MANAGING COMPLEX INDUSTRIAL PROJECTS
A COMPARISON BETWEEN HOLISTIC MODELS

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Abstract

Even though the management of large projects has been studied for many years, the track record is still poor, especially for those projects developing complex systems. This thesis studies projects such as these and attempts to find clues as to why some succeed while others do not. Among the challenges, is the specific yet basic need to create a shared understanding in a group of hundreds engineering specialists with their own ideas (biases) of how things actually work. Further, complex development projects are likely to change, especially those projects involved with new technologies that should be state of the art when they hit the market after several years of development time. Thus, there is a need for a tool that can be used to adapt to changes.

An important part of this thesis is the evaluation of different diagram systems that have been used in different development projects. These diagrams function as a device to create a shared understanding of the project and enable those involved to maneuver the project through changes. The evaluation focuses on what the diagrams can express and how easy it is to understand their content. In terms of expressiveness, one of the three evaluated models: the Anatomy Model, answers the largest number of questions relevant to the total project manager. In terms of ease of use, the evaluation shows that the Anatomy did not only answer more questions relevant to the total project manager, but was also easier to maneuver through compared to the alternative models. The thesis concludes that when working with complex development projects, a model like the anatomy provides the project manager with a simple tool that can be used to maneuver through changes and create a communal understanding. Such a simplified model addresses more questions that are relevant to the project manager and is easier to update than the traditional tools that are suggested in most literature.

Key words: Project Management, Complex Project, Anatomy, Dependency Diagrams.
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Chapter 1
Introduction and Summary

1.1 BACKGROUND

The management of projects is probably among the most important economic and industrial activities in modern society [Söderlund 2000]. Projects are used to create, shape and change the structure of society [Morris 1994] and activities in many firms. The scope of this thesis covers the projects developing complex products and systems. Such development projects play a significant role in maintaining competitiveness in most industries today.

The dominant approach to managing complex development projects originates from the fields of civil engineering and later the defense industry. The approach was developed during the 1950s and the 1960s [Morris 1994, Engwall 1995] by practitioners, but it wasn’t until management researchers began being interested in the area of project management in the 1970s that methods were rigorously developed. The idea behind the original approach was to establish a consistent method to meet the new demands of delivering a great deal of goods and services in a short period of time.

Throughout the years, numerous methods and techniques have been developed on various aspects of managing projects from initiation to completion. Despite the enormous attention project management has received during this period, the track record of projects is fundamentally poor, particularly for the larger and more difficult ones [Morris and Hough 1987]. Studies of project failure, such as the CHAOS-report [Standish Group 1999], have indicated that the early phases of projects do not get enough attention, meaning that companies have been unable to make satisfying requirement specifications, rigorous plans and system design before the execution of the project is initiated. Despite the intensified focus on requirements engineering and planning throughout the years, performance has failed to meet expectations [Standish Group 2004, RRV 1999]. The larger and the more complex
the product development task, the poorer the performances seem to be. Even in the best managed companies, initially set targets concerning time, cost and performance are not achieved – in fact, only on rare occasions is even a single one of the initial set targets held. Since today’s most powerful customers 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.

In this environment, project managers in system development companies invent, or try different methods to improve the results of the project. In most system development efforts however, it is not more descriptions of what is to be developed that are needed. Even if it would be possible to achieve better requirement specifications, the changes that come into play throughout the project will change them. Further, most often there are enough specifications on all the different parts of the system [Taxén 2003]. Using the traditional approach of work breakdown structure, all parts of the system are described in detail. However, there are no comprehensive views of how the system actually works as a whole that can be used in the communication with the customer, top management, and the different experts and developers involved in the system’s development.

In studies of successful system development projects conducted within the research presented in this thesis, the use of holistic models capturing the dependencies between different system parts seem to be a common success factor. However, such models have not been part of the project management manuals at these companies. Moreover, many of the models and their supporting methods created by project managers are forgotten once the project is dissipated and/or the project manager is promoted for doing a good job. Is this because the model has been of little or no use, or because of a lack of knowledge of the significant importance of these models? This thesis investigates two models that visually capture the dependencies in system development efforts used by two large Swedish companies. The first model is called the dependency diagram, and is an interface chart showing the dependencies and internal deliveries between different system components. The second model, called the anatomy is a construct that, in a compact way, shows the crucial functional dependencies in the system. The models are analyzed and compared to the dominant method of work breakdown structure.

