TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY
Julkaisu 669 • Publication 669

Marion Lepmets

Evaluation of Basic Project Management Activities
Study in Software Industry

Pori 2007

Tampereen teknillinen yliopisto. Julkaisu 669
Tampere University of Technology. Publication 669

Marion Lepmets

Evaluation of Basic Project Management Activities
Study in Software Industry

Thesis for the degree of Doctor of Technology to be presented with due permission for public examination and criticism in Auditorium 240, at Tampere University of Technology - Pori, on the 10th of August 2007, at 12 noon.

Tampereen teknillinen yliopisto - Tampere University of Technology
Pori 2007

ISBN 978-952-15-1796-9 (printed)
ISBN 978-952-15-1814-0 (PDF)
ISSN 1459-2045

ABSTRACT

In this research the relevance of the guidance of software process models to industry is studied - more precisely, how relevant the basic project management activities are to the industry projects and to the success of these projects.

To attain the research aim, a model of basic project management activities was constructed where model elements were derived mostly from the CMMI and ISO/IEC IS 15504, and the relevant ones from various project management literature sources. The model was then provided with metrics and evaluated against the industry data. The data was gathered using a survey questionnaire from 29 software project managers from Finland and Estonia who described the project management activities implemented in the projects they managed.

The model was evaluated by triangulating the data – three data analysis methods were used. We looked for the relationship between the implementation of the basic project management activities and the project success. Also, we aimed to find whether the characteristics of the project, the project manager and the company affect the intensity with which the basic project management activities are implemented in the industry projects.

The findings of the research suggest that the organizations improving their processes with the help of process models may not experience much benefit to their improvement work at the beginning, i.e. not until the processes reach higher capability levels than level 2. The results also indicate that successful software process improvement relies heavily on human factors, skills and teamwork competencies. A project manager has to motivate the team members, coordinate their interactions and supervise them when necessary to create a positive environment for the software development that supports the overall project success.

ACKNOWLEDGEMENTS

This thesis is based on the software process research I was involved with in Tampere University of Technology, Pori from 1999 to 2003. I wish to express my sincerest gratitude to my supervisor Prof. Hannu Jaakkola for providing me the opportunity to study and conduct research as part of his research team. I would also like to thank my co-supervisor Prof. Ahto Kalja for his assistance of my thesis work during the time I worked as a researcher in the Tallinn University of Technology. Many thanks also to reviewer Dos. Tero Varttiainen; and opponents Prof. Veikko Seppänen and Prof. Markku Tukiainen for reviewing and commenting on my thesis.

I am deeply grateful to Timo Varkoi for assisting me throughout my studies in Finland and for his cooperation on a range of research projects. His continuous guidance and numerous discussions we held motivated me to strive towards the completion of the thesis. I also wish to thank Timo Mäkinen for his cooperation and comments, which have been vital to the research conducted. Many thanks also to Jari Palomäki for his comments on the study and encouraging me to carry it to the end.

I would also like to thank the organizers and participants of the INFWEST doctoral programme, especially Prof. Juhani Iivari and Prof. Pertti Järvinen, for their invaluable comments to my numerous versions of the thesis. I would like to express my gratitude to Risto Nevalainen from FiSMA, Juris Borzovs and Darja Smite from RITI, Erkki Savioja from Fidenta OY, Toomas Kirt from the Tallinn University of Technology and Henry Melnikov, for enabling this research by providing their assistance and support in collecting and analyzing the data from software industry.

On a more personal note, I would like to thank my family, who have always encouraged me to proceed in my studies, for always believing in me, and for reminding me to enjoy the process of conducting the research. For financial support I would like to thank EITF (Estonian Information Technology Foundation) and ITL (Estonian Association of Information Technology and Telecommunications) who have honoured me with several scholarships.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BP	Base Practice (ISO/IEC IS 15504)
BPM	Basic Project Management
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CoSE	Centre of Software Expertise
ESA	European Space Agency
ESI	European Software Institute
FA	Factor Analysis
FISMA	Finnish Software Measurement Association
GP	Generic Practice (CMMI)
GPI	Generic Practice Indicator (ISO/IEC IS 15504)
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
INSPIRE	Initiative for Software Process Improvement – Régions Extérieures
IPD-CMM	Integrated Product Development Capability Maturity Model
IPPD	Integrated Product and Process Development
IS	International Standard
ISO	International Organization for Standardization
IT	Information Technology
MAN	Management Process Group (ISO/IEC IS 15504)
PA	Process Attribute (ISO/IEC 15504)
PCA	Principal Component Analysis
P-CMM	People Capability Maturity Model
PMBoK	Project Management Body of Knowledge
PMC	Project Monitoring and Control Process Area (CMMI)
PP	Project Planning Process Area (CMMI)
R&D	Research and Development
SA-CMM	Software Acquisition Capability Maturity Model
SataSPIN	Software Process Improvement Network in Satakunta, Finland
SE-CMM	Systems Engineering Capability Maturity Model

SEI	Software Engineering Institute
SME	Small and Medium Sized Organization
SOM	Self-Organizing Maps
SP	Specific Practice (CMMI)
SPI	Software Process Improvement
SPICE	Software Process Improvement and Capability dEtermination (ISO/IEC TR 15504)
SRA	Software Requirements Analysis
SW-CMM	Capability Maturity Model for Software
TR	Technical Report
TUT	Tampere University of Technology

1. INTRODUCTION

This chapter provides a short overview of the dissertation research as described in Figure 1-1 below. The aim of this chapter is to provide the background of the research conducted. The background of the research includes an introduction to the research area and the motivation behind the research.

