and is instead supplemented by a *product anatomy* and an *I&V Plan* that guides action. Integration, testing and verification of actual functionality replace the traditional quantitative control of input measures such as man-hours, lines of code and number of functions. In the approach based on *integration-driven development*, project management actions based on deviations from plans are reduced in emphasis and supplemented by proactive work and active presence in troublesome interfaces by a number of key actors. In the approach based on *dynamic synchronization*, project management actively engages a large number of actors in taking collective responsibility for interdependencies and progress, with attention focused on interpretative routines and sensemaking procedures.

In summary, it is not certain that complex product development projects are best managed by minimizing deviations from plans, avoiding potential risks and focusing on set targets; rather, complex product development projects may be best managed by continuously updating plans to emerging prerequisites, capturing opportunities and focusing on emerging targets.

Theoretical Implications – Toward a Paradigm Shift in how to Manage Complex Product Development

The organizational settings analyzed and approaches illustrated above point to a number of important theoretical implications, as the principal ones from a more practical perspective noted in the preceding section. Although it is premature to state that the present analysis of organizational settings and applied approaches suggest a new theoretical paradigm, there are ingredients that contradict prevalent theory and weigh in favor of an alternative, more practice-centered paradigm. Hence, the use of the term *"paradigm shift"* can be justified when compiling findings from the cases that are directly opposed to prevalent theory. The analysis and discussions above and illustrated alternative approaches based on fundamentally different basic assumptions indicate at least four important aspects that must lead us to reconsider the prevalent theoretical paradigm for understanding complex product development.

The Static Organizations being Replaced by Dynamic Organizing

Static structures and procedures in both emerging approaches were successfully replaced by a more dynamic structure – intentionally adaptive, limited only by final project goal and defined product specifications. Hence, replacing strong beliefs in design theory with beliefs in action and a capacity to take into account experience gained from action. Both emerging approaches also consider the technology and the organization to be integrated, i.e. managing both product and project configuration as an integrated process. This mutual adaptation of technology and organizations has been termed organizing by Leonard-Barton (1988):

> *"...the re-invention of the technology and the simultaneous adaptation of the organization..." [Leonard-Barton 1988, p. 253]*

It is further elaborated by Lundqvist (1996), among others:

> *"...The basic idea is that organizing product development is an ongoing process of defining, assigning and controlling tasks in a dynamic temporary work system that eventually yields a new product..." [Lundqvist 1996, p. 19]*

The approach based on *dynamic synchronization* as it is applied by *Japanese Subsystems* takes the concept of dynamic organizing one step further by its use of sensemaking primarily based on action and reflection upon action. By using action and results from action as a guiding principle for the sensemaking and an ideal based on *"what is working is true, and therefore useful knowledge"* the process of self-organizing become both fast, flexible and not captured by its previous solutions.

Replacing a Striving for Separation with a Striving for Integration

Both the approach based on *integration-driven development* and the approach based on *dynamic synchronization* define functional chains that support the process of integration, rather than separation, as the traditional product structure. The traditional striving for separation is clearly replaced by a striving for integration in the two emerging approaches. This gives actors, in the organizational settings applying these approaches, an opportunity but also an imperative to relate to the project's other parts.

Integration becomes a stronger and more developed way of co-ordinating by distributing responsibility for both interfaces and the different sub-systems and by engaging actors from the different sub-systems into a common creation of knowledge and not only an exchange of information.

Rigorous Planning being Replaced by Building Organizational Capacity

Very early on, Marshall and Meckling (1962) stressed the difficulty of planning in the "*right*" way from the beginning. Rhenman (1969) showed that procedures for strategic planning lower the ability to notice and handle strategic problems. Pearson (1983) demonstrated, after studying 10 years of research in the management of product development, that gifted indicators and regular evaluation instruments become ever more important for allowing continuous re-planning and re-evaluation of plans. Blomberg (1998) showed that project management, in the sense it is seen in the dominant literature, inhibits the inclination to change. Blomberg (1998) also showed that successful projects are often relatively unplanned, while failed projects are often extremely well planned. Despite a series of contributions like this, as chapters 2 and 7 show, the dominant way of managing complex product development is still based on planning.

The logic of embracing uncertainty as a means of stimulating integrative dialogue is in direct opposition to the traditional information-processing view that redundancy and uncertainty should be reduced as much as possible beforehand by planning. The hands-off logic for project management in the approach based on *dynamic synchronization* is directly opposed to the prevalent idea of managers (such as *"heavyweight"* project managers) being extensively involved in daily coordination activities. It is also important to note, however, that evidence from the cases contains aspects that are less controversial to the dominant theory and dominant basic assumptions. One such aspect is the relatively centralized product and project configuration procedure used in the approach based on *integration-driven development*, which complies more with the dominant theory favoring reduction of uncertainty beforehand and is a new form of rigorous planning. Regarding this aspect, the approach based on *integration-driven development* might be seen as a hybrid between the new and the old paradigms.

Managing and Monitoring Project Progress

The dominant way of following up project progress is to focus on input measures and sub-systems' progress, while in the emerging approaches one takes account of the interdependencies and dependencies between sub-systems in judging progress by focusing on output. Integration is seen in the dominant model as unproblematic, given stable (and properly defined) sub-systems, whereas actors in the emerging approaches see it as impossible to define these sub-systems properly.

This chapter has provided a number of arguments that together clearly show that the two emerging approaches represent actual alternatives to the prevalent way of managing complex product development that are based on fundamentally different basic assumptions. The potential strengths of these two alternative approaches that are presented clearly motivate the notion that the prevalent theories and assumptions behind them are being revisited and reconsidered to meet emerging business conditions. The next part of the thesis will revisit the analysis performed and the findings presented in this thesis and sketch out a number of important implications.

SUMMARY OF PART III – THE DOMINANT APPROACH IN COMPARISON TO NEW APPROACHES FOR MANAGING COMPLEX PRODUCT DEVELOPMENT

The approach based on *planning* was given its name to illustrate its principal characteristic – strong focuses on project planning prior to project execution and on monitoring fulfillment of and deviations from those plans. Plans are used as the central framework around which the projects are organized and managed. The approach based on *integration-driven development* was given its name to illustrate its principal characteristic – a strong focus on system integration. System integration is used as the vehicle for project progress and functionality growth. The approach based on *dynamic synchronization* was so called to illustrate two principal characteristics – dynamic and synchronization. "*Dynamic*" captures the ability of projects applying the approach to make fast adjustments to new prerequisites. "*Synchronization*" captures the ability of projects applying the approach to refocus all actors towards a new situation, maintaining high convergence and transparency through sensemaking based on action, reflection upon action and short feedback loops.

Major differences between the three approaches are:

- in the emerging approaches, products are built up instead of broken down;
- in the approach based on *dynamic synchronization*, projects are organized by building dependencies instead of minimizing them;

- there are few key actors in the approach based on *integration-driven development*;
- most actors in the approach based on *dynamic synchronization* are exposed to full complexity and are fully responsible for all tasks;
- in the emerging approaches, system integration is performed early or continuously and interdependencies are seen as an engine for renewal. Progress control is based on actual functionality tests and/or actors' subjective opinions, project management works proactively and rapidly in real- time, actors perceive complexity as less troublesome and, finally, the emerging approaches are superior in meeting set and emerging targets.

The analysis of the three approaches clearly shows two alternative emerging approaches that make projects equally or more manageable, successfully alter rigorous planning for a capacity to handle situations in real time and successfully manage complexity by providing actors with wholenesses. These alternative approaches also increase speed by integrating, manage learning and renewal by integrating it into actual work and distribute more authority to the project organization.

There are, however, a number of important contingencies in applying the different approaches, such as the organizational settings themselves: product characteristics, coordination need, and how familiar the product is. Changes from one approach to another are presented as dependent on the perceived need among actors in each organizational setting, how well known each approach is, and where principal authority resides in the organization. The sustainability and dispersion of the emerging approaches are dependent on actual performance and how well each approach can be articulated and described.

PART IV – CRITICAL REVIEW OF THE EMERGING PATTERN

"...the theorist's task is to make the most of his insights by developing them into systematic theory. His sociological perspective is never finished, not even when he writes the last line of his monograph – not even after he publishes it, since thereafter he often finds himself elaborating and amending his theory, knowing more how than when the research was formally concluded." [Glaser&Strauss 1967, p. 256]

THIS PART of the thesis will, at the inspiration of Glaser and Strauss, recapitulate basic ideas and examine some of the preconditions for them. It will also critically analyze the results presented in earlier chapters and bring these into relation to experience from other parallel studies, analyze their validity and reliability and discuss possible generalizations. This part will also evaluate whether the questions asked have been answered and evaluate the experiment on table tennis research, its research design, data collection, analysis and validation. A discussion of the shifts in approaches and a potential paradigm shift will also be included. Finally, implications for managing complex product development, for theories on managing complex product development and for further research will be presented.

CHAPTER ELEVEN

Theoretical and Practical Implications

This chapter recapitulates the basic ideas in the thesis, critically discusses how well the questions asked have been answered and analyzes what is new and how this differs from the prevalent domains of knowledge sketched out in chapter 2. The purpose of the chapter is to present theoretical and practical implications from the findings.

Have the Purpose been Achieved?

Chapter 3 described the purpose and the goal of this thesis, the strategy for achieving this purpose and a number of questions were formulated to guide the search for a better understanding of the process of managing complex product development. This section revisits that purpose and those questions, provides examples from the thesis on the actual answers and discusses whether and where they have been met and/or answered in the thesis.

The Overall Purpose and the Focus of the Study

The main purpose of the study was formulated on page 144 as:

> *"...to suggest an alternative theoretical foundation and a new conceptualization of managing complex product development that can guide further practical and theoretical development of the emerging approaches."*

This purpose will then, according to chapter 3, be fulfilled by exploring how new and successful approaches have been developed and applied, and to compare them with the dominant approach. An *experimental research approach* will be used to enlarging the known area for actors in the organizational settings and for researchers in the domain. The principal findings are that the new approaches differ substantially from the dominant one based on *planning*; especially important are differences in basic assumptions as to where each approach is derived. The differences found concern how products and projects are configurated, the transparency and the convergence within them.

This main purpose is in focus in chapters 7-10. Hence, the thesis explores how the two new approaches have been developed and applied, compares this with the dominant approach, and both discusses and introduces alternative theoretical foundations and conceptualizations in order to better explain differences in performance between organizational settings applying different approaches.

Two (so far successful) alternative approaches in question are introduced with fundamentally different basic assumptions. The important differences are such as *early system integration is necessary to accomplish speed and a continuous functionality growth, complexity is best managed by providing actors with the full picture* and *uncertainty is best managed by building a capacity to handle most situations in real-time.*

This main purpose was developed through five distinct research questions that are recapitulated and discussed below.

> *How did the high-performing organizational settings actually cope with the challenges, and how did this differ from the dominant approach for managing complex product development at the firm and elsewhere?*

In summary, new perspectives, guiding principles and actual models derived from fundamentally new basic assumptions have been applied by the two high-performing settings. The approach based on *integration-driven development* configurate products and projects according to built-up principles and to facilitating system integration, allocating specialized resources to work with troublesome interfaces, controlling progress by step-wise functionality growth and building real-time support for integration such as the system emergency board. The approach based on *dynamic synchronization* builds dependencies to facilitate the distribution of responsibility and systems thinking, using action and reflection upon action to guide the process of sensemaking and managing complexity by providing actors with the full picture.

Why does performance in the high-performing organizational settings repeatedly differ from performance in organizational settings applying the dominant approach?

In summary, the approaches applied by the high-performing organizational settings better reflect the current business conditions by providing a continuous overview of actual project progress, speed by early integration and reconsidered product and project configuration. In the approach based on *dynamic synchronization*, flexibility was achieved through sensemaking based on action and by integrating the process of organizational learning with performing actual work.

What are the enabling factors giving rise to the new approaches in the present cases, and what disabling factors threaten their sustainability and dispersion?

In short, sustainability and dispersion are enabled by close and demanding customer interaction, system focus, improvement activities integrated in ordinary work and timing. Sustainability is primarily disabled by lack of actual depicted frameworks and development models, distributed resources, insufficient knowledge about each approach and existing decision and authority structures.

To what extent are the dominant theories insufficient in explaining repeatedly successful behavior in the organizational settings applying any of the emerging approaches?

Some of the fundamental assumptions behind the dominant theories are outdated. For example that *complexity* is best managed (reduced) by breaking it down into its pieces and making these pieces as independent from each others as possible. That *uncertainty* is best managed (reduced) by rigorous planning before execution. Or that *control* is best gained by following up deviations from plans and hierarchical co-ordination.

What new operational and actionable organizing concepts and models can be proposed from studies and analysis of organizational settings applying the emerging approaches, and how can these patterns be interpreted as emerging paradigms as well as made more general?

The thesis presents a number of operational and actionable organizing concepts and models. The approach based on *integration-driven development* clearly shows the potential in using *"system integration"* as an engine for project progress, the *"product anatomy"* and *"integration and verification plan"* as important maps guiding action and new effective mechanisms for real-time co-ordination as the *"system emergency board"*. The approach based on *dynamic synchronization* clearly shows the potential benefits in *"building dependencies"* to enforce co-ordination and integration, to distribute responsibility and to develop resources. This approach also clearly shows the potential benefits in *"sensemaking based on action and reflection upon action"* to make real-time adjustments and redesigns based on new prerequisites, related to changes in customer preferences or technological development.

What is New?

The most important contribution is to introduce, operationalize and analyze actual alternative approaches on how to manage complex product development that reach beyond variants on the existing knowledge and are based on new basic assumptions fundamentally different from the Fayolian ones based on administrative command and control.

The Emergence of new Approaches based on Fundamentally New Basic Assumptions

The analysis and discussions above show that new approaches focusing on the dynamics of *interactive knowledge creation* are gaining a foothold. One of the fundamental assumptions in these emerging approaches is that *the operation of development work must, to a great extent, be self-organizing in order to avoid the creation of unnecessary barriers to* *learning and adaptability.* The concept of self-organizing contains a potentially powerful motivating force for the individual, in that each person becomes a guardian of the whole. The concept of self-organizing also captures the ability to handle changes in prerequisites in real-time as opposed to the restrictions introduced by relying on rigorous planning in beforehand.

How easily the approach based on *integration-driven development* or *dynamic synchronization* can be diffused to and developed in other organizations, and how sustainable the approaches will prove to be, remain to be seen. Early experiences from diffusing the two new approaches clearly points out the necessity of basing operative work practices and actual models for organizing in the set of perspectives and principles behind them, as well as in the basic assumptions from which they have been derived. One early example of the application of the approach based on *integration-driven development* in a setting where basic assumptions from the approach based on *planning* still resides shows clearly how the full potential of the approach is lost. Another early example from trying to capture the approach based on *dynamic synchronization* into a process map clearly shows the difficulties in describing the new approaches by traditional means. One of the key actors made the following judgement of the attempt:

> *"The process map that was sent to me and was supposed to illustrate our way of working had really missed its purpose. In the description every-thing seemed to be most important except for what was really important." [Senior Manager, Japanese Subsystems]*

However, the empirical examples illustrated above ought to inspire research and practice to explore new perspectives, principles and models for organizing and ought to provide the courage to abandon old dysfunctional management perspectives, principles and models for organizing.

New Strategies for Product and Project Configuration

As shown above, the challenges and new demands facing the organizational settings that have introduced the new approaches were met mainly through radically rethinking the processes of configurating both products and processes. The changes was not only in how products and projects were considered at a meta level but also in how management were implemented, in how power was distributed and in how work was actually organized. Left with practically no good examples elsewhere, the two settings established their own perspectives on and principles for product and project configuration, which in many respects have become negations of existing practices. While not practicing the full potential of the new approaches, the present examples with their extraordinary success contain strong empirical evidence for the benefits of new perspectives.

The analysis above of the three different approaches showed that is not only the early phases in a project that defines prerequisites, it is rather the actual *"mind-set"* applied by actors in these early phases. Hence, the set of perspectives, guiding principles and actual models for organizing derived from the basic assumption both enables and limits performance in complex product development.