1.2 RESEARCH QUESTION

The purpose of the research has been to understand why these two holistic models have been deployed and used instead of the method advocated in corporate project management models. In order to understand the surrounding of the models and why they are used, the research process has undergone three steps. The first step: to study complex system development projects to achieve an understanding of the problems and needs of these efforts. As stated above, two models that had a profound practical impact and were considered successful by the practitioners were chosen for further evaluation. The second step: to
analyze the characteristics of these two models. The third step: the model that was found to be the best in step two, the anatomy, was further evaluated. Since the model had been used differently in different projects, an attempt to theoretically describe the model was performed. For each step a question was formulated in order to guide the work:

Q 1: What are the needs of complex system development projects?
Q 2: Which are the unique features of holistic models?
Q 3: How is the anatomy theoretically grounded?

1.3 RELATED WORKS

There are several academic disciplines that deal with the complexity of managing system development related to the present research. The single most important one is found in the project management community. This is the topic of the first subsection below. Other relevant disciplines such as Systems Engineering and Organizational Theory are summarized in the second subsection.

1.3.1 PROJECT MANAGEMENT

The discipline of project management originates in the construction and defense industry. Its ideas build upon the accumulated experience and knowledge of project managers who have carried out one or more successful projects.

The literature within this discipline strongly emphasizes the importance of systematic planning and structuring of project work tasks [Cleland and King 1988, Meredith & Mantel 1995, PMBoK 2000, Kerzner 2001, Milosevic 2003, Pinto and Morris 2004], which are clearly considered a prerequisite for having the right activities in the correct order. The original approach to structure projects is called Work Breakdown Structure (WBS). WBS is used for identifying which work must be done in a systematic manner. However, WBS is only the first step in the formal project-planning process in project management literature. The literature suggests that subsequent steps include: identifying relationships between activities, determining the logical order in which activities occur, ascertaining when each respective activity must be completed in order for the next one to begin, calculating the elapsed time and quantity of resources required for each activity, and deciding who will bear the responsibility for the activities.

The dominant methods for planning a project are the network planning techniques known as PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) [Cleland and King 1988, Meredith & Mantel 1995, PMBoK 2000, Kerzner 2001, Milosevic 2003, Pinto and Morris 2004]. These techniques were developed in the late 1950s and PERT/CPM shows graphically the sequence of, and relationships among, the individual work tasks that are required for the completion of a project [Engwall 1995]. The network consists of activities, momentary events and the dependencies between events and activi-
ties. Network planning technique strives to identify the critical path of the project. The critical path is the longest sequence of depending activities, and calculating the time of this path will give the shortest possible time to complete the project. When the critical path is identified, all other activities in the project are scheduled based upon the assumption that the shorter the “running time”, the greater the amount of resources required; and conversely 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. The drawback with PERT and CPM in terms of complex system development, is that they are based upon the assumption that the functionality of the finished products is given; assuming the only elements that need to be manipulated are time and resources.

Goldratt [1997] is one of those who criticize the dominant approach, and advocates the critical chain method (CCM). CCM addresses two of the key problems of critical path methods – the inherent uncertainty of task durations and the associated opportunistic behavior in establishing the true duration of tasks, and the resourcing of tasks. In CCM, the critical chain is the longest resource constrained path through the network, theorized as a constraint to be elevated. Thus a critical chain looks like a critical path, but it includes resourcing in the dependencies [Winch and Kelsey 2005].

The current dominant ideas and concepts within the project management discipline are put forth by practitioners who are individual project managers, by international special interest associations such as the Project Management Institute (PMI) or International Project Management Association (IPMA) or local interest groups belonging to these organizations, or software producers of support systems. The most prominent literature in the field is based upon the accumulated experience gained from project managers who continue to be active in the real-world applications of these principles [Kerzner 2001, Meredith & Mantel 1995, PMBoK 2000, Forsberg et al 2000].

1.3.2 ADJACENT DISCIPLINES

Even though it can be presented as a discipline in its own right, Project Management can be seen as a mishmash of several other disciplines in cooperation. The trick for Project Management boils down to how all of these other theories are to be combined. Below a short account is given of related work that has had impact on the present research, but which is not labeled project management. The aim is not to explain the references, but merely to give the reader background into the mindset of this thesis. However, the multidimensional aspect of project management implies that many more disciplines than the ones stated below could be considered adjacent disciplines.