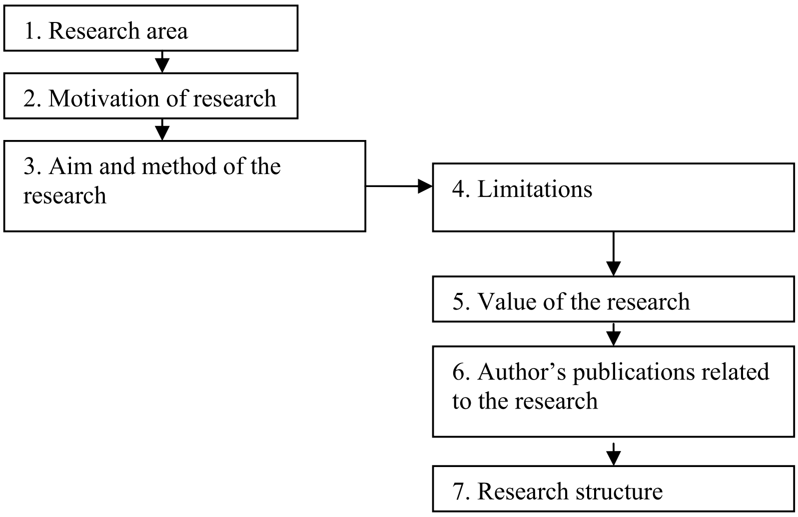


Figure 1-1. Structure of the Introduction chapter

The section describing the aim and the method of the research illustrates the process which led to the final method and aim of the study through the pilot study. The limitations and the value of the research are also described. The author's earlier publications related to the theoretical background of this study are listed here. The chapter ends with a description of the structure of the rest of the thesis.

1.1. Research area

Software process improvement (SPI) is an applied academic field, rooted in the software engineering and information systems disciplines, which has been studied for almost twenty years now. It deals primarily with the professional management of software firms, and the improvement of their practice, displaying a managerial focus rather than dealing directly with the techniques that are used to write software. It has been primarily practiced in the USA, Scandinavia and Australia. In its theoretical heritage, SPI is equally indebted to the software engineering tradition and the Total Quality Management movement. Classical SPI techniques relate to software processes, standardisation, software metrics, and process improvement. (Hansen et al., 2004)

Software process improvement is based on process assessment. Most process improvement models and standards applied in SPI primarily provide guidance for process assessment. There are currently dozens of software process models available for assessing and improving software development and its related practices. CMMi (SEI, 2002), ISO 9001 (ISO 9001, 2000), ISO/IEC IS 15504 (ISO/IEC 15504, 2006), ISO/IEC 12207 (ISO/IEC 12207, 2004), ISO/IEC 15288 (ISO/IEC 15288, 2002) are only a few of the popular ones.

Both ISO/IEC IS 15504 and CMMI provide guidance for process assessment to software development organisations in their attempt to map activities against the best practices of the chosen model. For companies new to software process assessment and improvement, one of the most important questions is the relevance of the process assessment model guidance to its activities, i.e. how well do model practices correspond to industry best practices. ISO/IEC IS 15504 and CMMI have been studied in this research because they are both being maintained and widely used in software industry for process assessment purposes. ISO/IEC IS 15504 is the only international standard for process assessment at the moment. CMMI, whose underlying ideas have endured over time, has evolved from the concepts of software maturity framework that was developed by Software Engineering Institute already in 1986 and is used extensively today.

1.2. Motivation of the research

Despite the fact that an increasing number of articles about the benefits of SPI have been published, there is still resistance against process improvement in the software industry. The opposition to process models, as with any standard, stems from the belief that process models enforce bureaucracy, eliminating the creativity that is considered the essence of software development. True, almost any process can become bureaucratic if it is not properly managed. The key is to ensure that all the organization's processes focus on clearly defined business objectives. The process itself should not be the goal. As long as the improvement goals address customer-relevant issues like product quality, cost, or delivery, the processes will likely stay effective. (Humphrey, 2004)

Another reason for resistance comes from SMEs who argue that standards have been created to respond to the needs of large companies alone. True, CMM models were created for quality assurance of software providers to the US Department of Defense. Also, many of the well-reported success stories refer to relatively large, expensive projects in larger software firms connected to the American defence and aerospace industry. At the same time in Scandinavia, researchers have carried out a number of case studies about SPI in small organisations. (Hansen et al., 2004) It can be concluded that in order for small companies to benefit from SPI work, the process models should be tailored for process assessment and there should be a more flexible improvement approach used (Lepasaar et al., 2001).

Software process improvement increases productivity through shortening the software production cycle time (Lepasaar, 2001). Calculating and acknowledging the return on investment is an important issue in software process improvement. As (Jones, 1996) points out, it is not wise to start software process improvement work if managers do not calculate the return on investment or collect the data to demonstrate the progress. Unfortunately there are almost no reliable statistical studies carried out across the SPI field that would help software firms become aware of the benefits of SPI. (Hansen et al., 2004) These and other ideas described in greater detail throughout the thesis have led to conducting this research, which would tell us how well model guidance corresponds to the industry needs.