New Perspectives on and Principles for Managing Perceived Complexity and Uncertainty

The cases illustrated above clearly show that the dominant and traditional way to manage complexity will be counterproductive in many cases of performing complex product development. Hence, breaking down the full complexity into pieces and providing different groups of actors with only the *"necessary"* amount of complexity to create manageable organizational units and tasks are not a sufficient way. The two emerging approaches both show the potential benefits in providing actors with the full complexity and with the means for handling it. The experience from these applications provides strong support for the formulation of an alternative basic assumption, i.e. that the exposure of actors to the full complexity actually decreases the perceived complexity.

Focus on Transparency and Convergence

The analysis points to the value of high transparency and high convergence when performing complex product development. The study has shown that the two concepts could be vital focuses to be taken into consideration in both product and project configuration.

New Perspectives and Strategies for Project Progress and Progress Control

The analysis of the cases clearly demonstrates that the dominant and traditional way to perceive and control progress is not sufficient or relevant. Progress in sub-systems is not a sufficient indicator of progress at the system level in complex product development. Neither is progress in terms of any input variable such as man-hours or lines of code a sufficient (or in some cases even relevant) indicator of progress at a system or sub-system level. However, the emerging approaches have demonstrated that integrated and tested actual functionality growth is a sufficient (and relevant) indicator of progress in performing complex product development.

Interdependencies and System Integration in Focus

The settings applying the dominant approach with a focus on sub-systems systematically underestimate the integration endeavor and seldom meet set or emerging targets or renew their perspectives on products or processes. The settings applying any of the two emerging approaches build their work around the need for early and frequent or continuous system integration and also devote a great deal of energy and resources not only to defining interdependencies before execution but also to managing interdependencies in real- time.

Building Organizational Flexibility through Enforced Coordination

The analysis of the setting applying the approach based on *dynamic synchronization* clearly shows the dynamic consequences of consciously building interdependencies between actors and groups of actors and by forcing increased coordination. Highly interdependent actors build a high coordination capacity to cope with their intense coordination need, and this coordination capacity (based on high transparency and convergence) then supports organizational flexibility and the capacity to handle changes in prerequisites in real-time.

Introducing Table tennis Research

This thesis and the ten research projects on which it is based have all been conducted by using and experimenting with a number of research methods that, in retrospect, constitute a new way of performing research within this domain. Several aspects of my work distinguish it from traditional research and earlier methods introduced to cope with the challenge of performing applied research together with practitioners. First, the research is conducted in close cooperation with the studied organizational settings – based not only on involving practitioners in defining issues or areas for research, but rather on engaging actors from the organizational settings in data collection, analysis and validation. Secondly, the research is based on an effort to expose both the academicians and the practitioners to each other's full complexity. Finally, and most significantly, this research is performed to build knowledge for action, i.e. knowledge that is useful in guiding actors in how to manage complex product development.

Summing Up

To fully examine the relevance and the impact of the results, there is a need for more research on this focus and on performing research in this way. The illustrations, discussions and analysis performed in the thesis, and the introduction of early pieces of some new dimensions, will hopefully motivate readers to further elaborate on new approaches for how to manage complex product development. The research approach and the early experiences from this will also hopefully motivate readers to further elaborate on new approaches for how to perform applied research in close cooperation with the organizational settings under study.

How were the Emerging Approaches Found and Formulated?

My thesis project started with a notion of the importance of product development for competitiveness in knowledge-based firms and successively facing the multidimensional complexity that a company such as Ericsson must master to successfully manage and organize product development. From the beginning, no specific nomenclature or model for investigation was used; rather, my thesis work became a part of working in different research projects with different focuses and scopes. The initial purpose was to increase understanding of how to manage complex product development. The first research project clearly showed insufficient performance in most settings performing complex product development, but it also showed great differences in performance between settings. Each research project found new aspects of the differences in performance and between ways of managing complex product development. However, the differences were not easy to understand or explain by using the dominant literature on managing complex product development. The actual process of managing complex product development appeared more complicated than described by the literature. Over time, with an increasing understanding of the domain of complex product development and experience from different ways of handling the endeavor, a frame of reference emerged to structure impressions, observations and notions.

The integrated map of three different approaches on how to manage complex product development was not clear to me until a number of research projects had been finished, and this raises important questions. Would another set of organizational settings lead to the identification of another set of approaches? Would a study of a further seven organizational settings lead to the identification of three more approaches? Do the different approaches represent a natural development in the organization's maturity in how to manage complex product development, or do they represent different solutions to different problems?

The first question is not only directed towards the validity of the three approaches; it also touches on aspects of generalization, i.e. whether the approaches are relevant for actors in other settings than the ones studied. My conclusion is that the approaches are not company or even industry-specific. The relevance of the approaches is connected rather to the complexity of the task to be performed. This conclusion is mainly based on a number of workshops held with actors from other companies (e.g. Astra, Enator, TeleNordia, Telia and Volvo) and industries (e.g. cars, telecom operators, IT consultants and pharmaceuticals) discussing the relevance of my research for their companies. However, my findings also fit with recent and ongoing work among a number of other researchers (see for example Iansiti 1998, MacCormack 1998, Staudenmayer 1999 and Dougherty 1999).

To fully answer the second question, a new study is required. However, theoretically, it is difficult to imagine a large number of approaches that differ in fundamental assumptions about the important subsets of managing complex product development.

The third question addresses the issue of movements and also exchangeability between the approaches. My impression is that there is no clear or natural development from one approach to another – it is rather the case that different competitive settings and customer-specific demands shape prerequisites for each approach. A tentative conclusion is that the dominant approach based on *planning* is developed to cope with the competitive settings and customer-specific demands that, at least in an Ericsson context, represent yesterday's conditions. A number of key actors from different parts of Ericsson sketched out a simple picture (see Figure 11.1) to illustrate changes in their prerequisites in one of the workshops underlying this thesis. All actors present at the meeting agreed that this was a valid depiction, underscoring that much of the content also had to be delivered in the agreed short time. And also, that the dominant approach was better suited to the old conditions while the two emerging approaches are better suited to the new ones.

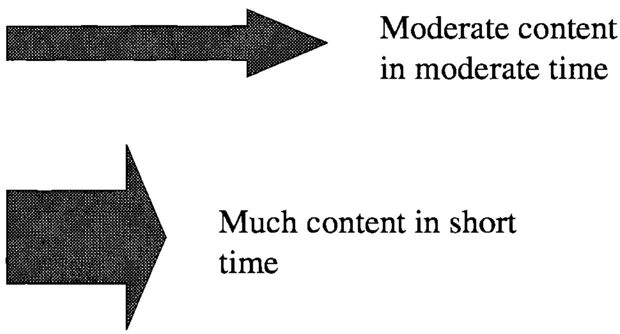


Figure 11.1. From moderate content in moderate time to much content in short time

Table tennis Research – Revisiting Some Actual Events

The experimental research approach, called *table tennis research*, was originally applied primarily to expose the researcher(s) to the full complexity that the practitioner(s) in the organizational settings face and to expose practitioner(s) to the full potential of performing research. This is brought about by letting practitioners participate in all phases and activities in the research process and letting researchers to actively participate in important processes and activities in the companies. The purpose was to increase the possibilities of understanding the deep structures in each organizational setting, to open up to a real-time combination of perspectives normally not held at the same time, exploring the subject from a number of perspectives and to continuously protect and develop validity in findings. This section will briefly revisit a number of actual events in the research projects in this thesis to consider the contribution of table tennis research.

In one of the research projects, both the researchers and the practitioners had defined capturing and understanding the actual co-ordination mechanisms in use in *Japanese Systems* as both a red and hot issue. One of the researchers had earlier experience of using questionnaires for depicting communication patterns introduced by Krackhardt (1993) and further developed by Hörte (1995) and presented a possible research design using this technique. Some of the practitioners pointed out that there was something missing in the result that would have been possible to gain. Hence, the technique gave a fair picture of the communication pattern but not of the communication content and, according to all participating practitioners, the pattern without its content would not help them. The questionnaires were then jointly developed and tested to capture communication pattern and content. The technique was applied at *Japanese Systems*, leading to a series of workshops that discussed the results and made them actionable. One important result was the development of the *co-ordination banana* that was then used by practitioners to illustrate a specific type of dependence. This new technique and research design has then been used in a number of subsequent research projects.

In another project the researchers together with a small number of practitioners depicted the total organization responsible for performing complex product development by using significant groups of actors, their interdependencies, their formal responsibilities and the activities and decisions in which they were engaged. The full map was then depicted on an overhead and termed *"the organizational anatomy"*. This organizational anatomy was presented to the management team, who recognized the pattern for each group of actors but was very surprised by the total picture and its full complexity. The most senior manager expressed his reaction as:

> *"It was exactly this that we wanted, but we never imagined it would turn out to be that complex" [Senior Manager, Large Switches]*

By analyzing each group of actors, each perspective and each type of decision by itself, this emerging organization - from a system perspective

- was full of contradictions and impossible to manage. On the basis of this presentation by the researcher, a number of change activities were started and this work gave both the researchers and the practitioners insight into the limitations of the dominant basic assumption that complexity is best managed by breaking it down into its pieces.

A third example is in one of the research projects when the researchers and the practitioners first captured the project configuration at *Japanese Subsystems*, where each team was working in at least two sub-systems and each sub-system had at least two teams working in it. All were convinced that this was one of the worst project configurations they ever had seen. After a number of workshops and gaining a better understanding of the whole set of perspectives, guiding principles and actual models for organizing, a more sophisticated picture emerged. In this picture it was evident to both researchers and practitioners that this configuration was necessary to make the approach work and to meet the requirements that the product development projects faced.

These are only three examples from the large set of close interactions between perspectives and between action and reflection that have constituted the foundation for the findings in this thesis. Despite large and complex endeavors in opposing perspectives meeting each-others' full complexity and endless discussions, table tennis research has made the findings what they are, developed by me as a researcher and meeting the initial expectations for the experimental research approach.

An Analysis of Results Found and Research Performed

This thesis presents two alternative approaches on how to manage complex product development which are unlike the dominant approach and it also uses a research method that includes new elements and is based on new assumptions. However, these results raise questions about both the validity and generalizability of the results found and about the reliability of the research performed.

Validity of the Results Found

The validity of the results found has mainly been secured by continuous and rigorous interaction and tests in the organizational settings where research was performed. The large number of applied research methods and the large number of workshops (63 workshops during a five-year period) for the purpose of analyzing and developing preliminary results constitute an important foundation for validity of the results found in the thesis. This is further strengthened by the continuous movement from being a part of the activities performed in each organizational setting to being an analytical observer comparing different organizational settings. However, it is justified to discuss a number of issues relating to the validity of the results.

First, if I were to do the same study once again, would I use the same research design? One important aspect of this study is that it has not been one integrated project with one focus; it has been a part of ten different research projects with different purposes. Each project has initially had an important role in shaping this study and my model for investigation, and where each project in the late phases has been shaped largely by my studies' focus and my emerging model for investigation. One important effect of this process has been low resource effectiveness, where over 243 interviews, 63 workshops and over 1000 respondents were involved in producing the results presented. Another effect has been a highly complex process in comparing and analyzing data collected for different purposes and with differences in the maturity of the model for investigation. A third effect has been that it takes time. The empirical phase of the project stretched over a five-year period, and time – rather than other important aspects – has played an important role in delimiting the study. A fourth effect has been that the organizational settings have not been chosen according to a distinct focus. The criteria for selection have rather emerged during research projects and the maturing of the model for investigation, and finally were limited by time. However, this multi-project and multi-method study has facilitated a firm and deep understanding of the full intricacy of managing complex product development and has opened a path for successively redefining the aim, purpose and focus of the study towards greater refinement. This multi-project process has also trained me as a researcher in identifying, maintaining, continuously developing and believing in a research focus despite other parallel demands, focuses and discussions. The multi-method design has trained me as a researcher in using different methods, evaluating their respective contributions and analyzing their results in relation to each other. Hence, as an apprentice preparing for my apprenticeship test, I have found this process very valuable and would not want to have designed it in another way. As a potential researcher in the field of management of technology, I have acquired perspectives and insight from this journey into the area of managing complex product development that would be difficult to obtain in any other way. However, as a customer or orderer of my thesis as an integrated study, I would have designed the study differently so as to decrease noise and shorten lead-time.

Secondly, does this thesis meet reasonable demands on presentation in order to give the reader sufficient insight into the researcher's interpretations and the concepts' plausibility? The presentations in the thesis are based on two principal strategies: integrated approaches that are compared to show differences and the use of quotations to illustrate the characteristics of each scenario. To provide a substantial contribution toward understanding, the assumptions that have guided the constructions in this thesis are that they must be both accurate and comprehensive. It is also of vital importance that they are typical, i.e. that patterns in the empirical data clearly seem on first consideration to belong to a certain type. If the differences discussed are to provide a substantial contribution toward understanding, the greatest differences ought to be highlighted and focused upon, rather than representing all differences and similarities equally. To build confidence into the patterns, comparisons and research results presented, it is important to show the coherence between empirical observations, descriptions and analyses performed. To master these endeavors, the ideal types and the relevance of the dimensions under comparison have been rigorously tested with a large number of actors from the organizational settings under study, and quotations have been selectively chosen to illustrate relevant aspects of the differences between approaches.

Thirdly, when using a multi-method and multi-project approach, how are data made comparable and analyzable? One important risk when comparing data from different research methods and research projects is that it is difficult to find points of comparison and systematic ways to comprehend a whole set of data when searching for patterns. I have deliberately chosen not to use any support or expert system in finding these patterns, but have used only white paper, whiteboard and, most importantly, continuous discussion with actors from the studied organizational settings. Once the model for investigation and its inherent variables have become clear, the empirical data have successively been integrated into a set of comparisons. An important question to raise in this context is how dependent the results are on the variables and dimensions selected to sort out the data. My belief is that the use of a system perspective and, when possible, actual tests of the validity of the different preliminary results has reduced this dependency on the single formulated variables and dimensions to the benefit of the integrated set of variables and dimensions. A number of research colleagues and practitioners have also continuously helped by offering further perspectives on the findings that emerged.

Finally, is short-term project performance a relevant dependent variable for analyzing each approach? The thesis argues for the potential superiority of two new and emerging approaches for how to manage complex product development. One of the important arguments for this potential superiority is to show performance gains. Using project performance in terms of lead-time, cost and performance as indicators for success and explaining different approaches' applicability for today's business conditions have their weaknesses. There are stories about projects that do not meet set targets but turn out to result in long-term cash-cows, and there are certainly examples of projects that meet set targets but do not pay back invested resources. However, from a company's perspective and in relation to its customers, it is imperative that most projects meet or nearly meet set targets and deliver what was once agreed upon (or became agreed upon). Hence, that projects are finished within the time frame that was once agreed upon (or became agreed upon) at the same (or lower) cost that was once agreed upon (or became agreed upon). Hence, from a single-project perspective, meeting set and/or emerging targets may prove to be of less relevance than the total impact of the results from the project. However, from a company's perspective, meeting set and/or emerging targets is the challenge that must be met in order to cope with global competition.

Generalizability of the Results Found

Development-intensive companies in the telecommunications field, such as Ericsson, face a number of difficult – and in several cases, very different – requirements. Competition calls for large investments in development, and development work is becoming an ever more important type of work involving many people. Process efficiency to handle and reduce costs becomes paramount, placing demands on structured and measurable processes. At the same time, the telecommunications field is confronting great changes such as deregulation, new customer groups, more software-based systems, increasingly complex technology, and demands for joint development across organizational boundaries. These requirements have together fostered complex organizations where most of the refinement occurs in various types of time-limited development projects. Such projects must create conditions for efficiency in their current work, as well as organizational learning between project generations and parallel projects, so as to maintain the organization's competitiveness.

Most parts of the Ericsson company compete on a global market with global resources. New product structures (larger and more reciprocal interdependent systems with high demands on modularization and flexibility), in addition to new customer requirements (higher degrees of customer and market adaptation, greater time focus in regard to throughput time and delivery assurance, as well as high demands on flexibility), add competition and have brought forth "new" complex forms of organization (knowledge-based, organic, time-limited, laterally coordinated, under constant change with geographically spread competence centers having several seats of power and impulses of control). These *"new"* forms are led and coordinated with tools based on theories of organization that build upon studies and analyses of "old" organizational forms, which an external observer may at first perceive as meaning that a clear control over structures and processes is largely lacking. This picture is in agreement with similar descriptions of other old, large and successful companies given by such researchers as MacCormack (1998), Iansiti (1998) and Staudenmayer (1999).