Systems engineering is a discipline that has been developed in parallel with project management [Hughes 1998]. Both disciplines were somewhat defined in the large U.S.-military programs in the 50s. While project management spread and was mainly developed in the private sector, the discipline of systems engineering was mainly developed in the military.
Systems engineering is the interdisciplinary approach governing the total technical effort required to transform a requirement into a system solution. It focuses primarily on technical planning in the front end of the system’s life-cycle and for verifying that plans are met at the projects end [DERA 1997, INCOSE 2000, Stevens et al. 1998]. A comprehensive introduction to systems engineering in the context of project management is given in Eisner [1997].

Software engineering is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software. A general coverage of software engineering is for instance found within Pressman [2000] and IEEE’s Software Engineering Body of Knowledge [2001]. Examining the area closer, influential sub-disciplines include for instance: requirements engineering [Davies 1993, Macaulay 1996, Kotoyna and Sommerville 1998]; development processes and software project management [Brooks 1995, Royce 1970, Boehm 1988] and the closely related topic of configuration management [Leon 2000, Berczuk and Appelton 2003] both engaging in organizational issues and workflow dealing with the connections to users and their organizations, and is thus related to the project management discipline in general. The sub-disciplines that are most closely related to the present work are software design and modeling, and in particular object oriented approaches including use-cases, which by some practitioners is considered similar to one of the models examined in this thesis [Jacobson et al. 1992, Booch 1991].

Both software engineering and systems engineering are related to project management, all three disciplines address the complexity of systems (or software systems) and have different models to manage the complexity. However, systems engineering and software engineering focus on the technical aspects of the system to be developed, and leave out aspects such as integrating the various engineering specialties and design groups, i.e. project management focuses more on the communication between people.

Other works that are related to this thesis are those studying the management of complex development projects (or product development) and especially focusing on coordination. Different approaches to manage product development are covered in Adler [1999], who studied several projects at Ericsson. Adler also reports on the use of the System Anatomy Concept in one of the studied projects. Another aspect of coordinating complex development projects is covered in Danilovic [1999], who in his theses reports on the use of a Dependency Structure Matrix in the development of an aircraft. The use of matrices in system modeling can be traced back to Warfield in the 1970s, but it was not until 1990s that the method received attention and spread. However, the Dependency Structure Matrix is used for analyzing dependencies in product development, and it is not used to promote communication throughout the project in the same way as the models reported on in this thesis. Malone and Crowston [1994] define the “Coordination Theory” in which they state that “problems arise when dependencies goes unmanaged”. As a suggestion to this they advocate different processes to manage different dependencies. In this thesis, their work is used to evaluate the models examined, but their suggested processes to manage dependen-
cies are beyond the scope of this thesis. Finally, the work of my colleagues at the department, whose research architecture based models for decision making, has been an influence throughout this research project. Their work focuses on how the CIO (Chief Information Officer) can use Enterprise Architecture in order to manage and coordinate IT related concerns, see for instance Ekstedt [2004] and Johnson [2002]. The role and the concerns of the CIO are in terms of this thesis however, more similar to that of a project sponsor rather than the project manager as discussed in this thesis.

1.4 THE THESIS

This thesis consists of the chapter Introduction and summary and the seven below listed published publications.

Paper A - How to Manage Complex, Multinational R&D Projects Successfully
M. Eriksson, J. Lilliesköld, N. Jonsson and D. Novosel,

Paper B - Starting a Global Project: What is Different Compared to a “Normal” Project?
M. Eriksson, N. Jonsson, and J. Lilliesköld

Paper C - Coordinating dependencies in complex system development projects
J. Lilliesköld

Paper D - Making Project Complexity Understandable: The Elegance of Notations
M. Ekstedt, P. Johnson, J. Lilliesköld and N. Jonsson

Paper E - Coordinating dependencies in global system development projects – The use of dependency diagrams
J. Lilliesköld and Dr. L. Taxén

Paper F - Manifesting Shared Affordances in System Development – the System Anatomy
Dr. L. Taxén and J. Lilliesköld
Paper G - Managing complex development projects – a case study of the use of the system anatomy
J. Lilliesköld, Dr. L. Taxén, and M. Klasson

1.4.1 THE MAIN CONTRIBUTION OF THE THESIS
The main contributions of the present work are found in the seven included papers; paper A – G. The figure presented below attempts to show the relation between the research questions, contributions, and papers.