1.3. The aim and method of the research

This section describes the aim and the method of this research. First, a short introduction to research methods in general is provided allowing better illustration of the positioning of the research method used in the current study. Next, we describe the process that led us to the aim and method of this research through revising the preliminary goals and method after a pilot study. Finally, we present the research question and the method that we chose to solve the research problem.

1.3.1. Background of the research methods

In the taxonomy of research methods by Järvinen and Järvinen (Järvinen, 2001, p.10) in Figure 1-2, there are two different research approaches – approaches studying the reality and the mathematical approaches. They first differentiate the mathematical methods from other methods, because they concern formal languages, algebraic units etc., in other words, symbol systems not having any direct reference to objects in reality. From the rest of the methods concerning reality they then use research questions in differentiation. Two classes are based on whether the research question concerns what is a (part of) reality or whether it emphasizes the utility of an innovation. From the former, they differentiate conceptual-analytical approaches, i.e. methods for theoretical development, from empirical research approaches.

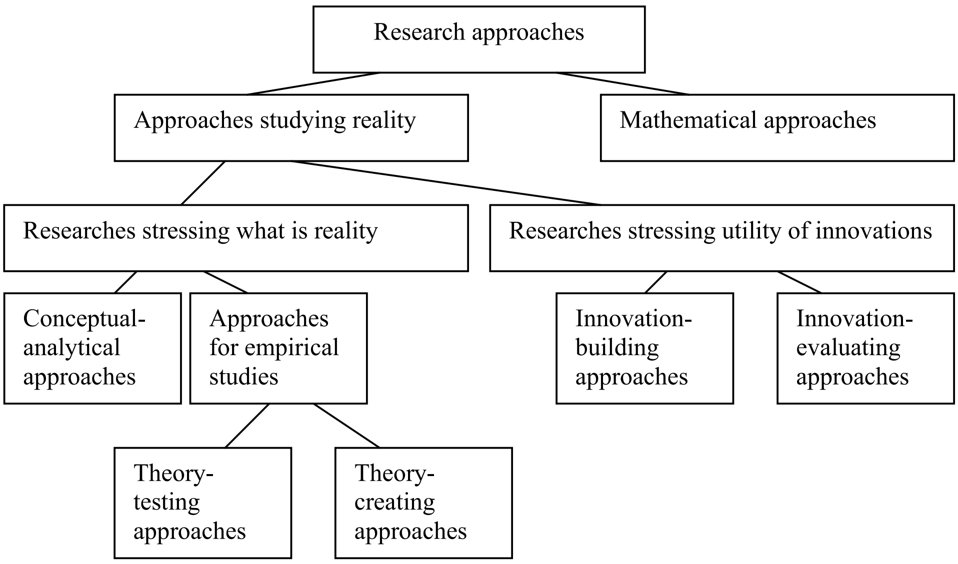


Figure 1-2. Järvinen and Järvinen's taxonomy of research methods

When we empirically study the past and present, we can use theory-testing or theory-creating methods depending on whether we have a theory, model or framework guiding our research or are we developing a new theory grounded on the gathered raw data. As for innovations, we can either build or evaluate them. In building a new innovation utility aspects are striven for and a particular development model applied. In evaluation of the innovation, some criteria are used and some measurements performed.

In conceptual-analytical studies basic assumptions behind constructs are first analyzed; theories, models and frameworks used in previous empirical studies are identified, and logical reasoning is applied thereafter. In theory-testing studies such methods as laboratory experiments, survey, field study, field test etc. are used. In a study where the theory-testing method is used the theory, model or framework is either selected from the literature after competition or developed or refined for the study. In the theory-creating approach methods like case study, ethnographic method, grounded theory, phenomenography, contextualism, discourse analysis, some longitudinal study methods, phenomenological study and hermeneutics are used.

Based on (Iivari, 1991), there are three categories of research methods: constructive, nomothetic and idiographic. The constructive approach involves developing and evaluating a new contribution, which can be a theory, algorithm, model or framework. The process of building a new innovation is based on existing knowledge and/or technical, organizational advancements. The utility of new innovation is sooner or later evaluated. (Järvinen, 2001, p. 88) The nomothetic approach lays emphasis on the importance of basing research upon systematic protocol and technique as in natural sciences. The idiographic approach is based on the view that one can only understand the social world by obtaining first-hand knowledge of the subject under investigation. (Järvinen, 2001) The following sections describe how the aim and the method of this research were reached through the pilot study of the preliminary research approach.

1.3.2. Preliminary research

It is common knowledge that software projects have a high rate of failure and although various strategies have been tried, such as structured programming, rapid prototyping, CASE tools and so forth, there is still no end to the software crisis.

During the last decade, the software process movement has moved to the forefront of the attempts to eliminate the software crisis. (Paulk, 2001)

With the intensification, acceleration in the rate of change, and expansion in the use of information technology, particular attention is being focused on the opportunities and difficulties associated with sharing knowledge and transferring "best practices" within and across organisations (Orlikowski, 2002). A best practice is public knowledge, a tactic or method that has been shown through real-life implementation to be successful (Cooper, 1993).

Models and standards that provide guidance for process improvement include a set of best practices for product and service development and maintenance. (SEI, 2002) First, the focus was on the best practices of project management and risk management.

The research started out with the aim of finding out whether the scope of project and risk management practices selected from process models correspond to the scope of industry software project and risk management practices. In other words, the aim was twofold – a) to find out which selected process model practices are (not) implemented in industry projects, and b) which practices are implemented in the industry projects and are not described in the scope of the selected practices from process models.