Many parts of Ericsson are now in a situation of seeking and testing new methods and aids for managing and organizing complex development processes. Taken together, this makes the telecommunications industry a suitable environment for studying the management and organization of such processes.

As discussed earlier, I see the approaches' applicability outside the studied organizational settings as high. I base this assumption mainly on the reactions of actors performing complex product development in other settings, but also on the fact that the competitive conditions and characteristics sketched out above are not specific to Ericsson or the telecommunications industry.

Reliability of the Research Performed

The basic principles that have guided me in becoming a researcher have been (1) closeness to the organizational setting so as to be able to understand its full complexity, (2) engaging actors from the organizational setting in performing the research to enhance validity, (3) using multi-methods to enhance reliability and, when possible, (4) actually testing preliminary results to enhance applicability and usefulness. Because of these principles, I have spent much time working within the organizational settings under study and, during some periods, have worked more together with actors from those settings than with my research colleagues. The principles have also resulted in a study based on longitudinal analysis of a few cases rather than a cross-section of a large number of cases. However, I have continuously used research colleagues to give more and new perspectives on the emerging findings. By being a part of more than one research organization I have had the opportunity to face my findings with a different set of research ideals.

Research performed in this way has its upside and its downside. The researcher comes close to the data and their context but is normally seen as becoming a part of the empirical findings and losing objectivity. This risk has primarily been avoided by applying a number of different perspectives and continuously testing and discussing the findings that emerged with research colleagues from a number of research settings. Through a long-term perspective, patterns and outcomes can be obtained which are sums of individual decisions and actions, and intensive case studies over longer periods of time can reveal more stable effects and phenomena so as to construct ideal types that allow a more basic understanding of the topic investigated. As for objectivity and the traditional effort to maintain a distance from the studied phenomena, it is not certain that greater distance (see for example discussions by Argyris 1993) than what is acquired by transforming actual observations into patterns, models and ideal types would be helpful in gaining a better understanding of the domain of complex product development.

Implications for Managing Complex Product Development

The analysis performed and results presented above have a number of implications for the process of managing complex product development.

First, different approaches for managing complex product development processes have a substantial impact on both short-term and long-term performance for the setting that applies them. These approaches must be adapted to the specific context in which they are used and not only blueprinted from best practices in different contexts. It has clearly been shown that it is not so much differences in operative work practices or actual models for organizing that it is differences in basic assumptions, perspectives and guiding principles that make a difference.

Secondly, the choice is not so much *"either-or"* as *"both-and"*. It is not the case that the dominant perspectives, principles and models in use are all insufficient and no longer useful in any context. However, new perspectives, principles and actual models for organizing must be considered in order to provide actors with more powerful tools to master the process of managing complex product development. The conditions for performing complex product development have been and still are under transition. More and more projects face emerging prerequisites under which many important factors for the final result are unknown at the start. The preconditions under which the approach based on *planning* has its origin and is shown to work best - stable, predictable and primarily internally driven targets - are becoming less and less common. Hence, the approach based on *planning* may have made its most important contributions in developing the area of complex product development and ought to be replaced by new approaches based on basic assumptions that agree with emerging business conditions.

Implications for Project Management

The role of and the options for project management change with the approach applied. When applying the emerging approaches, product and project configuration becomes an issue and an important tool for project management in dealing with the prerequisites for performing the projects. Different strategies for product and project configuration have a direct effect on actors' capacity to integrate their work and to meet set and/or emerging targets. The results presented above also suggest that the role of planning techniques for project management ought to be reconsidered. Rigorous planning does not automatically reduce uncertainty and make projects more manageable. Therefore, project management must complement its toolbox, not only use different planning techniques to design an optimal project beforehand and use deviations from plans as guidelines for taking action. The results rather show the importance of project management in creating convergence and transparency in the project organization and among actors engaged in the project.

Implications for the Development of New Products and Processes

First, the results presented in this thesis demonstrate that the dominant strategy for managing the development of new products and processes is not the superior strategy in all contexts. Two alternative approaches are found to be superior to the dominant one in certain contexts. Hence, the implication for the development of new products and processes is that the dominant approach cannot be taken for granted as an effective strategy – rather the specific context must guide actors in choosing or developing a suitable approach, and a number of "truths" must be questioned. The results show that breaking products or organizations into their sub-systems and defining the sub-systems as independently of each other as possible do not always reduce complexity for actors or make the project more manageable. The results instead indicate the potential strength in building up the product in a stepwise manner and in deliberately building dependencies into the organization.

Secondly, if most value-added work is performed in project organizations, this is complicated when most authority still resides in the line organization. The results show the potential benefits in developing the degree of projectification and integrating main responsibility – both for meeting set targets and continuously developing work processes – into the organizations responsible for performing most value-added work.

Finally, the results demonstrate the potential danger in neglecting the dynamics of the development processes. The analysis of the three approaches above shows the potential gains in supporting actors in seizing emerging opportunities rather than minimizing deviations from an initial plan. When the development process is considered as a predictable and well-structured process of knowledge convergence, engineers – like craftsmen during the industrial revolution – are becoming de-skilled and their tasks are becoming more fragmented. However, if the development process is considered as an unpredictable and non-structured process of knowledge creation, they gain in autonomy and in the influence they have on their work situation and the products and processes at hand.

Implications for Building new Knowledge

First, to manage the knowledge-intensive and highly reciprocal interdependent work that characterizes complex product development, an important focus should be to create a capacity to handle the inherent dynamics, rather than providing tools for rigorous planning and tools for rigorous control and minimizing of deviations from plans. The results confirm and strengthen the message of earlier contributors (see for example Lundqvist 1996, Iansiti 1998 or Dougherty 1999) that managing complex product development is not only about effectively processing information; it is also about using knowledge that is being created in the process and seizing opportunities that emerge.

Secondly, high performance is in some cases contradictory to conditions for learning, and recent success tends to focus actors to learn within the same base of knowledge and decrease the inclination for learning that questions this base of knowledge. Hence, a recently successful organization may be less able to learn and renew its knowledge base than a less successful one. The results also clearly show that an inclination to learn is not a sufficient prerequisite for learning in an organization. Hence, the capacity to implement learning is also a vital part of the prerequisites.

Finally, the results demonstrate that most functionality is realized in the boundaries and in the interaction between different traditional sub-systems and disciplines. The results also show that major innovations in how to manage complex product development include reconsidering the character of the sub-systems and their boundaries. Hence, organizations must manage their knowledge from a system perspective that is not limited by definitions of sub-systems.

Implications for Building Competitiveness

First, effective management of overlapping between project phases is clearly much more than simply modifying the timing chart. Properly managed, even in the presence of numerous engineering changes, concurrency can simultaneously reduce lead-time and reduce the cost of engineering changes. However, to successfully apply the approach based on concurrency, it is not enough to change planning tools and techniques – actors must reconsider the fundamental assumptions behind the perspectives, principles and actual models for organizing that control behavior.

Secondly, the results and discussions above demonstrate that the single project is not a sufficient unit of analysis. To fully analyze and evaluate a specific approach, a series of projects must be analyzed. This thesis has shown the usefulness of analyzing project families, i.e. a group of projects that to a large extent build on the same knowledge base and use the same resources.

Thirdly, to build long-term competitiveness, it is of vital importance that organizations develop the means and the tools for supporting both the sustainability and dispersion of new work practices and new approaches for how to manage complex product development. The results presented in this thesis demonstrate the difficulty of using existing means and methods to illustrate, describe or motivate the application of either of the two emerging approaches. The discussions in the thesis also show the need to enlarge known areas for actors as regards manifest and latent, functional and dysfunctional attributes in each approach.

Finally, given the inherent complexity, the dynamics and the continuously emerging opportunities and potential problems, this thesis shows the competitive benefits of a focus on staying in control in, instead of over, different possible situations. Hence, traditional control – based on prediction, rigorous planning and a continuous effort to minimize deviations from plans so as to control the project and its actors – is replaced by a new form of control. A form of control where actors are provided with the necessary skills and means to handle most situations in real-time, and where transparency and convergence become vital elements in a strategy for organizing.

Implications for Theories of Managing Complex Product Development

The thesis has introduced two new approaches on how to manage complex product development and compared the applied perspectives, principles and actual models for organizing to the ones applied in the dominant approach. The analysis of the two emerging approaches indicates a number of important implications for theories on managing complex product development.

First, theories with a focus on understanding wholenesses (and not only single dependencies), i.e. group C in the stipulation model of Wigblad (1997) - see discussion on page 102-103 - are more powerful in explaining differences in performance. Hence, building increased knowledge in the domain ought to be based on fundamental assumptions in agreement with group C. Those theories consider complex product development as an interconnected system where approaches are best understood by focusing on the whole rather than specific structures, models or behavior.

Secondly, theories with a focus on understanding the full complexity and not decomposing that complexity into single dependencies (also group C in Wigblad 1997) are more powerful in explaining such differences.

Thirdly, this thesis clearly shows the potential gains and need for further knowledge about the process of managing multiple projects, about managing multiple phases of a project and about managing the full integration of disciplines.

Finally, the results point to the possibilities of promoting heterogeneity in managing complex product development. The analysis of the two emerging approaches indicates a number of important elements and fundamental assumptions that ought to widen our view of how complex product development is considered. This follows from only one study, and a large number of studies in diverse settings will probably further expand the scope of considering the domain, with high relevance for contemporary ideas about organizing.

Implications for Further Research

The analysis and results presented raise a number of important questions about managing complex product development. The early experience from the application of two new approaches motivates the belief that perspectives, principles and actual models for organizing complex product development need to be revisited and dominant assumptions need to be reconsidered. However, the study has its natural limitations in time, scope and organizational settings; it has therefore only been able to introduce and take some first important steps towards increased understanding and towards the emergence of new approaches and paradigms for how complex product development is considered. Hence, the study has probably raised a number of new questions along with the ones it has answered, but it has also hopefully done more than say once again that we live in a complex world.

Standing at a crossroads at the end of this initial path, one sees a number of interesting routes that ought to be further explored. The section below will introduce six potential paths that will help to explore the domain of complex product development and to strengthen the empirical foundation for further discussions on emerging approaches, emerging paradigms and paradigm shifts. This thesis also introduces a methodological experiment where actors from the organizational settings are invited into the core of the research process and participate not only in formulating areas or questions for research, but also in data collection, analysis and validation of results. The studies behind this thesis have involved hundreds of practitioners taking an active part in more than formulating research issues and formal presentations of results. In some cases, practitioners have worked in the research team as full members; in some cases they have taken an active part in performing interviews; and in most cases a large number of practitioners have taken an active part in performing analysis and validation.

The Single-Product Development Initiative as an Island or as an Engine in its Context

This thesis has demonstrated that projects performing complex product development are parts of a larger whole and that individual development projects are not islands unto themselves. Each single project interacts with other development projects and must fit with the surrounding organization in order to be effective. Projects may share critical components, resources, people and support. Additionally, products may require compatibility in design and function and must be sold by existing sales groups. Thus, effective development projects mean designing and developing many elements that fit and work well as a total system. Projects might best be considered as members of a family, and much research is needed to better understand the process of managing multiple projects performing complex product development.

Long-term Knowledge Creation – a Disciplinary Necessity or a Multi-disciplinary Effect

Both of the new and emerging approaches introduced in this thesis show an intense focus on integrating and circumvent what have previously been perceived as natural disciplines with a responsibility for long-term knowledge creation. In a short-term perspective, i.e. a single project or a series of single projects, the analysis indicates potential performance gains in striving for integration and bridging. However, there is a vast critique of the long-term effect on knowledge creation when reducing the significance of each traditional discipline as a primary habitat. This critique is based on certain assumptions, and there is a growing need to further explore whether this is the case. It could as well be found that multi-disciplinary efforts will develop into the foundation for radically new disciplines, and hence that this integration will work as an engine in long-term knowledge creation and facilitate leaps in knowledge that otherwise would be impossible within each discipline. To develop an increased understanding would be an important contribution for both practitioners and academicians in the field.

Building Dependencies – a Complicating or Facilitating Strategy

The analysis of both of the emerging approaches revealed a number of weaknesses in minimizing dependencies as an organizing strategy and a number of strengths in building dependencies as an organizing strategy. The approach based on *dynamic synchronization* successfully built very complex dependencies to facilitate the development of a coordination capacity and system knowledge among most actors. This thesis is based on observations and analysis of too few cases to formulate any strong conclusions regarding the applicability of this specific strategy in other settings. However, the indicative results are so unpredictable and provide actors with such completely new tools that further research is necessary to find out more about the dynamic effects of building dependencies.

Challenges in Sustainability and Dispersion – a Mere Lack of Methods for Pedagogical Illustration or a Conscious Fight for Authority

This thesis has illustrated and discussed some difficulties in the sustainability and dispersion of new approaches on how to manage complex product development and illustrated some early examples where attempts have failed. Are these failures caused by a lack of methods for capturing the spirit of the new approaches and making the implicit parts explicit and describable for actors who have not themselves experienced working in the new fashion? Or are the failures natural effects of trying to change the existing structure of authority? In any of the cases, it is of vital importance to develop ways of better illustrating the new approaches so as to facilitate both sustainability and dispersion.

The Role of the Project Manager and Project Management

This thesis has analyzed integrated approaches for managing complex product development and illustrated a number of important changes in focus and prerequisites. The roles of the project manager and project management have not received any specific attention in this thesis, but the results clearly show that the roles will have to change in order to master the new approaches. Specific studies on leadership and the role of leaders in the two emerging approaches will be important contributions to building actionable knowledge useful for the organizational settings.

Involving Actors from the Organizational Settings in the Process of Research

The studies on which the thesis is based have all had an ambition to expose actors from the organizational settings to more of the research process than simply formulating research issues and presenting results. The analysis of research performed in this thesis demonstrates benefits in closeness and understanding of the full complexity in the organizational settings that will help in building new knowledge and it shows benefits in building knowledge for action. This integration will make both full-scale experiments, real-time analysis and continuous utilization of preliminary results possible. It is of vital importance for the applied sciences that we further elaborate on these huge possibilities to increase the opportunities for building and validating knowledge for action, as well as to develop applied science into a real-time activity rather than a tool for retrospective analysis.

Retrospective Reflections

This thesis has hopefully not only once again shown that we live in a complex world. It has also provided readers with two new, alternative approaches and their potential consequences as a guide to better understanding and mastering the process of managing complex product development. If that is so, the thesis has contributed to the process of renewing the base of knowledge that guides practitioners involved in performing complex product development and academics involved in better understanding the area of complex product development. The illustrations, discussions, analyses and results presented above to some extent support the originally presented idea about managing complex product development being the same as *managing the unmanageable,* but they also introduce an alternative interpretation. It may be so that *managing the unmanageable* is only a perceived contradiction constructed by attacking the challenge from the wrong angle. It is not so simple as focusing on the early phases to improve performance in complex product development. Rather, the applied approaches derived from basic assumptions; perspectives and guiding principles must be in focus and be developed in harmony with the business conditions that emerge. Perhaps it will turn out that complex product development will improve performance in the coming ten years, if most projects are performed according to the approach based on *integration-driven development* and some projects are performed according to the approach based on *dynamic synchronization.*

SUMMARY OF PART IV – CRITICAL REVIEW OF THE EMERGING PATTERN

This part of the thesis has recapitulated the basic ideas: the potential benefits of self-organizing, product and project configuration as a powerful tool for project management, the strength in building up the product, building dependencies and allocating resources for boundary work, the benefits in providing actors with the full complexity and with means for handling it, the strength of transparency, convergence, early integration and actual functionality tests, and finally the capacity of table tennis research as an alternative research strategy for building knowledge for action.

A number of hypotheses are also presented; the approaches are not company or even industry-specific, and the relevance of the approaches is connected rather to the complexity of the task to be performed. There are a limited number of approaches to be found but an almost infinite number of combinations of these approaches. In some specific respects, the differences between the approaches are merely in degrees on the same scale, but in the fundamental assumptions behind each approach there are differences between species. Finally, the applied approach gives a strong explanation for differences in performance in complex product development, and it is closely linked with the individuals or sway-group(s) engaged.