![Figure 1 – The relation between papers and research question](image)

Q1: What are the needs of complex system development projects?
In order to identify the needs of complex system development projects, the success factors of such projects were studied. The total amount of needs identified within this contribution are found within paper A, paper B and paper G. In particular, the research has identified the following necessities: 1) neutral and easy to use tools to improve communication be-
between different actors involved in the system development; 2) an additional project supporting group, besides the normally used steering committee, that can make fast decisions when necessary; 3) an engineering process that can adapt to changing requirements; 4) implementation of a push-and-pull concept, where responsibilities becomes clear and where there is a receiver for every internal delivery from the beginning of the project to the final system solution; 5) a shared understanding of project goals; and 6) an instrument that can coordinate the involved actors’ actions, while still allowing them to employ the tools and methods they normally use (This last need of a holistic model has been the subsequent focus of the following research).

Q 2: Which are the unique features of holistic models?

In order to address this question two holistic models were evaluated. The total set of contributions is found in paper C, paper D, and paper E. The difficulties of understanding and using models are determined by the expressiveness and the ease of use of the employed notations. An amount of information can be expressed more or less successfully using verbiage and symbols to communicate knowledge to others. In order to compare different models, firstly a general concept called elegance is introduced for measuring the relation between expressiveness and ease of use of models (or rather meta-models). (Paper D)

In terms of expressiveness, three models are evaluated: the dependency diagram (used at one company studied and described in paper A, C and E), the system anatomy (used at another company studied and described in paper C, E, F and G) and the Gantt-chart (the original model described in paper E). Following the method developed in paper D it can be shown that the anatomy model answers the largest number of questions relevant to the total project manager (Paper E). Further, the dependency diagram and the system anatomy are theoretically evaluated on what they can express in terms of the coordination theory [Malone and Crowston 1994]. Both diagrams were found to only focus on two (out of three) types of dependencies. (Paper C)

In terms of ease of use, the evaluation in Paper E also shows that the anatomy did not only answer more questions relevant to the total project manager. It was also easier to find the answer in the anatomy compared to the alternative models.

Q 3: How is the anatomy theoretically grounded?

The system anatomy is a construct that, in a compact way, shows the crucial functional dependencies in the system. Since it has had a profound practical impact, it is analyzed how this construct can be grounded theoretically. Paper F presents grounding in which the anatomy and its associated plans are seen as manifestations of affordances. These affordances enable different groups of actors to reconcile their actions. The findings indicate that the suggested theory is a promising socio-technical approach that may complement existing approaches for the development of complex systems.
1.5 Research within Project Management

This subsection covers the methodological aspects that have guided the present work. The first part of the subsection contains a general discussion on how research is and can be performed within project management. The second subsection covers the particularities of how the present work has been conducted.

Project management research is still at an early stage; and it is still fragmented. Lundin et al [1992: in Söderlund 2002] states that one of the reasons why the theoretical knowledge of project management is still very fragmented is that project management is a research area that suffers from lacking a natural home-discipline. Researchers from many disciplines, such as engineering, business schools, organizational theory, behavioural science etc. are doing research in the area. Consequently, research approaches varies with the different disciplines. In order to describe research approach that have been guided the present work, this section is divided in the areas of research method, case studies and data collection.

1.5.1 Research Method

Research methods can be classified in various ways. However, one of the most common distinctions is between: qualitative and quantitative methods [Myers 1997].

Quantitative research methods were originally developed in the natural sciences to study natural phenomena. In time, quantitative methods have become well accepted in the social sciences, including survey methods, laboratory experiments, formal methods (e.g. economics) and numerical methods such as mathematical modeling [Myers 1997]. In quantitative research the design is finished before the collection begins, and the data collected is usually in the form of numerical data. [Merriam 1994]

Qualitative research methods were on the other hand, developed in the social science to enable researchers to study social and cultural phenomena. These methods are for instance case study research, action research, and ethnography. Qualitative data sources include observations and participation observation, interviews and questionnaires, documents and texts, and the researchers’ impressions and reactions [Myers 1999].

In project management research, both qualitative and quantitative research approaches are used, depending on the topic studied. Quantitative methods are used when the research focus on the assignment of measures to studied phenomena, e.g. the number of days to a deadline. Qualitative reasoning is instead, focused on the multitude of characteristics of a phenomenon that cannot be measured. An example of a qualitative study is then the effect on quality of life of projectified society.