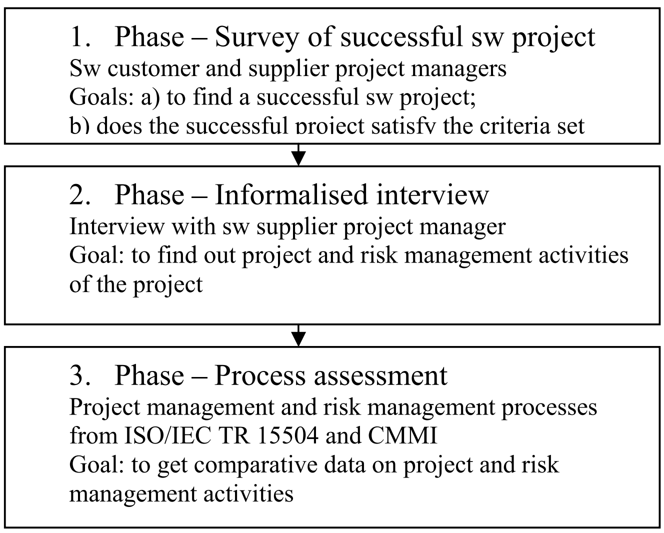


Figure 1-3. Preliminary research approach

Both theory-testing and theory-creating approaches were used here. This also explains why various methods that support different research approaches were used, like survey and case-study. The preliminary research approach is described in Figure 1-3.

Phase 1 aimed to identify the successful software projects. Since process models describe the good practices for software development, the industry projects under study should also be of high quality. With no objective criteria to use to pick out the successful projects, surveys were developed for both the customer and supplier project manager to find these projects. A project that was referred to as successful by both the customer and supplier project manager was taken under the more detailed study described in phase 2 and phase 3. Phase 2 aimed to identify the project management and risk management activities of the successful project through a semi-structured interview with the industry project manager. As a result of this phase the project and risk management industry best practices were defined. Phase 3 aimed to get comparative data about the industry and model practices through project management and risk management process assessments based on ISO/IEC IS 15504 and CMMI.

Different research methods were used in the preliminary research. A survey for customers and suppliers was used to identify the successful projects, a case study with semi-structured interviews with project managers to discover the project management and risk management industry best practices, and the process assessment of project management and risk management processes according to ISO/IEC IS 15504 and CMMI.

1.3.3. Pilot study

In order to verify that the chosen research approach applied to the preliminary research problem, a pilot study was conducted. In the pilot study, there was one software development project studied using the approach described. Three more projects were studied without the customer survey instead here senior management selected the most successful projects.

Various lessons were learned from the pilot study. First, the scope of the research was not set correctly. The project management and risk management processes of process models selected for the study are related to many more processes in reality. The scope of the revised research was therefore extended to all project-management-related practices of process models. Secondly, interviews did not provide the data that was comparable to process models. The revised research limits the basic project management activities to project management related literature and process models for their evaluation in industry. Also, the level of abstraction of practices made the industry and model practices incomparable. The industry best practices described in the interview were of a higher level of abstraction than the ones in the process assessments. There was no need for as detailed a level of practice descriptions as provided by the assessment therefore the revised research will be carried out using a different approach.

Of the above-mentioned problems, the most crucial lesson learned from the pilot study was that the approach was too heavy and time-consuming for industry participants. The research question was thus revised and another research method chosen: this is explained below in greater detail.

1.3.4. Revised research

Whereas the focus of the preliminary research was merely on the best practices of both project management and risk management, the revised research focuses on the project-management-related best practices. Process models also describe a few risk management best practices as closely related to project management, which are therefore also a part of this study. The revised aim of the research differs from the one set originally. The level of abstraction of model practices will be kept higher. The customers of software projects will not be included in the research as the focus is on the project management practices, i.e. practices that support the developers in project management.

It is clear that good project management practices alone do not guarantee project success, but it is certain that bad project management leads to project failure. The current study is limited to the project management and its related practices from process models. The benefits of SPI are stated to rise as a consequence of implementing combinations of practices that relate to one area as opposed to the implementation of an individual process. (Elemam and Birk, 2000) The purpose of the related practices is to get comparative data from industry, since the processes of one area are closely connected to each other.

Although higher process capability supports project success, there is basis to believe that basic project management practices described in process models do not necessarily increase project performance. There is evidence from literature (Jiang et al., 2004; Elemam and Birk, 2000) that higher process capability supports better project performance. There remains a question, however, about whether the implementation of basic practices of process models increases the project performance. Thus, the scope of the research is limited to the basic project management and its related practices of the two process models (ISO/IEC IS 15504 and CMMI Continuous v.1.1) and how well they correspond to the industry project management activities.

The aim of this study is to find out the relevance of implementing the basic project management activities to industry projects and whether their implementation supports the success of these industry projects. In order to attain the aim of this study, a model of basic project management activities is constructed based on the process models of CMMI Continuous v.1.1 and ISO/IEC IS 15504, Project Management Body of Knoweldge (PMBoK) and project management literature. The purpose of the project management activities derived from literature is to find out if there are activities which industry implements and regards as vital for success but which are not included in the scope of the selected practices from process models.