The research performed in this thesis has been critically analyzed. The key characteristics of the research process are presented as closeness to the organizational setting in order to be able to understand the full complexity, engaging actors from the organizational setting in performing the research to enhance both validity and actionability, using multi-methods to enhance reliability and, when possible, actually testing preliminary results to enhance applicability and usefulness. Both validity and reliability are presented as sufficient. The approaches' applicability outside the studied organizational settings is presented as high – mainly on the basis of reactions from actors performing complex product development in other settings. But also on the basis of the fact that the competitive conditions and characteristics sketched above are not specific to Ericsson or the telecommunications industry.

The principal implications are presented as an imperative need to reconsider the process of performing complex product development as well as the theoretical foundations of the domain. Finally, a number of possible next steps for further research are outlined, and the potential in renewing the process of performing applied research is suggested.

REFERENCES

Abernathy, W. J. and Utterback, J. M. (1978) Patterns of Industrial Innovation, *Technology Review* Vol.50, No.7.

Adler, N. (1996) Managing Complexity in Product Development Processes, In proceedings to *3rd International Product Development Conference*, Fontainebleau, France, April 15-16, pp. 1-14.

Adler, N. and Docherty, P. (1995) STS and the Development of the Knowledge-based Organisation, Paper to the symposium on *Organisational Innovations and the Socio-technical Systems Tradition: Challenges for the 90ies*, Melbourne, 26-27 May.

Adler, N. and Docherty, P. (1998) Bringing Business in to Sociotechnical System Theory and Practice. *Human Relations*, Vol. 51, No. 3. pp. 319-345.

Adler, N., Hart, H., Lundqvist, M., Marmgren, L. and Norrgren, F. (1997) Integrationdriven Development – How Ericsson Gained foothold at the Japanese Market. In proceedings to *5th International Conference on Management of Technology*, Gothenburg, June.

Adler, N. and Norrgren, F. (1995) Leverages and Mechanisms for Learning in Complex Organizational Systems. *Working Paper 1995:2, Center for Research on Organizational Renewal*. Göteborg.

Allen, T. J. (1970) Communication Network in R&D Laboratories, *R&D Management*, No.1.

Allen, T. J. (1977) *Managing the Flow of Technology*, MIT Press: Cambridge.

Allen, T. J. and Cohen, S. I. (1969) Information Flow in an R&D Laboratory, *Administrative Science Quaterly*, March.

Alvesson, M. and Sköldberg, K. (1994) *Tolkning och Reflektion [in Swedish]*. Lund: Studentlitteratur.

Ancona, D. G. and Caldwell, D. F. (1990) Beyond Boundary Spanning: Managing External Dependence in Product Development Teams, *Journal of High Technology Management Research*, No. 1, pp 119-135.

Andersen, E. S., Grude K. V. and Haug, T. (1989) *Målinriktad Projektstyrning. [in Swedish.]* Lund: Studentlitteratur.

Anderson, P. and Tushman, M. L. (1990) Technological Discontinuities and Dominant Designs – A Cyclical Model of Technological Change, *Administrative Science Quaterly*, Vol. 35, No. 4, pp. 604-633.

Archibald, R. D. (1976) *Managing High Technology Programs and Projects,* New York: John Wiley&Sons.

Argyris, C. (1993) *Knowledge for Action.* San Fransisco: Jossey-Bass Publishers.

Argyris, C. (1992) *On Organizational Learning.* Cambridge: Blackwell Business.

Argyris, C., Putnam, B., and McLain Smith, D. (1985) *Action Science.* San Francisco: Joessey-Bass Publishers.

Argyris, C. and Schön, D. A. (1974) *Theory in Practice.* San Fransisco: Jossey-Bass.

Argyris, C. and Schön, D. A., (1978) *Organizational Learning: A Theory of Action Perspective,* Massachusetts: Addison-Wesley.

Asplund, J. (1979) *Teorier om framtiden [in Swedish].* Stockholm: Liber.

Barnes, M. (1985) Project Management Framework for the Future in *International Project Management Yearbook 1985.* Butterworth&Co.

Bartlett, F. (1958) *Thinking : an experimental and social study.* London.

Bateson, G. (1972) *Steps to an Ecology of Mind.* New York, NY: Ballantine.

Bijker, W. E. (1995) *Of bicycles, bakelites, and bulbs: toward a theory of sociotechnical change,* Cambridge, Massachusetts: MIT Press.

Björkegren, D. (1989) *Hur organisationer lär. [in Swedish].* Lund: Studentlitteratur.

Blomberg, J. (1995) *Ordning och kaos i projektsamarbete – en socialfenomenologisk upplösning av en organisationsteoretisk paradox [in Swedish].* Stockholm: Ekonomiska Forskningsinstitutet, EFI.

Blomberg, J. (1998) *Myter om projekt [in Swedish].* Stockholm: Nerenius&Santérus Förlag.

Boehm, B. W. (1984) Software Engineering Economics, *IEEE Transactions on Software Engineering.* No. 1, pp. 4-21.

Boehm, B. W. and Papaccio, P. N. (1988) Understanding and Controlling Software Costs. *IEEE Transactions on Software Engineering,* No. 10, pp. 1462-1477.

Bohlin, E. (1995) *Economics and Management of Technology: An International Investigation of New Technology Decision-Making in Telecommunications,* Doct Diss., Dept. of Industrial Management and Economics, Chalmers University of Technology.

Booz, Allen and Hamilton, (1982). *New Product Management for the 1980s.* New York: Booz, Allen&Hamilton.

Brodin, B. (1976) *Produktutvecklingsprocesser: En studie ur marknadsföringssynvinkel av produktutveckling i svenska företag [in Swedish].* Stockholm: EFI.

Brown, J. and Duguid, P. (1991) Organizational Learning and Communities of Practice: Toward a Unified View of Working, Learning and Innovation, *Organization Science*, Vol. 2, No. 1, pp. 40-57.

Bruzelius, L. H. and Hansen, O. R. (1986) *Styrning av utvecklingsprojekt – en handbok. [in Swedish]*. Lund: Studentlitteratur.

Buccarelli, L. L. (1988) An Ethnografic Perspective on Engineering Design, *Design Studies*, Vol. 9, No. 3, pp. 159-168. July

Buchanan, D. and Badham, R. (1998) *Winning the Turf Game: The Politics of Organizational Change*. Paul Chapman Publishing Human Resource Management Series.

Buchanan, D. and Boddy, D. (1992) *The Expertise of the Change Agent, Public Performance and Backstage Activity*, London: Prentice Hall.

Burns, T. and Stalker, G. M. (1961) *The Management of Innovation,* London: Tavistock.

Calantone, R. J., Schmidt, J. B. and Di Benedetto, C. A. (1997) New product activities and performance: The moderating role of environmental hostility. *The Journal of Product Innovation Management*, May.

Cantril, H. (1941) *The psychology of social movements*. New York: John Wiley.

Chada, S. (1981) *Technology Transfer Project Management*. Dissertation. Royal Institute for Technology.

Ciborra, C. U. (1991) Intervening in the Future of Work and Design in *On Business Work – Towards New Frontiers*, (pp. 331-346) Geneva: International Labour Office

Clark, K. B. (1985) The Interaction of Design Hierarchies and Market Concepts in Technological Evolution. *Research Policy* 14, No. 5.

Clark, K. B. and Fujimoto, T. (1991) *Product Development Performance - Strategy, Organization, and Management in the World Auto Industry*, Harvard Business School Press, Boston.

Clark, K. B. and Wheelwright, S. C. (1992) Organizing and Leading "Heavyweight" Development Teams, *California Management Review*, Vol. 34, No. 3, pp. 9-28.

Clark, K. B. and Wheelwright, S. C. (1996) *Leading Product Development*. New York: Free Press.

Cleland, D. 1. and King, W. R. ([1968] 1983) *Systems Analysis and Project Management* New York: McGraw-Hill.

Clipson, C. (1988) *First Thing First*. Ann Arbor: The University of Michigan.

Clipson, C. and Kornbluh, H. (1993) "Designing and learning." In *Appropriate Architecture - Workplace Design in Post-Industrial Society, IACTH 1993:1*, edited by

Törnqvist, A. and Ullmark, P. Gothenburg: Industrial Architecture and Planning, Chalmers University of Technology.

Cole, R. (1994) A Comparative Perspective on Individual and Organizational Learning in Western and Japanese Industry. Paper presented at the conference *På väg mot lärande arbetsliv* [Towards Learning in Working Life]. The Swedish Work Environment Fund, 17-18 November at Piperska Muren, Stockholm, Sweden.

Cook, T. D. and Campbell, D. T. (1979) *Quasi-experimentation : design & analysis issues for field settings*. Chicago: Rand McNally

Cooper, R. G. (1979) The Dimensions of New Industrial Product Success and Failure, *Journal of Marketing,* Vol. 43.

Cooper, R. G. (1980) How to identify potential new product winners. *Research Management,* Vol. 23, No. 10.

Cooper, R. G. (1986) *Winning at New Products*. Reading, MA: Addison-Wessley Publishing Co.

Cooper, R. G. (1990) Stage-gate Systems: a New Tool for Managing New Products, *Business Horizons,* Vol. 33, No. 3.

Cooper, R. G. (1994) What distinguishes the Top Performing New Products in Financial Services. *Journal of Product Innovation Management,* No. 11, pp. 281-299.

Cooper, R. G. and Kleinschmidt, E. J. (1986) An investigation into the new product process: Steps, deficiences. *Journal of Product Innovation Management,* No. 3, pp. 71-85.

Cooper, R. G. and Kleinschmidt, E. J. (1987) New Products: What separate winners from losers? *Journal of Product Innovation Management,* No. 4, pp. 169-184.

Couglan, P. D. (1992) Engineering Change and Manufacturing Engineering Deployment in New Product Development.

Cusumano, M. A. and Kemerer, C. F. (1990) A Quantatitive Analysis of U.S. and Japanese Practice and Performance in Soft-ware Development. *Management Science,* No. 11, pp.1384-1406.

Cusumano, M. A. and Nubeoka, K. (1992) Strategy, Structure and Performance in Product Development: Observations from the Auto Industry. *Research Policy,* No. 21, pp. 265-293.

Cusumano, M. A. and Selby, R. W. (1995) *Microsoft Secrets,* New York: Free Press.

Cyert, R. and March, J. (1963) *A Behavioural Theory of the Firm.* Englewood Cliffs: Prentice-Hall.

Danielsson, A. (1983) *Företagsekonomi – en översikt. [in Swedish].* Lund: Studentlitteratur.

Davis, S. and Lawrence, P. (1977) *Matrix,* Reading: Addison-Wesley.

Dellarocas, C. (1995) *A Co-ordination Perspective on Software Architecture: Towards a Design Handbook for Integrating Software Componets.* PhD-dissertation, Massachusetts Institute for Technology.

DeMeyer, A. (1991) Tech Talk: How managers are stimulating global R&D communication, *Sloan Management Review,* Vol. 32, pp. 49-66.

DiMaggio, P. J. and Powel, W. W. (1983) The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review,* No. 48, pp. 147-160.

Docherty, P. (1996) *Läroriket [in Swedish].* Stockholm: Arbetslivsinstitutet.

Dougherty, D. A. (1992) Practice-Centered Model of Organizational Renewal through Product Innovation, *Strategic Management Journal,* No. 13, pp. 77-92.

Dougherty, D. A. (1999) *Re-imagining the differentiation and integration of innovation work as heedfully interrelating communities of practice,* Working Paper, Rutgers University.

Dubinskas, F. A. (1993) Modeling Cultures of Project Management, *Journal of Engineering and Technology Management,* No. 10, pp. 129-160.

Dunbar, R. L. M. (1981). Designs for organizational control. In P. C. Nystrom and W. H. Starbuck (Eds.) *Handbook of organizational design* (Vol 2, pp. 85-115) New York: Oxford University Press.

Edström, A. and Galbraith, J. (1977) Transfer of Managers as a Coordination and Control Strategy in Multinational Organisations, *Administrative Science Quaterly,* No. 22.

Ehrenberg, E. and Jacobsson, S. (1997) Indicators of discontinuous technological change: an explanatory study of two discontinuities in the machine tool industry, *R&D Management,* Vol. 27, No. 2, pp. 107-126.

Eisenhardt, K. M. (1989) Building Theories from Case Study Research, *Academy of Management Review,* Vol. 14, No. 4, pp. 532-550.

Eisenhardt, K.M. and Tabrizi, B.N. (1995) Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry, *Administrative Science Quaterly,* Vol. 40, No. 1, pp. 84-110.

Ekvall, G. (1983) *Organisationsklimat och innovativ förmåga. En jämförande studie av tre industriföretag. [in Swedish].* Arbetsrapport, FA-rådet, Stockholm.

Ellegård, K., Engström, T. and Nilsson. L. (1991). *Reforming Industrial Work: Principles and Reality, In the Planning of the Volvo´s car assembly plant in Uddevalla.* Stockholm: The Work Environment Fund.

Ellström, P-E. (1992) *Kompetens, utbildning och lärande i arbetslivet: Problem, begrepp och teoretiska perspektiv. [in Swedish].* Stockholm: Publica.

Engwall, M. (1995) *Jakten på det effektiva projektet [in Swedish]*, Ph.D dissertation, Department of Industrial Economics and Management, Royal Institute of Technology, Stockholm.

Eppinger, S. D., Whitney, D. E., Smith, R. P. and Gebala, D. A. (1994) A Model-Based Method for Organizing Tasks in Product Development, *Research in Engineering Design*, No. 6, pp. 1-13.

Evans, M. W., Piazza, P. and Dolkas, J. P. (1983) *Principles of Productive Software Management.* John Wiley&Sons.

Fayol, H. (1949) *Genral and Industrial Management.* London: Pitman.

Feldman, M. S. (1989) *Order without design.* Stanford University Press.

Fleming, Q. W. and Fleming, Q. J. (1991) *A Probus Guide to Subcontract Project Management & Control: Progress Payments*, Chicago Illinois: Probus Publishing.

Flood, R. L. and Carson, E. R. (1993) *Dealing with Complexity – An Introduction to the Theory and Application of Systems Science.* New York: Plenum Press.

Forslin, J. and Fredholm, E. (1996) *Att reflektera över praktiken: ett projekt om lärande organisation inom Volvo [in Swedish].* Stockholm: Arbetslivsinstitutet.

Fox, J. (1998) Process uncertainty: A new dimension for new product development, *Engineering Management Journal*, Sep 1998; Vol. 10, Iss. 3; pp. 19-28.

Friedlander, F. and Margulies, N. (1969) Multiple Inputs of Organizational Climate and Individual Value Systems Upon Job Satisfaction, *Personal Psychology*, No. 22.

Galbraith J. R. (1973) *Designing Complex Organizations*, Addison-Wesley Publishing Company.

Gersick, C. J. (1988) Time and Transition in Work Temas: Towards a New Model of Group Development. *Academy of Management Journal*, No. 1, pp. 9-41.

Gibbons, M. and Limoges, C *et al* (1994) *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, London: Sage.

Gioia, D. A. and Chittipeddi, K. (1991) Sensemaking and sensegiving in strategic change initiation, *Strategic Management Journal*, No. 12, pp. 433-448.

Glaser, B. G. and Strauss, A. L. (1967) *The Discovery of Grounded Theory.* New York: Aldine de Gruyter.

Gleick, J. (1987) *Chaos*, New York: Viking Press.

Goleman, D. (1985) *Vital lies, simple truths: The psychology of self-deception.* New York: Simon&Schuster.

Granath, J. Å. (1991) *Architecture, technology and Human Factors: Design in a Socio-Technical Context.* Ph.D. Diss. Gothenburg: Industrial Architecture and Planning, Chalmers University of Technology.

Granstrand, O. and Sjölander, S. (1990) Managing Innovation in Multi-Technology Corporations, *Research Policy,* Vol. 19, pp. 36-60.

Gunasekaran, A. (1997) Essentials of international and joint R&D projects, *Technovation,* Nov/Dec.

Gupta, A. K. and Wilemon, D. L. (1990) Accelerating the Development of Technology-Based New Products. *California Management Review,* winter: pp. 24-44.

Gustavsen, B., Hart, H. and Hofmaier, B. (1991) From Linear to Interactive Logics, *Human Relations,* Vol. 44, No. 4, pp. 309-332.