This research effort is based mainly on the qualitative case study method. A qualitative method is appropriate since qualitative data focus on naturally occurring, ordinary events in natural settings. Because of its data collecting methods it is well suited for locating the meanings people place on events, processes, and structures of their lives, i.e. their percep-
tions, assumptions, prejudices, presuppositions and for connecting these meanings to the social world around them. [Miles 1984] In brief, qualitative research methods are designed to help researchers understand people and the social and cultural context within which they live [Myers 1997]. Since project management research is multi-disciplinary, ranging from social sciences to mathematics and engineering sciences, a qualitative method is well suited. Another reason for choosing qualitative research is that coordination of complex system development projects make sense only in the context of the purpose to which they are employed. This implies that the units of analysis will be fairly complex, such as a large-scale telecommunication system in an organizational context, and therefore a qualitative research approach is the most well suited strategy. Apart from the above stated reasons a qualitative method is appropriate to use if there is a lack of theories in the research domain and absence of empirical arguments. This since qualitative methods is good at discovery, exploring a new area and developing hypotheses [Miles 1984].

The choice to use case study methodology is supported by Yin [1994] who stresses that a case study is appropriate when explorative questions such as “why” and “how” are asked, and when a modern phenomenon is in focus, which is the case in this thesis. Yin [1994] advocates that a case study approach is especially appropriate when the studied phenomenon is inseparable from its environment and the environment is difficult to control, which is also the case in studies of coordination of complex system development projects.

1.5.2 Case Studies

Although there are numerous definitions, Yin [1994] defines the scope of a case study as follows:

“A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”

Thus, a case study is an investigation of specific real-life phenomena, such as individuals, organizational or managerial processes, programs, and organizational change. Clearly, the case study research method is very well suited to global project management research, since the object of the discipline is concerning organizational and human issues rather than technical issues.

This research effort has been strongly influenced by suggestions from Yin [1994]. Yin advocates the use of a case study protocol to document the research process. It is important that the protocol is written at the start of the project, taken into account, and then updated continuously. During the course of data collection, multiple sources of evidence are used. This means that several sources: e.g. documentation, interviews, observations, is used to get a clear picture of the studied phenomenon. Triangulation is usually used to verify that the data actually is valid. Triangulation is the process of confirming that all pieces of information point to the same fact. Data analysis can start as soon as the relevant parts of data collection are finished.
The main criticism of case study methodology is that early case study research efforts have lacked rigor and that it has sometimes not gained creditability since the research procedures were not made explicit. Therefore, the readers of the study could not judge the soundness of the effort. In response to the critique, Yin has suggested a framework for case study research. Another weaknesses, according to Galliers [1992], and Yin [1994], are the case study’s restriction to a single event or organization, and that it is difficult to acquire similar data from a statistically meaningful number of similar organizations in order to make generalizations. To reduce the impact of these weaknesses, Yin [1994] suggests the use of multiple case studies. Multiple case studies also minimize the risk that the “wrong” cases are chosen, which will lead to incorrect conclusions. Other weaknesses are that a case study strategy is too time-consuming and craves too much documentation.

1.5.3 Data Collection

Interviews and surveys with open-ended questions are a common way of gathering data. The method is characterized by qualitative data collection where the researchers ask questions directly or indirectly via a survey or questionnaire, to a respondent. The design of the survey or questionnaire to use is very important. The design must be done with care in order to ensure that the correct operational measures for the studied object are covered by the question.

When interviews are performed as research, it is important to include questions that clarify the respondent’s personal views in the matter, in order to correctly interpret the replies. Further, it is important that the respondent feel comfortable with answering questions on his/her involvement in the studied events in order to get honest and unbiased replies to the questions.

The analysis should be free from subjective reasoning and bias. Further, it is possible to perform quantitative analysis of data collected through interviews and surveys. As an example of this, the number of respondents’ reference to a specific event in the studied project can be counted. Irrespectively of whether a qualitative or quantitative analysis is done on the collected data, the data can then be compared to the operational measures.