This research is related, on one hand, to the field of project management and, on the other hand, to the field of software process improvement. The field of software process improvement has evolved from quality thinking in manufacturing (Hunter and Thayer, 2001), described in greater detail in Section 2.1. Project management, often seen as having no explicit underlying theory, is argued in (Koskela et al, 2002) to be based on the theory of project and the theory of management, described in greater detail in Section 2.2. Thus the theoretical bases of the research lie in the disciplines of quality management, and the theory of project and the theory of management.

Figure 1-4 explains the core of the study, i.e. the model elements of basic project management activities. The basic project management practices are derived from the process models.

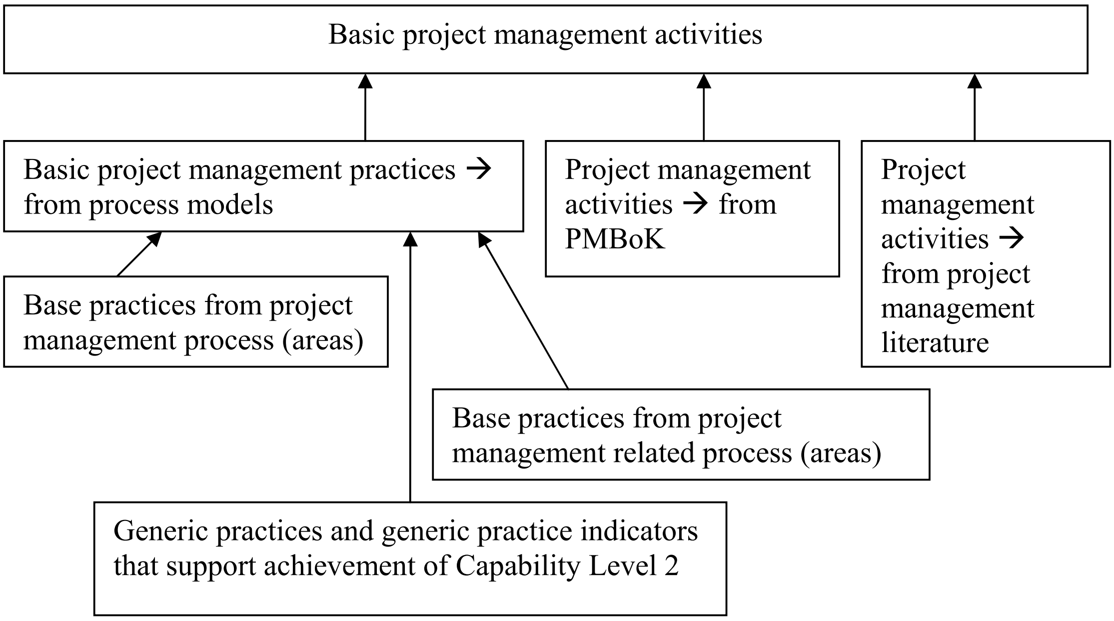


Figure 1-4. The model of basic project management activities

These are the base practices of project management and project management related process (areas) from CMMI and IS 15504. Generic practices and generic practice indicators that support the achievement of generic goal/process attributes of Capability Level 2 are also a part of basic project management practices in this study. The project management activities are also collected into the model from various sources of project management literature and the Project Management Body of Knowledge. The purpose of these pertinent project management activities in the research is to find out whether there are activities which industry implements and regards as vital for success, but which are not included in the scope of the selected practices from the process models. Together with the basic project management practices of process models the project management activities from literature are referred to as the basic project management activities throughout this research (Fig. 1-4). Details about the process of building the model of basic project management activities are given in Chapter 3 further on in the thesis.

The model of basic project management activities is evaluated against the industry data. Metrics are developed through a survey questionnaire and the data is gathered from software project managers concerning industry project management activities. Through triangulation of data the model is evaluated and the aim of the study attained. The survey also describes a set of project success factors that provide the data for measuring the relationship between implementing the basic project management activities and the project success.

The research question is how relevant are the basic project management activities to industry projects and to the success of these projects? Based on the description of the research aim and scope above, the following questions are answered as a result of the study:

Question 1: what is the relationship between implementing the basic project management activities and the type of the project or company?

Question 2: what is the relationship between implementing the basic project management activities and the size of the project or company?

Question 3: what is the relationship between implementing the basic project management activities and the success of software projects?

Five additional questions are considered in this research. These questions aim to find additional characteristics that influence industry project success and the implementation of basic project management practices in industry projects. The questions are the following:

1. What constitutes project success for project managers?
2. Which background variables affect project success?
3. Do companies that use software process models implement more basic project management practices in their projects than the companies that are not using standards?

4. Is implementing the basic project management practices related to life cycle models used in the project?
5. Validation of each basic project management activity group – correlation of the variables of the group with the summarizing variable of that same group.

The revised research approach is described in Figure 1-5. The revised research approach consists of the following three steps. First, the model of basic project management activities is constructed, its elements derived from process models, Project Management Body of Knowledge (PMI, 2000) and other sources of project management literature. The questions about the background of the company, the project, the project manager and the project success factors were derived from similar questionnaire in (Huisman, 2000). Project success factors reflect the success factors described also in (Goldenson and Herbsleb, 1995).