Göjeryd, S. and Söderlund, J. (1995) *Projekt – plan, organisation och lärande [in Swedish]* Linköping: Ekonomiska institutionen.

Hackman, J. R. and Wageman, R. (1995) Total Quality Management: Empirical, Conceptual and Practical Issues, *Administrative Science Quaterly,* No. 40, pp. 309-342.

Hage, J. and Aiken, M. (1966) Program Change and Organizational Properties, *American Journal of Sociology,* No. 72.

Hage, J. and Aiken, M. (1967) Relationship of Centralization to Other Structural Properties, *Administrative Science Quaterly,* No. 12.

Hage, J. and Aiken, M. (1969) Routine Technology, Social Structure and Organizational Goals, *Administrative Science Quaterly,* No. 14.

Hall, R. (1963) The Concept of Bureaucracy: An Empirical Assessment, *American Journal of Sociology,* No. 69.

Hammarlund, Y. (1977) *Projektadministration [in Swedish].* Lund: Studentlitteratur.

Harrison, F. L. (1992) *Advanced Project Management,* Aldershot: Gower Publishing.

Hartley, J. R. (1990) *Concurrent Engineering.* Cambridge Massechutas: Productivity Press.

Hatchuel, A. and Molet, H. (1986) Rational modelling in understanding and aiding human decision making. *European Journal of Operational Research,* Vol. 3, No. 4.

Hatchuel, A. and Weil, B. (1995) *Experts in Organizations.* Berlin-New York: Walter de Gruyter.

Hatchuel, A. and Weil, B. (1999) Design-oriented Organizations – towards a unified theory of design activities, presented at the *6th International Product Development Conference*, EIASM, Cambridge, July 5-6.

Hedberg, B., Dahlgren, G., Hansson, J. and Olve, N. G. (1994) *Imaginära organisationer [in Swedish]*. Stockholm: Liber Hermods.

Hedlund, G. (1994) A Model of Knowledge Management and the N-form Corporation, *Strategic Management Journal*, No. 15, pp. 73-90.

Hedlund, G. and Ridderstråle, J. (1992) Toward the N-form Corporation: Exploitation and Creation in the MNC. Paper presented at the conference *Perspectives on International Business Theory: Theory, research and institutional arrangements,* Columbia, May.

Helgesson, C-F. (1994) *Coordination and Change in Telecommunications,* EFI Research Report, Stockholm School of Economics.

Hellquist, E. (1980) *Svensk etymologisk ordbok [in Swedish]*. Lund: Liber.

Hellström, T. and Stymne, B. A. (1999) *KM state-of-the-art compilation.* Presented at the Gemini Consulting KM and Networking Project Meeting, Stockholm, July 15-16.

Hice, G. F., Turner, W. S. and Cashwell L. F. (1974) *System development methodology,* North-Holland.

Hofstede, G. (1991) *Cultures and Organizations – Software of the Mind.* London: McGraw Hill.

Holt, K. (1983) *Product Innovation Management.* 2nd edition. Butterworths.

Howard, R. (1993) *The Learning Imperative.* Cambridge MA: HBS Press.

Huber, G. P. and Daft, R. L. (1987) The information environments of organizations. In F.M. Jablin, L. L. Putnam, K. H. Roberts and L. W. Porter (Eds.) *Handbook of organzational communication* (pp. 130-164). Newbury Park: Sage.

Hörte, S-Å, (ed), Börjesson, S., Lindberg, P., Trygg, L. and Tunälv, C. (1991) *Tillverkningsstrategier i Sverige 1982-1989 [in Swedish]*. Göteborg: IMIT.

Iansiti, M. (1995) Technology Development and Integration: An Empirical Study of the Interaction Between Applied Science and Product Development, *IEEE Transactions On Engineering Management,* Vol. 42, No. 3, August, pp. 259-269.

Iansiti, M. (1998) *Technology Integration – Making critical choices in a dynamic world,* Harvard Business School Press.

Iansiti, M. and Clark, K. B. (1994) Integration and Dynamic Capabilities: Evidence from Product Development in Automobiles and Mainframe Computers. *Industrial and Corporate Change,* No.3, pp. 557-605.

Ingelgård, A. (1998) *On Macroergonomics and Learning Strategies in Improving Working Conditions*. Dissertation. Department of Psychology. Gothenburg University.

Jones, A. M. and Hendry, C. (1992). *The Learning Organization: A review of literature and practice*. London: HRDP.

Järkvik, J. and Kylberg, L. (1994) *Om att lyckas – lite tur behövs också. [in Swedish]* EN/LZT 1231987.

Karlsson, B. (1994) *Product Design - Towards a New Conceptualization of the Design Process*. PhD-dissertation, Royal Institute of Technology.

Karlsson, C. (1998) Black box engineering: Redefining the role of product specifications, *The Journal of Product Innovation Management*, Vol. 15, Iss. 6, pp. 534-550.

Karlsson, T. (1965) *Nätverksplanering. [in Swedish]*. Göteborg: Akademiförlaget.

Katz, D. and Allen, T. (1982) Investigating the Not Invented Here (NIH) Syndrome: A Look at the Performance, Tenure and Communication patterns of 50 R&D Project Groups, *R&D Management*, vol. 1, nr. 12, pp. 7-19.

Katz, D. and Kahn, R. L. (1966) *The Social Psychology of Organizations*, New York: John Wiley.

Kelly, J. E. (1982) Scientific Management, Job Redesign and Work Performance. London: Academic Press.

Kemps, R. R. (1992) *Fundamentals of project performance measurement*. San Diego Pub. Co.

Kim, D. H. 1993. The link between individual and organizational learning. *Sloan Management Review*, vol. 35, No. 1, pp. 37-50.

Koestler, A. (1989) *The Ghost in the Machine*. London: Arkana.

Kogut, B. and Zander, U. (1992) Knowledge of the firm, combinative capabilities and the replication of knowledge, *Organization Science*, Vol. 3, No. 3, pp. 383-397.

Kuhn, T. S. (1970) *The Structure of Scientific Revolutions*. (2nd Edition). Chicago Press.

Kylén, S. (1999) *Interaktionsmönster i arbetsgrupper – offensiva och defensiva handlingsrutiner. [in Swedish]*. PhD-thesis. Department of Psychology. Göteborg University.

Lambert, D. and Slater, S. F. (1999) Perspective: First, fast and on time: The path to success, or is it? *The Journal for Product Innovation Management*, Vol. 16, Iss. 5.

Lawrence, P. R. and Lorsch, J. W. (1967) *Organization and Environment*. Boston Massachussets: Harvard Business School Press.

Leonard-Barton, D. (1988) Implementation as Mutual Adaptation of Technology and Organization. *Research Policy,* vol. 17, pp. 251-267.

Leonard-Barton, D. (1992) Core Capabilities and Core Rigidities: A paradox in managing new product development. *Strategic Management Journal.*, vol. 13. pp. 111-125.

Leonard-Barton, D. (1995) *Well-springs of Knowledge*, Boston: Harvard Business School Press,

Lewin, K. (1949) Cassier´s Philosophy of Science and Social Science, in Schlipp (Ed.), *The Philosophy of Ernst Cassier,* New York: Tudor.

Levinthal, D. A. and March, J. G. (1993) The Myopia of Learning, *Strategic Management Journal,* Vol. 14, pp. 95-112.

Levitt, B. and March, J. G. (1988) Organizational Learning, *Annual Review of Sociology,* Vol. 14, pp. 319-340.

Lindblom, C. E. and Cohen, D. K. (1979) *Usable Knowledge – Social Science and Social Problem Solving.* Yale University Press.

Lindell, M. (1988) *Utveckling av nya produkter, en organisatorisk studie, [in Swedish].* Dissertation. Swedish School of Economics and Business Administration. Helsingfors.

Lord, G. R. and Foti, R. J. (1986) Schema Theories, Information Processing, and Organizational Behaviour. I: Sims, H. P. and Goia, D. A. *et al, The Thinking Organization – Dynamics of Organizational Social Cognition.* San Fransisco: Jossey-Bass.

Lundin, R. A. (1995) A Theory of the Temporary Organization (Ed.) *Scandinavian Journal of Management,* Vol. 11, No. 4, pp. 437-455.

Lundin, R. A. and Söderholm, A. (1994) A Theory of the temporary Organization, in *proceedings of the International Research Network on Organizing by Projects (IRNOP) Conference on "Temporary Organizations and Project Management"*, 22-25 mars, Lycksele.

Lundqvist, M. A. (1994) *Process Management in Product Development.* Dep. of Operational Management and Work Organization, Chalmers University of Technology: Göteborg.

Lundqvist, M. A. (1996) *Organizing Product Development - Formalizing the informal in interdependent knowledge work,* PhD Dissertation, Dep. of Operational Management and Work Organization, Chalmers University of Technology. Göteborg.

Löwstedt, J. (1989) *Föreställningar, ny teknik och förändring. Tre organiseringsprocesser ur ett aktörsperspektiv. [in Swedish].* Lund: Doxa.

MacCormack, A. (1998) Towards a Contingent Model of Product Development: A Comparative Study of Development Practices, in proceedings to *5th International Product Development Management Conference*, Como, May.

Maidique, M. A. and Zirger, B. J. (1984) A study of success and failure in product innovation: the case of the U.S. electronics industry. *IEEE Transactions on Engineering Management*, No. 31, pp. 192-203.

March, J. G. ed. (1965) *Handbook of organizations.* Chicago: Rand McNally.

March, J. G. (1991) Exploration and Exploitation in Organizational Learning. *Organization Science*, no. 1. February.

March, J. G. and Olsen, P. O. (1986) Garbage Can Models of Decision Making in Organizations, in March, J. G. and Weissinger-Baylon, R. *Ambiguity and Command,* Cambridge, Massachusetts: Harvard Business School Press.

March, J. G. and Simon, H. A. (1958) *Organizations,* New York: John Wiley & Sons.

Marshall, A. W. and Meckling W. H. (1962) *Predictability for the Cost, Time and Success of development in the Rate and Direction of Inventive Activity*, The National Bureau of Economic Research 1962.

Marples, V. (1969) *Dynamics of machines*, New York: McGraw-Hill.

Mattsson, P. (1995) *Generativt Lärande - en miljöpedagogisk studie av kunskapsintensiva företag 1991 - 1993. [in Swedish].* Stockholm: Industrilitteratur.

McKee, D. (1992) An Organizational Learning Approach to Product Innovation. *The Journal of Product Innovation Management*, No. 9, pp. 232-245. New York: Elsevier Science Publ.

Melin, L. (1977) *Olika strategier, olika organisationsformer och olika värdesystem: en studie av inköpsverksamhet i Grängeskoncernen [in Swedish].* Linköping: Ekonomiska institutionen.

Mentzeil, H. (1965) Information Needs and Uses in Science and Technology, in Cuarda, C. (editor) *Annual Review of Information Science and Technology,* New York: Wiley.

Meridith, J. R. and Mantel, S. J. ([1985] 1995) *Project Management: A Managerial Approach.* New York: John Wiley&Sons.

Meyer, M. and Lehnerd, A. P. (1997) *The Power of Product Plattforms – Building Value and Cost Leadership*, New York: Free Press.

Meyer, M. and Rowan (1977) Institutionalised Organizations: Formal Structures as Myth and Cermony. *American Journal of Sociology.* Vol. 82, No. 2, pp. 340-363.

Meyer, M. and Utterback, J. (1993) The Product Family and the Dynamics of Core Capability. *Sloan Management Review*, Spring 1993, pp. 29-47.

Midler, C. (1995) `Projectification`of the Firm: The Renault Case, *Scandinavian Journal of Management,* Vol. 11, No. 4, pp. 363-375.

Miles, M. B. and Huberman, A. M. (1984) *Qualitative data analysis: a sourcebook of new methods.* Beverly Hills: Sage.

Mintzberg, H. (1978) Patterns in Strategy Formation, *Management Science,* No. 9, May, pp 934-948.

Morris, P. and Hough, G. (1987) *The anatomy of major projects.* Wiley.

Moss Kanter, R. (1989) *When the Giants Learn to Dance: Mastering the challenges of strategy, management and carrers in the 1990s.* London and New York: Routledge.

Murmann, P. A. (1994) Expected Development Time Reductions in the German Mechanical Engineering Industry. *Journal of Product Innovation Management,* No. 11, pp. 236-252 (June)

Nadler, D. A. Gerstein, M. S. Shawn, R. B. & Associates. (1992) *Organizational Archiechture - Designs for Changing Environment.* San Fransisco: Joessey-Bass Publisher.

Nadler, D. and Tushman, M. L. (1987) Managing Linkages, in Tushman, M.L. and Moore, W.L. (red.) *Readings in the Management of Innovation,* New York: Harper Business.

Nakahala, M., Soler, L. G. (1996) *Project Management, Internal Contracts and Dynamics of Organizations.* Cahiers de recherche No 8. Centre de Gestion Scientifique. École des Mines de Paris.

Nevis, E. C. DiBella, A. J. and Gould, J. M. (1995) Understanding Organizations as Learning Systems. *Sloan Management Review.* Winter.

Nobeoka and Cusumano, M. (1997) Multiproject Strategy and Sales Growth: The Benefits of Rapid Design Transfer in New Product Development, *Strategic Management Journal,* Vol. 18, pp. 169-186.

Nonaka, I. (1988) Creating Organizational Order Out of Chaos: Self-Renewal in Japanes Firms, California Management Review, Spring, pp. 57-73.

Nonaka, I. (1990) Managing Innovation as a knowledge creation process: A new model for a knowledge creating organization. Institute of Buisness Research, Hitotsubashi University, Tokyo.

Nonaka, I., (1994) A Dynamic Theory of Organizational Knowledge Creation, *Organization Science,* Vol. 5, No. 1, February, pp. 14-37.

Nonaka, I. and Takeushi, H. (1995) *The Knowledge-Creating Company.* New York: Oxford University Press.

Normann, R. (1985) "Developing capabilities for organizational learning." In *Organizational Strategy and Change: New Viewpoints on Formulating and Implementing Strategic Decisions*, edited by J. M. Pennings et al. San Fransisco: Jossey-Bass.

Normann, R. (1975) *Skapande Företagsledning. [in Swedish]*. Stockholm: Aldus.

Norrgren, F. (1990) Designing and Implementing a Software Factory - a case study from telecommunications. *R&D Management*, Vol. 20, No. 3, pp. 263-275.

Norrgren, F. and Schaller, J., (1999) Leadership Style: its impact on Cross-Functional Product Development, *Journal of Product Innovation Management*, Vol. 16, No. 4, pp. 377-384.

Norrgren, F., Schaller, J., Ollila, S. and Olsson, M. (1997) *Industriell FoU – Vad utmärker best practice projekt? [in Swedish]* Stockholm: IMIT.

Ogawa, D. and Ketner, L. (1997) Benchmarking product development, *Telephony*, Jan 27.

Olsson, K. G. F. (1976) *Systematisk konstruktion. [in Swedish]*. Institutionen för maskinkonstruktion, Lunds tekniska högskola.

Packendorff, J. (1993) *Projektorganisation och projektorganisering. [in Swedish]*. Umeå universitet.

Packendorff, J. (1995) Inquiring into the Temporary Organization: New directions for project management research, *Scandinavian Journal of Management*, Vol. 11, No. 4, pp. 319-333.

Pahl, G. and Beitz, W, (1984) *Engineering Design a Systematic Approach*, The Design Council, London: Springer Verlag.

Pasmore. W. A. (1988) *Designing Effective Organizations: A Sociotechnical Systems Perspective*. New York: John Wiley & Sons.

Pasmore, W. A. (1994) *Creating Strategic Change: Designing the Flexible, High-Performing Organization*, New York: John Wiley & Sons.

Pava, C. (1983) *Managing New Office Technology, An Organizational Strategy*, New York: Free Press.

Pearson, A. W. (1983) Planning and Monitoring in Research and Development – a 12 year Review of Papers in R&D Management, *R&D Management*, Vol. 13, No.2, April.

Pelz, D. C. and Andrews, F. M. (1966) *Scientists in Organizations - Productive Climates for Research and Development*. New York: John Wiley & Sons.

Perrow, C. (1986) *Complex Organizations: a Critical Essay*, New York: McGraw-Hill.