1.6 Design of Present Research

One of the criticisms of case study research is, as mentioned above, that the procedures have not been explicit enough. In this section, the author attempt to address the critique by thoroughly explaining how the research was conducted. The work with this thesis has been divided into four parts. The first two parts were documented in a licentiate thesis by Lillieskold [2002]. Part III concerned communication problems in complex development projects. Part IV investigated and evaluated two models that were referred to as state-of-the-practice in part II, III and the secondary studies.
1.6.1 **Case Study Descriptions**

Part I included four case studies of problems in procuring, developing and delivering complex industrial systems. These studies were carried out through 1998-2001. The studies investigated four different projects; two of these were in the energy producing industry looking at the building of two new energy plants; and the other two within the pulp-and-paper industry investigating two renewal projects of an existing plant. All four case studies were conducted in close co-operation with the industry, and the different perspectives of clients, suppliers, contractors, and consultants were examined. Furthermore, the collected data has been extended with a series of interviews with executives to further explore system development and system procurement.

Part I was performed in two rounds, both following three steps with 1) a comprehensive literature review, 2) two case studies, and 3) supplementing interviews. In the first step, a literature search of the experiences from international and Swedish projects carried out during the last years was undertaken. Then, in the second step two complementing case studies in each round were chosen. The case studies were interesting since the clients had chosen totally different approaches in the management of the projects. The last step in the data gathering was a series of interviews made with key personnel of the different actors in the industry, such as consultants, entrepreneurs, clients, and suppliers. In total, 33 interviews were made in Part I. Further, we had access to all project documentation such as specifications, contracts, meeting protocols, etc.

Part I contributed to the state-of-the-practice description of: 1) procurement trends in the basic industry of Sweden, and 2) who could be responsible for project management and systems engineering in complex industrial projects. Further, part I contributed to increase...
the prerequisite state-of-the-practice in the management of industrial projects, and was used as a profound to latter studies.

Part II focused on complex system development projects. One case study was conducted 1999-2000 at a system supplier. The case study examined the third development project, out of a series of three, which the system supplier carried out with a similar scope. The case was interesting, since the supplier failed to meet the scope, cost, or time constraints in the first two projects, while the last project met its scope, was delivered on time, and was considered by the supplier to be a success. In this study, 4 interviews were made. Further, one of the researchers had also been actively involved in the two failed projects, and was still granted access to the project database and all project relevant data. The most interesting question is what in particular attributed to the success of the third project.

Part II contributed with a state of the practice description of problems and success factors in global industrial development projects. One of the success factors, the use of a dependency diagram was further examined in the latter studies. The results from part I and part II was reported in a Licentiate thesis [Lilliesköld 2002] and in paper A.

Part III focused on the communication of global development project, i.e. projects were the project members have different cultural background and are distributed to different locations all over the world. This part included one case study examining problems in global communication and the tools used to promote global communication. Thus, the study did not focus on one single project, but on the experience of the project managers and project members that was interviewed. In the case study, 9 interviews in four companies were performed, and in parallel with the case study, secondary case studies were performed as well.

Part III contributed with a description of the communication problems in global industrial projects. It also provided survey of the different communication tools used in projects and its advantages and disadvantages. The results from part III was reported in paper B and in one of the secondary case studies [Hessel 2003].

Part IV focused on analyzing two different tools that was found as state-of-the-practice in the prior studies; the system anatomy and the dependency diagram. The two tools were analyzed in two different ways. First, using Coordination theory developed by Malone and Crowston [1994]; and second, using a framework custom-built for the evaluation of these kind of models. The framework is based on the expressiveness on a given notation and the ease-of-use of the same. Finally, a case study was performed, further describing the notation that was found as the most promising: the system anatomy. One of the first projects using the concept was studied. This study was mainly based on written material, studies by others [Adler 1999, Westling 2002, Taxén 2003, and Anderstedt et al. 2002] and project documentation. However, one interview was conducted to make sure that what we found in the documentation was correct, and further the outcome of the study was reviewed by the Total Project Manager of the project.
Part IV contributed with a framework to examine different models reported in paper D; and an evaluation of two state-of-the-practice models for coordinating complex system development projects, the dependency diagram and the system anatomy reported in paper C, paper D and paper E. Further, it contributed with a description of the model that was considered the best out of the two, the system anatomy, and the context in which it was developed reported in paper G. Finally, it contributed with a theoretical grounding of anatomy reported in paper F.

1.6.2 SECONDARY STUDIES

Within the framework of this research project a number of Master projects have been conducted under the supervision of the author. Below the masters’ projects that have contributed the most to the work are outlines and their contributions are presented.