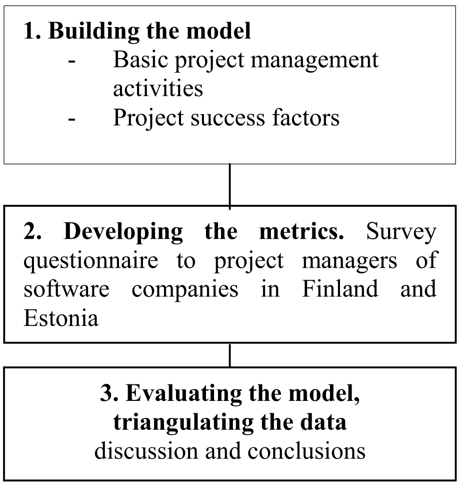


Figure 1-5. Revised research approach

Second, the metrics are developed, i.e. to measure the model elements a survey questionnaire is developed and sent out to the project managers of software companies in Finland and Estonia. And third, the model is evaluated by triangulating the data. Data triangulation refers to using more than one method on the same set of data. In the current research the data is triangulated with three different data analysis methods to answer and illustrate the answers to the research questions set. Additional questions were constructed to describe additional findings about possible relationships between the implementation of basic project management activities and characteristics of the responses.

1.3.5. The research method

This research has characteristics of analytical and evaluative research and it follows mainly the constructive research approach. Based on (Järvinen, 2001) there are two processes in the constructive approach – first, the process of building a construct, artefact or model; and second, the process of determining how well the construct, artefact or model performs. In this research, a model of basic project management activities is constructed based on already existing process model practices and project management activities, which is then evaluated against the surveyed industry data by triangulating the data, i.e. using three different data analysis methods on the same set of data. The analysis results show how relevant the constructed model is in the software industry. The data from the industry is collected using the survey approach.

According to Yin (Yin, 1989, pp. 13-25), a survey is an appropriate strategy when the form of research question is "who", "what", "where", "how many" or "how much". As Yin states, the different research strategies are overlapping and case studies could also be used for this study. Yet he points out that survey strategy is of advantage when the research goal is to be predictive about certain outcomes. In case studies the "how" and "why" are the questions being studied and explanations are the typical outcome, rather than the "what" of "how much" and "how many", which are typical questions for the predictive survey approach. The current research is focused on "what" basic project management activities project managers favour, i.e. "how" useful are the basic project management activities to industry projects and their success.

Survey cases are typically used for establishing proof or verifying propositions and are much like questionnaire research with selective samples (Cunningham, 1997). Using these terms, the current study verifies the applicability of basic project management activities in industry software projects.

Järvinen (2001, p.51) points out that survey approaches usually provide for generalizability but lack internal validity, i.e. the research results can be explained by factors other than those explicitly incorporated in the design. True, in the current research the focus is on "which" basic project management activities are relevant to industry projects and their success, and not "why" some of the basic project management activities are regarded useful and others not. At the same time the detailed background description of each response through company, project and project manager descriptions should provide more validity to the study and the data analyses. The research aims to increase its internal validity through the first two exploratory research questions which explicitly deal with discovering "why" some basic project management activities are (not) implemented in certain industry projects. The validity of the research results are also increased through data triangulation, where the findings of the data analysis are confirmed by three different methods.

1.4. Limitations

Although we aim to validate the relevance of the guidance the process models provide, this research is limited only to the basic project management practices of ISO/IEC IS 15504 and CMMI. The processes and process areas selected for the study exclude the advanced practices, i.e. those that support the achievement of higher than Level 2 generic goals/process attributes. The generic practices and generic practice indicators of generic goals/process attributes up to Level 2 have also been included in the study.

The companies participating in the research are from Finland and Estonia. As the aim of the study is to find the relevancy of model practices in industry, there were two groups of companies studied – the companies familiar with the software process improvement (from Finland) and those with no previous experience with it (from Estonia). This allows for analysis of whether companies without previous knowledge of the topic still implement the same practices. These two countries were selected also due to the author's earlier work being conducted in the region.

The sampling method imposes yet another limitation on the research. It is impossible to determine the companies interested in software quality or software process improvement, which makes determining the sample from that population equally impossible. The non-probability sampling method used in the research allows us to generalize the results of the data analysis only to the respondents of the survey.

1.5. Value of the research

This research studies the relevancy of basic project management activities to industry projects and to the success of these projects through the perspective of the project manager. It also describes the success factors of software projects through software process improvement perspective.

In this research the differentiation of known and unknown factors was used to group elements from various sources into the model of basic project management activities. Similar grouping technique could be used in other studies where straightforward integration of model elements is out of the question.

The constructed model was triangulated by three data analysis methods in this research. Triangulation of data means using more than one method on the same set of data. When the results are the same with all the methods used, the validity of the results is established. Triangulation of data can be used in various studies to increase the validity of the research results.

This research can be of interest to the standardizing bodies as it deals with the issues of standards' relevance in industry, more precisely whether the guidance the standards provide is relevant to the guidance the industry needs. Although process models have been subject to much research in recent years, to the knowledge of the author no such research on relevance of process model guidance has yet been published.

1.6. Author's publications related to the research

Although this research has been individually conducted by the author, there are five publications by the author that have been applied and referred to in describing the theoretical background of this research. Four of them have been accepted for presentation at international peer-reviewed conferences and have been published in the proceedings of these conferences. One of them is a journal article.

All five publications are used in this thesis in Chapter 2, where the theoretical frameworks of the research are described. A list of the related publications and a short overview of each publication follows.