Peters, T. J. and Waterman, R. H. (1983) *In Search of Excellence.* Harvard Business School Press.

Pettigrew, A., McKee, L. and Ferlie, E. (1988) Understanding Change in the NHL, *Public Administration,* Vol. 66, No. 3, pp. 297-317.

Pimmler&Eppinger (1994) Integration Analysis of Product Decomposition, *ASME Design Theory and Methodology Conference,* Minneapolis, MN, September.

Piore, M. J., Lester, R. K. and Malek, K. M. (1997) *The Division of Labour, Co-ordination and Integration: Case Studies in the Organization of Product Design in Blue Jeans Industry,* MIT, Sloan School Working paper.

Prigogine, I. and Stengers, I. (1984) *Order out of Chaos: Man's New Dialogue with Nature,* (Bentam Books, New York).

Purser, R. E. and Pasmore, W. A. (1992) Organizing for Learning, *Research in Organizational Change and Development,* No. 6, pp. 37-114.

Purser, R. E., Pasmore, W. A. and Tenkasi R. V. (1992) The Influence of Deliberations on Learning in New Product Development Teams, *Journal of Engineering and Technology Management,* No. 9, pp. 1-28.

Rehnman, E. (1969) *Företaget och dess omvärld. [in Swedish]* Lund: Bonniers Förlag.

Ridderstråle, J. (1992) *Developing Product Development: Holographic Design for Successful Creation in the MNC,* Competetive Paper for EIBA Annual Meeting December 1992, Stockholm: Institute for International Buisness.

Robertson, and Ulrich (1998) Planning for Product Plattforms. *Sloan Management Review,* Summer, pp. 19-31.

Rosenau, M. D. (1988) Speeding your new product to market. *Journal of consumer Marketing,* No. 5, pp. 23-36.

Roy, R. and Riedel, J. (1997) Design and innovation in successful product competition, *Technovation,* Oct.

Rubenstein, A. H. (1957) Setting Criteria for R&D, *Harvard Business Review,* Jan/Feb.

Rusinko, C. (1997) Design-manufacturing integration to improve new product development: The effects of some organization- and group-level practices, *Project Management Journal,* Jun.

Sahlin-Anderson, K. (1989) Oklarhetens strategi – Organisering av projektsamarbete [in Swedish]. Lund: Studentlitteratur.

Salancik, G. R. and Pfeffer, J. (1988) Who Gets Power – And How They Hold on to It: A Strategic-Contingency Model of Power in Tushman, M. L. and Moore, W. L. (Eds)

Readings on the Management of Innovation, (2nd Edition), Ballinger Publishing Company.

Scarbrough, H., Swan, J. and Preston, J. (1998) *Knowledge Management and the Learning Organization: The IDP Report.* October.

Schein (1992) *Organizational Culture and Leadership.* San Fransisco: Jossey-Bass.

Schrader, S., Riggs, W. and Smith, R. P. (1993) Choice over uncertainty and ambiguity in technical problemsolving. *Journal of Engineering and Technology Management,* Vol. 10, pp. 73-99.

Schön, D. (1983) *The Reflective Practitioner: How Professionals Think in Action.* New York: Basic Books Inc.

Segelod, E. (1986) *Kalkylering och avvikelser [in Swedish].* Malmö: Liber Förlag.

Selin, G. ([1974] 1980) *Praktisk projektledning [in Swedish].* Stockholm: Ingenjörsförlaget.

Selin, G. (1990) *Att hantera projekt vid produktutveckling [in Swedish].* Stockholm. Sveriges Mekanförbund.

Senge. P. S. (1990) *The Fifth discipline. The Art & Practice of learning Organization.* New York: Dubleday Currency.

Shani, A. B. and Stebbins, M. W. (1995) Organization design and the knowledge worker, *Leadership & Organization Development Journal,* Vol. 16, No. 1, pp. 23-31.

Shenhar, A. J., Dvir, D. and Schulman, Y. (1995) A two-dimensional taxonomy of products and innovations. *Journal of Engineering and Technology Management.* No. 12, pp. 175-200.

Simon, H. A., (1973) Applying Information Technology to Organization Design, *Public Administrative Review,* No. 33, pp. 268-278.

Sims, H. P. and Goija, D. A. (1986) Introduction: Social Cognition in Organizations. I: Sims, H. P. and Goia, D. A. et al *The Thinking Organization – Dynamics of Organizational Social Cognition.* San Fransisco: Jossey-Bass.

Sjölander, S. (1985) *Management of Innovation.* PhD Dissertation, Dep. of Operational Management and Work Organization, Chalmers University of Technology. Göteborg.

Smith, P. G. and Reinertsen, D. G. (1991) *Developing Products in half the time.* New York: Van Nostrand Reinhold.

Sommerhof, G. (1969) The abstract characterstics of living systems, in Emery, F.E. (ed) *Systems Thinking.* Harmondsworth, Middlesex: Penguin, pp. 147-202.

Souder, W. E., Song, M. X. and Kawamura, K. (1998) America's edge in new product R&D, *Research Technology Management,* Mar/Apr

Spinner, M. P. (1992) *Elements of Project Management – Plan, Schedule and Control,* New Jersey: Prentice Hall.

Stalk, G. Jr. 1990. *Competing Against Time: How timebased competition is reshaping global markets*. New York: Free Press.

Staudenmayer, N. (1999) Webs of Interdependency: Strategies for Managing Multiple Interdependencies in New Product Development, presented at the *6th International Product Development Conference*, EIASM, Cambridge, July 5-6.

Staudenmayer, N. and Cusumano, M. (1998) Alternative Designs for Product Component Integration, in proceedings to *5th International Product Development Management Conference,* Como, May.

Starbuck, W. H. and Milliken, F. J. (1988) Excecutives perceptual filters: What they notice and how they make sense. In D.C. Hambrick (Ed.) *The excecutive effect: Concepts and methods for studying top managers* (pp. 35-65), JAI, Greenwitch, CT.

Stymne, B. A. (1969) *Values and Processes.* PhD-thesis. Stockholm School of Economics.

Svensson, P. (1990) *Styrning av produktutveckling [in Swedish].* PhD-dissertation. Chalmers University of Technology.

Södersved, H. (1991) *Concurrent Engineering.* Tyresö: Mekanförbundets förlag.

Taylor, F. (1947) *Scientific Management.* New York: Harper.

Taylor, J. C. and Felten, D. F. (1993) *Performance by design – sociotechnical systems in north america.* Prentice Hall.

Taylor, W. J. and Watling, T. F. ([1970] 1979) *Successful Project Management.* London: Business Books.

Thompson, J. D. (1967) *Organizations in Action.* New York: McGraw-Hill.

Tolman (1948) Cognitive Maps in Rats an Men. *Phychological Review,* No. 55, pp. 189-208.

Thomas, H. (1984) Mapping Strategic Management Research, *Journal of General Management,* No. 4, pp. 55-72.

Thomke, S. H. (1998) Managing experimentation in the design of new products, *Management Science*, Jun, Vol. 44, Iss. 6, pp. 743-763

Tushman, M. L. (1979) Managing Communication Networks in R&D Laboratories. *Sloan Management Review*, Winter 1979.

Twiss, B. (1986) *Managing Technological Innovation.* (3rd Edition) Longman.

Ueno, K. (1995) From Product-Oriented Development to Technology-Oriented Development. *IEEE Transactions On Engineering Management,* Vol. 44, No. 2 June, pp. 220-224.

Utterback, J. M. (1994) *Mastering the dynamics of innovation : how companies can seize opportunities in the face of technological change.* Harvard Business School Press.

Waterman, R. H. (1990) *Adhocracy: The power to change.* Memphis: Whittle Direct Books.

Whipp, R., Pettigrew, A. and Sparrow, P. (1989) New Technology, Competition and the Firm – A Framework for Research, *International Journal of Vehicle Design,* Vol. 10, No. 4, pp. 453-469.

Weber ([1922] 1947) *The theory of Social and Economic Organization.* New York: Free Press.

Weick, K. (1979) *The Social Psychology of Organizing.* Addison-Wesley.

Weick, K. (1995) *Sensemaking in Organizations.* SAGE Publications.

Weick, K. E. and Bougon, M. G. (1986) Organizations as Cognitive Maps. Charting Ways to Success and Failure in Sims, H. P., Goia, D. A. m. fl. *The Thinking Organization – Dynamics of Organizational Social Cognition.* San Fransisco: Joessey-Bass.

Verganti, R. (1997) Leveraging on Systematic Learning to Manage the Early Phases of Product Innovation Porjects, *R&D Management,* Vol. 27, No. 4.

Verganti, R. (1999) Planned flexibility: Linking anticipation and reaction in product development projects, *The Journal of Product Innovation Management,* Vol. 16, Iss. 4, pp. 363-377.

Verganti, R., MacCormack, A. and Iansiti, M. (1998) Rapid Learning and Adaptation in Product Development: An Empirical Study of the Internet Software Industry, in proceedings to *5th International Product Development Management Conference,* Como, May.

Werr, A., Stjernberg, T. and Docherty, P. (1995) The Functions of Methods of Change in the Work of Management Consultants, *EIASM 3rd International Conference on Manegerial and Organizational Cognition,* Glasgow, June.

West, J. and Iansiti, M. (1997) Experience, Experimentation and the Accumulation of Organizational Capabilities, *HBS Working Paper, 96-032.*

Westley, F. R. (1990) Middle managers and strategy: Microdynamics of inclusion. *Strategic Management Journal,* No. 11, pp. 337-351.

Wheelwright, S. C. and Clark, K. B. (1992) *Revolutionizing Product Development.* Free Press.

Wigblad, R. (1997) *Karta över vetenskapliga samband. [in Swedish].* Lund: Studentförlag.

Wolfe, R. A. (1994) Organizational Innovation: Review, critique and suggested research directions. *Journal of Management Studies,* Vol. 31, pp. 405-431.

Womack, J. P., Jones, D. T. and Roos, D. (1990) *The Machine that Changed the World,* New York: Rawson Associates & Macmillan.

von Hippel, E. (1990) Task Partitioning: An Innovation Proces Variable. *Research Policy,* No. 19, pp. 407-418.

von Hippel, E. and Tyre, M. J. (1995) How learning is done: Problem identification in novel process equipment, *Research Policy,* Vol. 24, Iss. 1, pp. 1-13.

Woodward, J. (1965) *Industrial Organization – Theory and Practice.* London: Oxford University Press.

Yin, R. K. (1984) *Case Study Research: Design and Methods.* Beverly Hills: Sage.

Zander, I. (1994) *The Tortoise Evolution of the Multinational Corporation – Foreign Technological Activity in Swedish Multinational Firms.* PhD-thesis. Stockholm School of Economics.

Zander, U. and Kogut, B. (1995) Knowledge and the speed of the transfer and imitation of organizational capabilities – an empirical test, *Organization Science,* Vol. 6, No. 1, pp. 76-92.

Zucker, L. G. (1991) The Role of Institutionalisation in Cultural Persistence. I: Powel, W.W. and DiMaggio, P.J. (red) *The New Institutional Organizational Analysis.* Chicago: The University of Chicago Press.

APPENDENCIES

Appendix A contains descriptions of the seven organizational settings, all of which were written during the time that research was being performed at the setting. Appendix B contains descriptions of the ten research projects on which this thesis is based. All descriptions of the projects were written at the time they had been completed. The appendixes are best read as further information and specific descriptions of both organizational settings and research projects as a support for reading the thesis.

APPENDIX A

DESCRIPTIONS OF THE ORGANIZATIONAL SETTINGS

The unit of analysis for the study is individual product development projects; the project families to which they belong and the organizational settings in which they are embedded (1). All the project families studied were led by different development organization at Ericsson and had the purpose of developing products for the telecommunications branch (2). These development organizations are called business units in the thesis. A total of seven organizational settings were covered in the ten research projects that form the basis of the thesis: *Microwave Technology, Radar Technology, Large Switches, Increased Network Capacity, Japanese Systems, Japanese Subsystems* and *Central Processor*. Several of them have participated in more than one of the ten research projects. The names are not their own but are instead based on the products in focus in each project family's development endeavors. The ten research projects are all described in Appendix B.

Business Unit: Microwave Technology

The *Microwave Technology* business unit represents an organizational system in change, from having focused on a large customer in the defense industry with stable and mature products with long development times to working primarily toward a diversified customer structure with hard time press and demands on flexibility. *Microwave Technology* designs advanced technical systems for microwave applications. The quality of the products is very high and the engineers are on average very well educated. More than half of the design engineers has Master degrees and a few have PhDs. The organization works mainly with developing new products according to specific customer demands but meets a clear trend of competition created by platform products and more standardized selections of products. The organization has 120 development engineers, of whom almost 100 are design engineers and continuously carry out five to ten larger and 30-50 smaller complex product development projects as suppliers to larger projects in the company. The engineers belong to four different design groups that are responsible for different functions in the finished products and have different professional skills; the *mechanical design group*, the *high frequency microwave designers*, the *low frequency microwave designers*, and the *hybrid design engineers*.

The organization has a large number of *"old"* products for which they are responsible for maintaining. The major technology has traditionally been electromechanical development of hardware but more and more of the new development is of software.

The organization is characterized by a focus on several different areas and targets and is directed by multiple control processes. In addition to line and project hierarchies, there are two important hierarchies that affect development projects and the development organization. There is a process organization responsible for providing and developing methodology, processes and tools and a technical organization responsible for technical coordination and technical decisionmaking.

Material was collected in semi-structured interviews, discussions, workshops, questionnaires and sociometric studies and by following change work and change processes between February, 1994, and September, 1995, in the framework of the IMIT project "Key Competence for Employees and Businesses" (Pnr 8479).

Business Unit: Radar Technology (studied in three phases; A, B and C)

The *Radar Technology* business unit is a development organization responsible for the administration, exploitation, refinement and customer adaptation of one of the company's traditional core technologies. The organization consists of about 50 development engineers and operates two to three larger and several smaller projects in parallel (of which several are pure upgrades of delivered products). All projects can be considered to belong to the same project family and the projects represent all sub-projects in larger projects in the company.

The organization is characterized as Microwave Technology by a focus on several areas and targets and controls this in multiple control processes. In addition to line and project hierarchies, there are two important hierarchies that affect development projects and the development organization. There is a process organization that is responsible for providing and developing methodology processes and tools and a technical organization that is responsible for technical coordination and technical decisionmaking. The strongest hierarchy is the line.

Phase A

Material was collected via a detailed process map and active participation in a change project for re-organizing and re-structuring all operations between April, 1994 and January, 1995, in the framework of the IMIT project "Flows and processes in complex development activities", (Pnr 8439).

Phase B

Material was collected in discussions, semi-structured interviews and dynamic simulations of actual activities in a project conducted between January and June, 1996, in the framework of the IMIT project "System Dynamics in Complex Product Development Processes", (Pnr. 4622).

Phase C

Material was collected in structured interviews and questionnaires among 20 successful development projects in Swedish industry between July, 1996, and October, 1997, in the framework of the project "Best Practice Product Development", (Pnr 4660)

Business Unit: Large Switches (studied in two phases, A and B)

The *Large Switches* business unit is active in a branch in which competitiveness is more and more dependent on process effectiveness. The organization runs development in a certain functionality framework (defined by AXE 10), primarily via market adaptation, further development and creating cost advantages in the development processes. Work on development is thus very much a matter of *"variations on a theme"* and the development projects in large (although not always) are characterized by known technical parameters. Both the targets of the development work (=market demands) and the functionality based on existing platforms are comparatively well known, as are the means for the work (technical solutions, work methods and competence). The complexity lies in changes during execution and organizationally very complex systems. The organization runs a number of projects with the chief purpose of upgrading a technologically successful concept from the middle of the 1970s in order to extend the economic life span and rationalize further customer adaptation. The development projects are forced to bear a great part of the problems associated with the old platform and new development of interfaces and new functionality. The largest projects require 1000-2000 kiloman hours, run for a period of about 24 months and include from 12 to 20 geographically separate development organizations. The organization must take into consideration backward compatibility in the products owing to a very large number of installed systems. Service and maintenance count for a considerable portion of total activities. The organization as a whole has a range of customers from old telephone companies to new, innovative knowledge companies. The projects have no clear customers but are often associated with a number of stakeholders of different characters, from different customer-oriented delivery projects to internal rationalization and upgrading. The organization has a total of 3500 development engineers at 27 different local offices. Development work is however still dominated by a few, very large development projects that account for large parts of the development resources. In phases A and B, the study focused on four generations of a project family. Each project generation has involved over 1000 development engineers and 1300 kiloman hours.