**Project Management Method Critical Chain in reality - An empirical study of a development project at Ericsson Utvecklings AB**

A study conducted by Galmén [2001] of the first implementation of Critical Chain in a development project at a major telecommunication system supplier. Critical Chain is a relatively new multi-project management method. Its main goal is to shorten lead-times and increase project capacity. The concept introduces a new way of handling uncertainty and finding the projects constraint. The thesis effort surveyed and evaluated the implementation. The aim of the study was to discuss benefits and weaknesses in the methodology and identify problems in the implementation. The investigation is based on 30 interviews of people in and around the project. The conclusion was that there was a positive attitude to both the methodology and future implementations among project members. There have been problems in the implementation and there are weaknesses in the methodology, but they do not seem to harm projects, only lower the benefits from Critical Chain. The investigation also shows that the project have had a number of benefits from Critical Chain. The contribution to this thesis was in the area of using alternative methods to the traditional Work Breakdown Structure. The study was of special interest since Critical Chain Method could be stressed to be an alternative to the methods investigated in this thesis.

**Global industrial development projects – identification and handling of communication problems**

In a study by Hessel [2003] communication problems in global development projects were investigated. The data was based at interviews with persons from several Swedish companies with global development. The study results in a description of the advantage and disadvantage of the tools for communication and the possibility for one tool to exclude the others. The contribution to this thesis was in the area of communication in global development projects, especially the communication problems that occurred and the experience of different tools used in the industry to address these problems.

**Iterative Software Development at Elekta**
A study conducted by Gidlund [2003] investigated and developed an iterative software development process for a major supplier of advanced radiation oncology and neurosurgery solutions for treatment of cancer and brain disorders. The aim of the thesis was to find a complement to the traditional waterfall development process that was used at the company. The challenge of the study was not only to suggest an iterative software development process, but to make it valid under constraining regulations, such as FDA (Food and Drug Administration). Based on a literature review and interviews with Elekta personnel an iterative software development process was suggested. The contribution to this thesis was in the area of increased understanding of iterative software development in complex systems.

Project Portfolio Management at Elekta – Criteria for Product Development Project Evaluation

Another study at Elekta conducted by Lundberg [2004] aimed to propose a set of criteria that could be used for ranking projects to support the management of multiple projects in a project portfolio. Based on the literature review, interviews with benchmarking companies, and interviews with Elekta personnel, a set of criteria suitable assessment of multiple projects was proposed. The contribution to this thesis was in the area of managing multiple projects, especially problems related to the dependencies between different development tasks and the difficulties to always have an updated picture of the status in all the projects in a portfolio.

Resource Planning in Project Intense Re&D Organizations - A study of Rolling Forecast process at Ericsson

A study conducted by Thor [2005] investigated the quarterly resource planning process at a major telecommunication system supplier. The aim of the study was to evaluate and improve the resource planning process. The empirical data in the study was based on 16 formal interviews, and almost every meeting regarding the resource planning process was attended. The contribution to this thesis was in the area of increased understanding of coordination problems of resource planning in a multi-project setting.

1.7 RESEARCH QUALITY

As with all activities, the quality of the work is important. This quality is often measured in form of quality of the produced results. Measuring quality of research can however not be done merely by studying the results of the research, the quality of the research process itself is of even greater importance. Research quality is often judged depending on its validity and reliability. Validity is defined as the absence of systematic errors in research – i.e. does the research really study what it intendeds to? Reliability is defined as the absence of random errors – i.e. the research should not depend on who conducts the study [Lundahl & Skärsvad 1999].
1.7.1 **Reliability**

Issues of reliability deal with the possibility to reproduce the results. The objective of high reliability is consequently: to ensure that any other investigator at some other time, using the same set of collected data comes to the same conclusions. Achieving high reliability is done through careful documentation of collected data and performed analysis. When performing case studies, Yin [1994] suggests the use of a Case Study Protocol to ensure structured and complete documentation of the case. A further method to achieve good documentation of case studies is the creation of a repository of collected data: raw data as well as analyzed and refined results of performed surveys, interviews and experiments stored in a uniform way.

To increase reliability, all the interviews and case studies followed a protocol developed for each individual project or case study. Furthermore, great effort was made to search for relevant sources of data. As mentioned in the previous section, before the case studies began, a comprehensive literature review was made resulting in the case study protocols and the later theory chapter of the written reports, as well as this thesis.

The interview protocols served as a basis for the interviews, and later as a tool when analyzing the research material. Throughout the projects, the basic questions of the protocol were the same, complemented with some specific questions depending on the role of the respondent. The interviews were always carried out by at least two persons, one who led the interview and one that were taking notes. The interviews were then summarized and transferred to a clean copy.