1. Lepasaar M., Varkoi T., Jaakkola H. (2001), Models and success factors of process change. In Proceedings of the Product Focused Software Process Improvement at PROFES 2001, Springer-Verlag. Pp. 68-77

In this article the improvement models, which aim to introduce detailed actions for continuous process improvement and the key success factors of improvement based on various literary sources, were analysed. As a result of the comparison of the two improvement models of SW-CMM and ISO/IEC TR 15504, we pointed out issues, which, if considered in the improvement models, would help organizations in their improvement efforts.

2. Lepasaar M., Kalja A., Jaakkola H., Varkoi T. (2001a), Comparing Software Process Improvement in Estonia and Finland. Baltic IT&T Review: A Business Journal for the Information Society, no. 3 (22). Pp. 69-74.

This article was based on a comparison of regional programs that focused on software process assessment and improvement in Estonia and Finland. The prerequisites for a multi-organizational environment aimed at successful software process assessment and improvement were described as a result of the research.

3. Lepasaar M., Mäkinen T., Varkoi T. (2002), Structural Comparison of SPICE and Continuous CMMI. In Proceedings of SPICE 2002, Venice, Italy. Pp. 223-234

In this article we described and compared the general structures of the two widely known SPI models – ISO/IEC TR 15504 and the continuous representation of the CMMI, using UML notation.

4. Lepasaar M. and Mäkinen T. (2002a), Integrating Software Process Assessment Models using a Process Meta Model. In Proceedings of the IEMC 2002, Volume I, Cambridge, UK. Pp. 224-229

In this paper we described the results of the conceptual synthesis of CMMI and SPICE process models – an integrated meta model of SPICE and CMMI. Applying the integrated meta model contributes to a more complete process assessment, since it includes elements of various process models.

5. Lepasaar M. and Mäkinen T. (2002b), ISO/IEC TR 15504 Requirements for Compatible Software Process Assessment Models. In Proceedings of the EuroSPI 2002, Nuremberg, Germany. Pp. 189-197

In this article, the requirements for ISO/IEC TR 15504 compatible assessment model were described through structural analysis of ISO/IEC TR 15504-2 and illustrated with examples from ISO/IEC 15288 and ISO/IEC 12207.

1.7. Research structure

The thesis can be divided largely into five parts. In the first part of the thesis, Chapter 1, a short *introduction* to the thesis was provided: the research area was described and the motivation behind the research explained. The process of how the research aim and method were reached was illustrated. The related research by the author that has been used and referred to in the theoretical background part of this study was also described. All the topics are described in greater detail further on in the thesis.

In the second part, Chapter 2, *the theoretical frameworks* of the research are given, explaining in detail the background of the research area and of the study. The aim of this chapter is to provide an understanding of the research field in general and of the current problems that have led to the research questions of this study. The research related closely to this dissertation has been described and analysed here.

In the third and fourth part, Chapters 3 and 4, the conducted research is explained in full detail. In Chapter 3, *building the model of basic project management activities*, the process of building the model of basic project management activities is described. The development and conduct of the survey questionnaire through which the model elements are made measurable is also illustrated here.

Chapter 4, *evaluating the model of basic project management activities*, describes the triangulation of data to evaluate the model together with the thorough description of all the results of the research. The answers to the research and the additional questions set are described and illustrated.

In the fifth and final part of the thesis, Chapter 5, *discussion and conclusions,* a summary of findings is provided, followed by a comparison of the findings to those of the related research. Future research ideas are also described here.

2. THEORETICAL FRAMEWORKS

In this chapter the theoretical frameworks of the research are given explaining the background of the research area and the current study, as described in Figure 2-1.

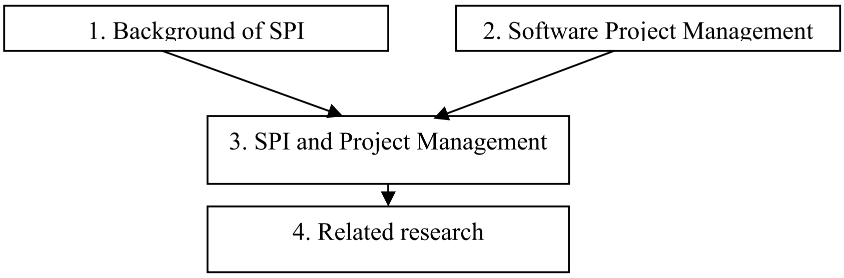


Figure 2-1. Structure of the theoretical frameworks chapter

Software Process Improvement (SPI) is described along with a few popular process models used in software industry. The two process models that are used extensively in the research – the CMMI Continuous Representation and ISO/IEC IS 15504 – have been illustrated in greater detail, based primarily on the author's earlier publications. Software Project Management is also described here, providing the necessary background for this study. The connection between SPI and Project Management is then provided. Relevant and closely related research to this study illustrates the originality of the study and provides the background to the research questions.

2.1. Background of SPI

In this section we introduce the concepts and the background of Software Process Improvement (SPI) along with some of the most popular software standards and process models in the field.

The notions of process assessment and process improvement are not unique to software but have been developed from more general notions in quality thinking of manufacturing (Hunter and Thayer, 2001). The Following is a short description of quality fundamentals including Shewart's cycle of quality improvement, Deming's approach to continuous improvement and Juran's trilogy of quality improvement.