Phase A

Material was collected in interviews and through measurements of activities and communication in three generations of platform development for the new AM switch between September, 1994, and September, 1995, in the framework of the IMIT project "Self Designing Design Teams", (Pnr 4599).

Material was collected in pre-measurements (questionnaires and interviews), participation in change work and the introduction of new work methodology and in post-measurements (interviews) from January, 1994, to June, 1995, in the framework of the IMIT project "Bottom-Up", (Pnr 4478).

Phase B

Material was collected in interviews, measurements of communication patterns and mapping perceived complexity among groups of significant actors in the organization between February, 1996, and June, 1996, in the framework of the IMIT project "Conditions for Convergence in Complex Development Settings". (Pnr 4626).

Business Unit: Increased Network Capacity

The *Increased Network Capacity* business unit involves a project that had been redefined and moved from one organization to another in connection with the redefinition of the project. The project was started in an R&D lab in order to develop a new telecom functionality and, under the time of study, involved approximately 300 persons but was planned to involve about 3 000 000 (engineer) man hours. The project aimed at a new technical arena in which few standards had emerged. After years of delay in comparison with project planning and without technological fulfillment, the organizational setting decided to redefine the project from being a knowledge build-up project to become a partly market-driven project working with market prototyping. In this context, the company transferred the project from a technology-driven unit to a business-driven unit. This was done by using two principal leverages: first, the internal customer was changed in favor of an expansive business area with strong market orientation and, secondly, the development activities became much tighter and centrally co-ordinated, aiming for a time-constrained and more specified functionality. It also involved a shift from an in-house product development strategy towards being a systems integrator and partly developing components in-house.

Increased Network Capacity works with new development and with technologies that are not stable and lack platforms and standards. The organization performed during the time of study one larger and a small number of smaller development projects. It was characteristic for the organization to involve actors from different parts of the world who belong to different organizations. The project studied is one of the larger first-generation projects that involved the greater part of the organization. The project also involved a large number of people at the company's research center that had previously had responsibility for the project.

Material was collected via semi-structured interviews, workshops and discussions between October and December 1994, in the framework of the Ericsson company-wide project "Competence Management Process".

Business Unit: Japanese Systems (studied in four phases: A, B, C and D)

The *Japanese Systems* business unit is a very expansive organizational system that works on the Japanese market. The organization has over 1000 development engineers located in Sweden, Finland and Japan and runs four to six large and a small number of smaller development projects in parallel. Two generations of the large projects were studied, both involving more than 500 development engineers at most and over 500 kiloman hours. The organization has enjoyed a favorable starting point in building up a great many new products from the beginning of 1991 and has in this process been able to adapt its organization and work methods according to experience in previous successful product areas and exploitations of technology. It has been able to take consideration to new ideas and thinking and the specific demands of the new customer. The organization is still sufficiently small for actors to have a good picture of the whole. The largest projects are 400 to 600 thousands of man hours and run over about 18 months, including about five to six geographically separate development organizations. The projects have a strong customer focus and each development of a new product generation is run by one or only a few clear principle customer(s). The projects are mainly based on exploitation, refinement and customer adaptation of established technology but also include a considerable amount of exploration of new methods.

Phase A

Material was collected in semi-structured interviews and discussion between October and December 1994, in the framework of the Ericsson company-wide project "Competence Management Process".

Phase B

Material was collected in semi-structured and structured interviews, discussions and process maps between May and September, 1995, in the framework of the IMIT project "Self Organizing Project Organizations", (Pnr. 4598).

Phase C

Material was collected in interviews, measurements of communication patterns and maps of perceived complexity among groups of significant actors in the organization between February and June, 1996, in the framework of the IMIT project "Conditions for Convergence in Complex Development Settings" (Pnr 4626).

Phase D

Material was collected in semi-structured interviews, participatory observations, communication measurements and arenas for development between January and December, 1997, in the framework of the IMIT project "Dispersion and Sustainability of Best Practice in Product Development", (Pnr 4679)

Business Unit: Japanese Subsystems (studied in two phases, A and B)

The *Japanese Subsystems* business unit works with exploiting, refining and customer adaptation of established technology and also carries out a significant amount of exploration of new methods. The organization has about 100 development engineers and runs two large and a number of smaller projects in parallel. As both the organization and the products for which it is responsible are new, the administrative duties are still small. The project family studied constitutes the basis of the line organization, which is organized as a support function for the projects. The projects that *Japanese Subsystems* runs cover up to 100 kiloman hours and 60 to 70 people during its most active phases. The smaller projects most often are sub-projects in larger projects at the company. The focus of the study was on a second-generation project in a new project family but in its context and relation to previous (first generation) and coming projects (third generation).

Phase A

Material was collected in discussions, semi-structured interviews and dynamic simulations of actual activities in a project between January and June, 1996, in the framework of the IMIT project "System Dynamics in Complex Product Development Processes", (Pnr. 4622).

Phase B

Material was collected in structured interviews and questionnaires to 20 successful development projects in Swedish industry between July, 1996, and October, 1997, in the framework of the IMIT project "Best Practice Product Development", (Pnr 4660).

Business Unit: Central Processor

The *Central Processor* business unit employs some 2000 engineers in the Stockholm region and uses as many in different design centers, primarily in Sweden, Germany and Australia. 65% of the employees have a master degree or more. *Central Processor* is responsible for some of the corporation's platform and core functionalities as the central processor but also central functions as architectural guidelines, methods, tools and training. The central processor is responsible for all communication between program blocks and the regional processors. The organizational setting is the result of the integration of two different organizations from two different parts of Ericsson. One of the organizations and many of its actors has their roots in together with Telia (a Swedish teleoperator) developing the fundament for the successful AXE-system. This organization has also primarily been working with pure R&D issues with internal customers, less focus on cost than functionality and long lead-times. The other organization and its actors that constitute the organizational setting have its roots in being a technological support organization to the *Large Switches* business unit. Many of the engineers engaged in the projects have been employed for 20 years or more in the same organizational setting.

However, the management in both the business unit and the project organization had at the time of study been newly recruited from the *Japanese Systems* business unit to introduce new ways of working to better meet set and emerging targets.

The most important challenge that the organizational setting meet is to reduce physical size and power consumption and in same time dramatic increase processor capacity, improve switching capabilities and ease of operations of the central processor.

Material was collected in semi-structured interviews, participatory observations, communication measurements and arenas for development between January and June, 1997, in the framework of the IMIT project "Sustainability and Dispersion of Best Practice in product Development, (Pnr 4679)

APPENDIX B

The Research Projects Contributing to the Thesis

This thesis is based upon ten different research projects described in chronological order below. All descriptions of the projects and names of organizations stem from the time the research projects were performed. The organizational settings that participated in the projects are all described in Appendix A.

Key Competence for Employees and Companies

An IMIT project (8479) carried out between February 1994, and September 1995.

The main purpose of the project was to analyze connections between strategy, activities and competence in two companies and, in doing so, to find operational descriptions of the concept of organizational learning.

The research team was: Sven-Åke Hörte (project manager), Luleå University of Technology (LUT), Niclas Adler, Peter Docherty, Stockholm School of Economics (SSE), Jan-Åke Granath, Chalmers University of Technology (CUT), Göran Lindahl (CUT) and Claes Tunälv (CUT). The research team also consisted of a number of practitioners; Ove Carstens, Mölnlycke Clinical Products AB (MCP), Arne Filipsson, Ericsson Microwave Systems AB (EMW), Arne Kristoffersson (MCP), Lars Marmgren (EMW), Thomas Olsson (MCP), Jöran Rubensson (SIF), and Claes Svensson (EMW).

The research was based on semi-structured interviews, discussions, workshops, questionnaires, sociometric studies and participation in change initiatives. I was mainly responsible for collecting data and participating in change initiatives in one of the organizational settings, called *Microwave Technology* in this thesis.

The analysis is based on 32 semi-structured interviews of one to three hours with engineers (22), team leaders (4), project managers (2) and line managers (4), questionnaires answered by 54 persons and measurements of communication patterns among 54 persons. Eighteen four-hour and two eight-hour workshops with approximately 10 participants were conducted once a month during the project to discuss and analyze emerging results from the study.

I participated in writing two articles during the project, *Organizational Learning Supported by Collective Design of Production Systems and Products* (Adler, N, Granath, J-Å and Lindahl, G.) presented at the EUROMAconference in Twente, May, 1995, and *Organizational Learning Supported by Design of Space, Technical Systems and Work Organization - A case study from an electronic design department* (Granath, J-Å, Adler, N and Lindahl, G) presented at the 5th International Conference - FAIM ´95 on Flexible Automation & Intelligent Manufacturing in Stuttgart June 28-30, 1995. The two articles are briefly described below.

Organizational Learning Supported by Collective Design of Production Systems and Products (Adler, N, Granath, J-Å and Lindahl, G.)

The ability to adjust to the ever-changing environment is a vital property for companies to stay competitive. To achieve this, companies must have the ability for organizational learning. This paper argues that collective design activities are, under certain circumstances, a tool that manages to take individual and team learning into organizational learning through mobilization around visions and missions and thereby change existing structures and develop old structures into new ones. A number of cases are referred to in order to illustrate the possibilities and obstacles in collective design processes and to show the managerial implications in terms of organizational learning.

Organizational Learning Supported by Design of Space, Technical Systems and Work Organization - A case study from an electronic design department (Granath, J-Å, Adler, N and Lindahl, G)

Companies are seeking new ways to manage learning and competence in order to improve company performance and competitiveness. Researchers and practitioners alike appear to be reaching a consensus that organizational learning is a key strategic variable for coping with this shift. In this paper the organizational issues are also viewed in a technical and spatial context. According to earlier experience we looked for more complex interactions between the use of space, technical systems and the organization of work. Methods used are interviews, a questionnaire and a collective design process resulting in an actual redesign of the premises. The design activity was a learning process that led to a better understanding and ability to continually manage and redesign organization, space and technical systems in order to reach the most appropriate combination between these dynamically dependent production factors.

The project also resulted in a book, *Organisatoriskt lärande [in Swedish],* edited by Sven-Åke Hörte and published by IMIT 1995. This book also functioned as the final report of the project.

Flows and Processes in Complex Product Development

An IMIT project (8439) performed between April 1994, and January 1995.

The main purpose of the project was to participate in and analyze the consequences of a process orientation and an intensified focus on speed in complex product development.

The research team was Sven-Åke Hörte (Project manager), LUT and Niclas Adler. The research team also consisted of a number of practitioners; Kristina Ericsson, Kjell Jarkvist, Mikael Johansson, Bengt Lövung, Jonny Magnusson, Micael Peterson, Roger Petersson and Willy Rasmusson. All from Ericsson Microwave Systems (EMW).

The research was based on detailed process mapping of the flow from idea to customer regarding new surveillance radar and participation in reorganizing and restructuring the organization towards speed in development. I was mainly responsible for all data collection in this project.

The organizational setting participating in the study is called *Radar Technology* in this thesis.

The analysis is based on semi-structured interviews of one to two hours with 31 persons, 16 smaller three-hour workshops with approximately ten participants and two larger workshops with approximately 50 participants.

The project resulted in a final report *Flows and Processes* by Adler, N. and Hörte, S-Å.

Bottom-Up

An IMIT project (4478) performed from September 1994, until June 1995.

The main purpose of the project was to involve a large number of engineers in developing their organizations and to analyze the effects of this involvement.

The research team was: Flemming Norrgren (Project manager) FENIX, Niclas Adler, Sofia Börjesson (FENIX), Horst Hart (FENIX), Sven Kylén (FENIX) and Max Ricciardi, Center for Research on Organizational Renewal (CORE). The research team also consisted of a number of practitioners; Siw Buchmayer, Göran Fröhling, Lars Jönsson, Per-Olof Nyquist and Lars Wiklund, all from Ericsson Telecom Systems AB (ETX).

The research was based on questionnaires, interviews (before and after), participating in change and implementing new ways of working. My role was to participate in follow-up interviews and analyses of the new ways of working.

The organizational setting participating in this project is called *Large Switches* in this thesis.

The analysis is based on 33 fairly structured interviews of approximately one hour with persons that had been participating in the change initiatives and four workshops.

One article was written on the basis of this and earlier projects, *Sociotechnical systems and the development of the knowledge-based company* (Adler, N. and Docherty, P.) presented at the –conference in Melbourne June 1995. The article is briefly described below.

Sociotechnical Systems and the Development of the Knowledge-based Company (Adler, N. and Docherty, P.)

The project also resulted in a final report: *Bottom-Up* by Hart, H. and Norrgren, F.

Competence Management Process

A research project performed between October 1994, and December 1994.

The main purpose of the project was to develop and analyze the use of a method for breaking down strategic goals to critical competencies at different levels of organizations performing complex product development.

The research team were Flemming Norrgren (Project manager) FENIX, Niclas Adler and Horst Hart (FENIX). Practitioners participating in the research project were: Björn Olsson, Ericsson Telecom Systems AB, (ETX), Lars Rydberg, Ericsson Components AB (EKA), Jan-Mikael von Schanz, Ericsson in Finland (LMF), Lars Wiklund, Ericsson Telecom Systems AB (ETX) and Lars Åkeson, Ericsson Radio Systems AB (ERA),

The research was based on semi-structured interviews, workshops and discussions. My role was as one among three in the team performing interviews and participating in workshops and discussions.

The organizational settings participating in this project are called *Increased Network Capacity* and *Japanese Systems* in this thesis.

The analysis is based on 25 semi-structured interviews of one to three hours, two larger workshops and full access to necessary material.

The project resulted in one article, *Leverages and Mechanisms for Learning in Complex Organizational Systems – Three Cases from the Telecommunications Industry* (Adler, N. and Norrgren, F.) presented at the pre-conference meeting at the R&D Management Conference "Knowledge, Technology and Innovative Organisations", Pisa, Italy, 20-22 September 1995. The article is briefly described below.

Leverages and Mechanisms for Learning in Complex Organizational Systems – Three Cases from the Telecommunications Industry (Adler, N. and Norrgren, F.)

The article compare the learning systems in the different organizational settings and shows that different preconditions need to be considered for different types of learning.

The project also resulted in a final report: *Competence Management Process* by Adler, N., Hart, H. and Norrgren, F.

Self Designing Design Teams

An IMIT project (4599) performed between September 1994 and September 1995.

The research team was Horst Hart (Project manager) FENIX, Niclas Adler and Flemming Norrgren (FENIX). Practitioners participating in the research project were Roland Fors (ETX), Göran Fröhling Ericsson Telecom Systems AB (ETX), Per-Olof Nyquist (ETX), Eva Salomonsson, Ericsson Radio Systems AB (ERA) and Sören Olsson (ETX).

The main purpose was to participate in creating and analyzing the results of design teams responsible for designing their own organizations and work processes.

The research was based on interviews, mapping of activities and mapping of communication. My role was to perform most interviews and collect most data.

The organization participating in this project is called *Large Switches* (for further descriptions see above or Appendix A).

The analysis is based on time and activity mapping of 20 persons over a six-month period and semi-structured interviews with 24 persons (of which one project manager and one main project manager were interviewed three times each) and four workshops (one internal with the project team, one internal with main project management, one external with the management team for the business unit and one with others interested and invited managers in the corporation) and 20 questionnaires.

The project resulted in a final report: *Interactive Design Organizations – a study of product development projects at Ericsson Radio Systems and Ericsson Telecom Systems* by Adler, N., Hart; H. and Norrgren, F.

Self-Organizing Project Organizations

An IMIT project (4598) performed between May 1995, and September 1995.

The main purpose was similar to the project above, but a higher organizational level participated in creating and analyzing results from project organizations responsible for organizing and work processes.

The research team was Niclas Adler (Project manager), Horst Hart (FENIX) and Flemming Norrgren (FENIX). Practitioners participating in the research project were Sören Elfsborg, Ericsson Telecom Systems AB (ETX), Hans Karlsson, Ericsson Radio Systems AB (ERA), Mats Karlsson, ERA, Eva Salomonsson, ERA and Sören Olsson, ETX.