1.7.2 **Validity**

Validity deals with the issue of systematic errors and avoiding bias and subjective reasoning. This is of course of the highest importance when the research has qualitative content such as for case studies. To reduce any systematic error, the following aspects were considered:

- Interviewees in the case studies were chosen to be the key actors in the project.
- Interviewees in the complementary interviews were managers of the engineering department; project managers, sponsors, or other key stakeholder of future projects.
- The summarized, clean copy of the interview discussions was sent to the interviewee for validation. Any changes were included in the final document that was used throughout the analysis and final documentation of the study.
- Triangulation has been attained by using multiple sources of evidence in all the case studies, including, documents and focused interviews, combined with open-ended interviews.
• Multiple case studies have been performed in part 1-3. Throughout this research journey, secondary studies have been of especial importance providing this research process with multiple case studies data.

1.8 CONCLUDING REMARKS

The introductions of models like the anatomy seem to come and go in the management of projects. There are of course several reasons for this, for instance, models like the anatomy is often invented by a project manager to address a specific problem in the manager’s project. If the model is successful, the project manager often gets promoted. However, since many companies lack career paths for project managers, promotions most often mean that project managers become managers in the permanent organization; thus, stop working as a project manager. The successful model is then used only in one or two consecutive projects, but, since the models are most often not thoroughly documented, the success of using it is poor after its inventor is gone. It is then abandoned, until another project manager either invents the same model once again or for some reason understands how to use the model, and maybe even improve the model. The model is then being used it again, until it is either forgotten for the same reasons as stated above or it becomes a part of the companies documented approach to manage projects. This scenario has occurred to the models described in the thesis. The anatomy for instance, was first used in the early 1990s, and then in the latter part of the 1990s it was improved upon and used in another project described in this thesis (Paper G). The anatomy is now becoming an established model in this company.

It is however not only the fact that the knowledge of models, like the anatomy is not put on paper that makes models like this come and go. Often it is hard to measure the benefits in terms of money or shorter project time when using new models. Therefore, the use of new models can be neglected by the project steering group or project sponsor promoting the use of traditional models. This thesis addresses some of the benefits of using a model like the anatomy from the perspective of the total project manager. However, an area suggested for further research in the following sub section is to further evaluate the economical benefits and the possibility to shorten the time frame when using models like the anatomy.

It is obvious that new models need to be more thoroughly investigated and described. The anatomy was described in an internal manuscript [Järkvik and Kyllberg 1998]; describing the success factors of the first project it was used in. This is probably the reason it was not totally forgotten, but it was not described with enough details that it was possible to implement directly into other projects.
1.9 **FURTHER WORKS**

As many other research journeys, more questions are created than answered, and this effort is no exception. Rather the thesis leaves many questions that would be of great interest to investigate further. This section suggests two areas of particular interest: using the anatomy concept to manage project portfolios and using the anatomy in the development of new systems.

**Using the anatomy concept to manage project portfolios.** It is interesting to note that the system increments in principle may be regarded as projects on their own. Thus, an anatomy based project may be apprehended as a multi-project, which raises the question of whether the anatomy can be utilized in managing a portfolio of projects, something which is currently receiving great interest. A topic for further research is then how to use the anatomy in connection with project portfolios.

**Using the anatomy concept in the development of new systems.** The anatomy has so far been mainly used in relation to new releases of an existing system. However, anatomical thinking might be helpful in developing completely new system architectures which enables easy-to-develop systems. Thus, the anatomy may work in two ways: as both an analytical and a constructive instrument.

**Evaluating the cost-benefits of using the anatomy.** The model has been used in many projects now, and it should thus be possible to make an evaluation how much it costs to use the anatomy and what the economical benefits are. This thesis shows the qualitative benefits for the project manager to use the anatomy.

1.10 **REFERENCES**


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The Standish Group, The CHAOS Study, [www.standishgroup.com](http://www.standishgroup.com), 2004


Paper A to Paper G – see referenced journals and proceedings
Appendix A - List of Publications not Included in the Thesis

Från idé till färdig anläggning– Krav på morgondagens aktörer, Byman K., M. Eriksson, M. Haglind, J. Helander, and J. Lilliesköld, External Report (In Swedish), Department of Industrial Information and Control Systems, The Royal Institute of Technology (KTH), 1998


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