The research was based on semi-structured and structured interviews, discussions and process mapping. My role was project manager responsible for research design, coordinating data collection, analysis and validation and performing most of the interviews and collecting most of the data.

The organizations participating in this project were *Japanese Systems* and *Large Switches*.

The analysis is based on mapping communication networks for project management (13 participants), 45 semi-structured interviews (of which 10 were in Japan) of two to four hours, three meetings with project management and seven workshops (two with main project managers at the business unit, approximately 10 participants, one with the project management team, approximately 10 participants, one with invited participants from different parts of *Japanese Systems* and *Large Switches*, 18 participants, one with the management team for *Large Switches*, approximately 25 participants, and two with a design center at *Japanese Systems*, approximately 60 participants) and 20 questionnaires.

One article was written on the basis of the results: *Managing Complexity in Product Development Processes- A comparative study explaining differences in performance and conditions for learning in two R&D organizations in the telecommunication industry* (Adler, N.), presented at the third EIASM conference in Fountainbleu, May, 1996. The article is briefly described below.

Managing Complexity in Product Development Processes- A comparative study explaining differences in performance and conditions for learning in two R&D organizations in the telecommunication industry (Adler, N.)

This study is based on a comparative study of large and in many aspects similar projects in two R&D organizations in the telecommunications industry - one organization that was high performing and continuously improving and one organization that showed medium performance with low conditions for improvement. Key differences between the projects in the two organizations are analyzed and summarized as to how the projects manage actors´ perceived complexity in terms of technical, organizational and business complexity. Perceived complexity is explained in degree of external and internal convergence, dominating value system and degree of projectification.

The project also resulted in a final report: *Managing Complex Product Development or Herding Cats,* Adler, N.

System Dynamics in Complex Product Development Processes

An IMIT project (4622) performed between January 1996, and June 1996.

The main purpose of the project was to use tools to illustrate development feasibility and potential insight to improve the understanding and management of project flexibility and temporal performance in individual development projects.

The research team was Flemming Norrgren (Project manager, FENIX), Niclas Adler, Hans Björnsson (Chalmers University of Technology, CUT), Sofia Börjesson, (CUT), David Ford (Stanford) and Lars Marmgren (FENIX). Practitioners participating in the research project were Stefan Brämberg, Arne Filipsson, Pär Mattisson, Stefan Torkelsson and Bo Venbrandt, all from Ericsson Microwave Systems (EMW).

The research was based on discussions, semi-structured interviews and dynamic simulation of project activities and project phases. I was one of five researchers in the project and performed or participated in performing most interviews and participated in discussions.

The organizational settings participating in the project were *Radar Technology* and *Japanese Subsystems.*

The analysis is based on 20 semi-structured interviews of one to two hours, two meetings with project management and three workshops of three hours each (one internal with the interviewees, approximately 20 participants, one external with the management team for both *Radar Technology* and *Japanese Subsystems*, eight participants, and one external with the extended management team, 30 participants for one hour).

One article was based on this and earlier projects, *Bringing Business into Sociotechnical Practices and Theory* (Adler, N. and Docherty, P.), in the special number of "Human Relations" on "Organisational Innovation and the Sociotechnical Systems Tradition: Challenges for the 90s". The article is briefly described below.

Bringing Business into Sociotechnical Practices and Theory (Adler, N. and Docherty, P.)

Current developments in the sociotechnical framework address a number of vital issues that failed to occupy the high ground in their formative years. These include (1) the purpose of the systems, to create customer value under social and resource constraints, (2) the context or external business environment and (3) the dynamics of the sociotechnical system. Due attention to the dominant issues of purpose, context and their dynamics makes it more meaningful to speak of sociotechnical business systems (STBS) and organizational learning instead of sociotechnical systems (STS) and individual learning. In STBS, each unit in an organization has business responsibilities and goal-based connections to its environment and focuses on the creation of customer value. The implications of this shift from STS to STBS are discussed and illustrated with current research and two summary case studies.

The project also resulted in three final reports:

A Comparison of the XX and the YY Projects by Adler, N., Börjesson, S., Marmgren, L., Norrgren, F., Ollila, S. and Olsson, M.

The Prototype Project Simulation Model by Ford, D.

Project House – A house as a metaphor for project-based development work, by the project group.

Prerequisites for Convergence in Complex Product Development

An IMIT project (4626) performed between February 1996, and June 1996.

The main purpose of this project was to analyze how prerequisites for product development projects were created and whether there were any other more sufficient ways to create better prerequisites.

The research team was Niclas Adler (Project manager), Horst Hart, Lars Marmgren and Flemming Norrgren. All from FENIX. Practitioners participating in the research project were Thomas Axelsson, Ericsson Radio Systems AB (ERA), Siv Buchmayer, Ericsson Telecom Systems AB (ETX), Jan Gustavsson (ETX), Ulf Holm (ETX), Mats Karlsson, (ERA), Mats Köhlmark, (ERA). Kerstin Lilje (ETX), Göran Lindmark, (ETX) and Stefan Svensson (ETX).

The research was based on sway-group interviews, mapping of patterns of communication and mapping of perceived complexity. I was responsible for the project and for performing most interviews.

The organizational settings participating in the project were *Large Switches* and *Japanese Systems* (for further descriptions see above or Appendix A).

The analysis is based on 33 semi-structured interviews of two to four hours and five workshops (two with the management team, one with all interviewed and others interested, one with both management teams, one with invited Ericssons managers) strategy documents and process descriptions of the development process.

The project resulted in a final report: *Konvergens 1997* [in Swedish] by Adler, N., Hart, H. and Norrgren, F.

Best Practice Product Development

An IMIT project (4660) performed from August 1996, to October 1997.

The main purpose of the project was to analyze a larger number of successful product development projects from different contexts to search for generic mechanisms explaining success.

The research team was: Joseph Schaller (Project manager, Gothenburg University, GU), Niclas Adler, Horst Hart (FENIX), Mats Magnusson (FENIX), Flemming Norrgren (FENIX), Susanne Ollila (FENIX), Maria Olsson (FENIX), Niklas Sundgren (CUT) and Lars Trygg (CUT).

The research was based on semi-structured interviews and questionnaires to five to six actors in 20 successful product development projects, with a total of 114 persons participating. My role was to participate in the design of the study and in analyzing the results of the studies.

The organizational settings participating in the project were *Radar Technology* and *Japanese Subsystems*.

The project resulted in a final report: *Industriell FoU – Vad utmärker Best Practice projekt [in Swedish]* by Norrgren, F., Ollila, S., Olsson, M., and Schaller, J., published by IMIT 1997.

Sustainability and Dispersion of Best Practice in Complex Product Development

An IMIT project (4679) performed from January 1997, to December 1997.

The main purpose of the project was to search for mechanisms enabling sustainability and dispersion of new work methods.

The research team was: Niclas Adler and Flemming Norrgren (Project managers), Horst Hart (FENIX), Sven Kylén (FENIX), Mats Lundqvist (FENIX), Mats Magnusson (FENIX), Lars Marmgren (FENIX), Susanne Ollila (FENIX), Maria Olsson (FENIX), Niklas Sundgren (CUT) and Gunnar Westling (FENIX). Practitioners participating in the research project were Thomas Axelsson, Ericsson Radio Systems AB (ERA), Gunnar M Eriksson, Mats Karlsson, Ericsson Utvecklings AB (UAB).

The research was based on semi-structured interviews, participative observations, mapping of communication and arenas for co-ordination. My role was participating in the design of the study and in analyzing the results of the studies.

The organizational settings participating in the project were *Japanese Systems* and *Central Processor* in this thesis.

One article was based on this and earlier projects, *Integration Driven Development – How Ericsson gained foothold in the Japanese Telecommunication Market* (Adler, N., Hart, H., Lundqvist, M., Marmgren, L. and Norrgren, F.), forthcoming in the International Journal for Product Innovation Management. The article is briefly described below.

Integration Driven Development – How Ericsson gained foothold in the Japanese Telecommunication Market (Adler, N., Hart, H., Lundqvist, M., Marmgren, L. and Norrgren, F.)

This article explores how radically new and successful work practices were applied by the Swedish telecommunications company Ericsson, when faced with extremely challenging development tasks and determines how these practices require an alternative theoretical foundation and new conceptualizations to be understood. The article presents three years of extensive empirical studies of development work in what in the corporation has been denoted the *"Japanese projects"*. The main point made is that the way in which Ericsson has gone about achieving repeated success differs substantially from normal practice (inside and outside the corporation). A central distinction is found in the way uncertainty is seen as a means for bringing about dialogue and integration of work rather than a problem that should have been reduced beforehand, to a large extent. The article argues that the empirical findings in this highly successful case constitute strong empirical evidence for a paradigm shift for the management of complex product development.

The project also resulted in a final report: *"Lärande och spridningsmekanismer inom produktutveckling" [in Swedish]* by Westling, G.

The Integrated Set of Projects

The thesis is based on close cooperation with the seven organizational settings during the calendar time specified in each project above. However, a number of practitioners from the studied organizational setting have played an important role, from the time of the first contact to the last written lines. Six of seven of the studied organizational settings have been revisited after the research projects have ended, and some of the studied organizational settings have continuously been sources of inspiration.

EFI
The Economic Research Institute

Reports since 1995

Published in the language indicated by the title

1999

Andersson, P., Experto Credite: Three Papers on Experienced Decision Makers.
Ekman, G., Från text till batong – Om poliser, busar och svennar.
Eliasson, A-C., Smooth Transitions in Macroeconomic Relationships.
Flink, H., Gunnarsson, J., Wahlund, R., Svenska hushållens sparande och skuldsättning– ett konsumentbeteende-perspektiv
Gunnarsson, J., Portfolio-Based Segmentation and Consumer Behavior: Empirical Evidence and Methodological Issues.
Hamrefors, S., Spontaneous Environmental Scanning.
Helgesson, C-F., Making a Natural Monopoly: The Configuration of a Techno-Economic Order in Swedish Telecommunications.
Japanese Production Management in Sunrise or Sunset. Christer Karlsson (editor).
Jönsson, B., Jönsson, L., Kobelt, G., Modelling Disease Progression And the Effect of Treatment in Secondary Progressive MS. Research Report.
Lindé, J., Essays on the Effects of Fiscal and Monetary Policy.
Ljunggren, U., Indikatorer i grundskolan i Stockholms stad före stadsdels-nämndsreformen – en kartläggning.
Lundbergh, S., Modelling Economic High-Frequency Time Series.
Mägi, A., Store Loyalty? An Empirical Study of Grocery Shopping.
Mölleryd, B.G., Entrepreneurship in Technological Systems – the Development of Mobile Telephony in Sweden.
Nilsson, K., Ledtider för ledningsinformation.
Rognes, J., Telecommuting – Organisational Impact of Home Based – Telecommuting.
Sandström, M., Evaluating the Benefits and Effectiveness of Public Policy.
Sjöstrand, S-E., Sandberg, J., Tyrstrup, M., (red) Osynlig Företagsledning.
Skalin, J., Modelling Macroeconomic Time Series with Smooth Transition Autoregressions.
Spagnolo, G., Essays on Managerial Incentives and Product-Market Competition.
Strauss, T., Governance and Structural Adjustment Programs: Effects on Investment, Growth and Income Distribution.
Svedberg Nilsson, K., Effektiva företag? En studie av hur privatiserade organisationer konstrueras.
Söderström, U., Monetary Policy under Uncertainty.
Werr, A., The Language of Change The Roles of Methods in the Work of Management Consultants.
Wijkström, F., Svenskt organisationsliv – framväxten av en ideell sektor.

1998

Andersson, M., On Testing and Forecasting in Fractionally Integrated Time Series Models.
Berg-Suurwee, U., Styrning av kultur- och fritidsförvaltning innan stadsdelsnämnds-reformen

Sandin, R., Heterogeneity in Oligopoly: Theories and Tests.
Sandén-Håkansson, U., Från kampanjmål till mediemix - en studie av samarbete mellan annonsörer, reklambyråer och mediebyråer. Research Report.
Stein, J., Söderlund, M., Framgång i arbetet, strategier för att utföra arbetsuppgifterna, arbetsuppgifternas karaktär och utbildningskvalitet. En empirisk studie av civil-ekonomer. Research Report.
Strömberg, P., Thorburn, K., An Empirical Investigation of Swedish Corporations in Liquidation Bankruptcy. Research Report.
Söderlund, M., Och ge oss den nöjda kunden. En studie av kundtillfredsställelse och dess orsaker och effekter. Research Report.
Thodenius, B., Användningen av ledningsinformationssystem i Sverige: Lägesbild 1995. Research Report.
Ulfsdotter, U., Internationalisering för expansion eller hemmamarknadsförsvar? De nordiska marknaderna för fruktyoghurt 1982-1994.
Westelius, A., A Study of Patterns of Communication in Management Accounting and Control Projects.
Wijkström, F., Den svenska ideella sektorn och pengarna. Research Report.
Örtendahl, M., Health and Time - A Problem of Discounting.

1995

Becker, T., Essays on Stochastic Fiscal Policy, Public Debt and Private Consumption.
Blomberg, J., Ordning och kaos i projektsamarbete - en socialfenomenologisk upplösning av en organisationsteoretisk paradox.
Brodin, B., Lundkvist, L., Sjöstrand, S-E., Östman, L., Styrelsearbete i koncerner
Brännström, T., Bias Approximation and Reduction in Vector Autoregressive Models. Research Report.
Ekonomisk politik i omvandling. red. Jonung, L.
Gunnarsson, J., Wahlund, R., Hushållens finansiella strategier. En explorativ studie.
Höök, P., Chefsutveckling ur könsperspektiv - Mentorskap och nätverk på Vattenfall - Research Report.
Levin, J., Olsson, P., Looking Beyond the Horizon and Other Issues in Company Valuation. Research Report.
Mägi, A., Customer Statisfaction in a Store Performance Framework. Research Report.
Persson, P-G., Modeling the Impact of Sales Promotion on Store Profits.
Roman, L., Institutions in Transition. A Study of Vietnamese Banking.
Sandberg, J., Statistisk metod - dess vetenskapliga hemvist, grundläggande principer och möjligheter inom samhällsvetenskapen. Research Report.
Sandberg, J., How Do We Justify Knowledge Produced by Interpretative Approaches? Research Report.
Schuster, W., Redovisning av konvertibla skuldebrev och konvertibla vinstandelsbevis - klassificering och värdering.
Söderberg, K., Farmartjänsten - Ny kooperation inom lantbruket. Research Report.
Söderqvist, T., Benefit Estimation in the Case of Nonmarket Goods. Four Essays on Reductions of Health Risks Due to Residential Radon Radiation.
Thorén, B., Användning av information vid ekonomisk styrning - månadsrapporter och andra informationskällor.

What is FENIX?

FENIX is a network organization that integrates academic research, business creation, and an executive PhD education. FENIX was initiated in autumn 1998 and the primary objective is to build lasting links between academy and industry through the development of knowledge that is of practical relevance. The main actors involved in this co-operation are the Stockholm School of Economics, Chalmers University of Technology, the Institute for Management of Innovation and Technology, Astra Hässle, Ericsson, Telia, and Volvo.

FENIX is mainly financed by Foundation for Knowledge and Competence Development and by industry.

The aim of the executive PhD programme is to train leaders to foster growth and renewal in tomorrow's businesses. Project based research activity in FENIX is organised around three broad yet interrelated themes:

1. Knowledge Management and Learning - in temporary organisations
2. Managing Complexity – especially in R&D projects
3. Business Creation – within established structures as well as new firms.

A leadership perpective is applied for each of these research themes.

The Myth of the FENIX bird

The Fenix was a fabled bird in Greek mythology. The story, which exists in several versions, tells of a bird with brilliant gold and reddish-purple feathers, as large or larger than an eagle. According to some Greek writers, the Fenix (or Phoenix) lived for exactly 500 years. At the end of each life cycle, the Fenix burned itself on a funeral pyre. Another Fenix then rose from the ashes with renewed youth and beauty, more noble and unique than before.

The long life of Fenix – also known as the firebird – and its dramatic rebirth from its own ashes, made it a symbol of immortality and rebirth. It was regarded as the companion of wisdom and knowledge. When the Fenix makes its appearance, it represents the characteristics of regeneration and renewal.