The Shewhart cycle (Figure 2-2) originates from Walter A. Shewhart, who worked with statistical process control in the Bell Laboratories in the US during the 1930s. It was adopted and promoted very effectively from the 1950s on by W. Edwards Deming, and is consequently known by many as the Deming Wheel. According to Deming, the Shewhart cycle is a helpful procedure that could be followed for improvement of any stage of production. (Eklund et al., 2002)

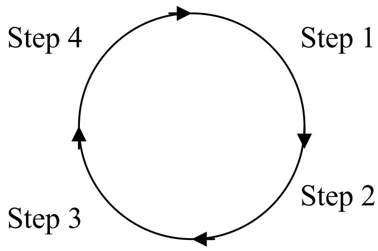


Figure 2-2. Shewhart cycle

Step 1: What could be the most important accomplishments of this team? What changes might be desirable? What data is available? Are new observations needed? If yes, then plan a change or test. Decide how to use observations.
Step 2: Carry out the change or test decided upon, preferably on a small scale
Step 3: Observe the effect of the change or test
Step 4: Study the results. What did we learn? What can we predict?

W. Edwards Deming exported the Shewhart cycle to Japan with a statistical approach, which led to remarkable rethinking in Japanese management concerning quality. Deming also added two steps to Shewhart's original cycle focusing on the importance of continuous quality improvement. The two additional steps were:
Step 5: Repeat step 1, with accumulated knowledge,
Step 6: Repeat step 2, and so on.

According to Deming, quality is an ongoing process towards better quality and better productivity and in order to achieve better quality one must do things beforehand, not afterwards. It is possible to manufacture good quality products by constant improvement and good leadership. The logic of Deming's quality thinking is total cost thinking, front-end impact, not inspections afterwards. To achieve quality a fundamental change of thinking in management is needed. (Eklund et al., 2002) For both Shewhart and Deming, better quality is achieved through a process of change and continuous improvement resulting also in higher productivity.

Based on Joseph M. Juran, long-term training, management commitment and company-wide involvement form the basis of quality improvement. For Juran, quality management consists of three interrelated processes which are therefore also known as Juran's trilogy: quality planning, quality control and quality improvement. (Ahvenjärvi et al., 2002)

According to Juran, quality does not happen by accident, but needs to be planned. The key elements in implementing company-wide strategic quality planning are seen as identifying the customers and their needs; establishing optimal quality goals; creating measurements of quality; planning processes capable of meeting quality goals under operating conditions; and producing continuing results in improved market share, premium prices and a reduction of error rates in the office and factory. (Ahvenjärvi et al., 2002)

Following planning, the process is turned over to the operating forces. They carry out the quality control to ensure the process is run at optimal effectiveness, or at least to ensure that any level of chronic waste inherent in the process does not get worse. Otherwise, the causes have to be determined and corrective action taken so that the process again falls into the zone defined by the "quality control" limits. (Juran, 2006)

Maintaining control will not guarantee the success of the business. One must constantly challenge the processes and continuously improve them. The reduction of chronic waste that leads the business to a new zone of quality control is a result of purposeful quality improvement. (Juran, 2006)

Juran's ideas are still carried out today, although under different titles. The structure of quality thinking starts with operating forces producing the product that meets customer's needs and ends with improving the actions to increase quality. Juran's focus in quality management is on process steering, the ability of quality production and on the continuous improvement of project tasks. (Ahvenjärvi et al., 2002)

Juran and Deming, among others, believed that the cause of poor quality stems from the management and the system rather than the workers, and that involvement of and leadership by top management is essential in improving the quality. They believed, like most quality managers today, that quality programs require organisation-wide effort and long-term commitment, especially commitment to training. (Ahvenjärvi et al., 2002)

2.1.1. Process-based approach

Although there are many publications describing the process-based approach, process assessment, process improvement and process models, they are all loosely based on the ideas of Humphrey and Zahran, which have had lasting impact and are described in greater detail in the following sections.

With software applications growing in their size and complexity, resulting in implementation difficulties and project failures, software process improvement is becoming increasingly popular throughout the software industry. (Lepasaar et al., 2001) For many years, Watts Humphrey was a pioneer in the application of process management principles to software development. He introduced the concept of process discipline in the software industry in 1989, when he said that an important first step in addressing software problems is to treat the entire software task as a process that can be controlled, measured, and improved. Humphrey defines process as a set of activities, methods and practices used in the production and evolution of software. (Zahran, 1998, pp.3-33)

Today large projects require the co-ordinated work of many teams. Complexity is outpacing our ability to solve problems intuitively as they appear. What is required is a more structured approach to software process management. Successful software companies have learned that even the best professionals need a structured and disciplined environment in which to do co-operative work. (Humphrey, 1989, pp.4-66)

Process thinking became popular in business already in the early 1990s. It was the failure of task-oriented thinking that led businesses towards process-oriented thinking. Task-based thinking – the fragmentation of work into its simplest components and their assignment to specialist workers – was failing and the shift to process thinking is underway. Instead of thinking about organizational structure, the companies should focus on the processes that control customer interfaces. (Zahran, 1998)

Zahran suggests that common process thinking across a group of individuals aligns the behaviour and activities of those individuals towards achieving their common goal. It brings consistency and uniformity to the group's behaviour, which turn into improved capability and better quality of results. It acts like a magnetic force aligning the particles of a piece of metal in one direction. It enables to measure objectively the achievement of individuals in terms of their contribution to the process results. In a software project, a process focus brings discipline to the individuals' activities and alignment towards achieving the project goals. Repeatability of earlier successes and achievements of the team will also be assured. This is possible because a process focus minimizes dependence on individuals. New joiners are trained in the common process to ensure that they do not degrade the overall results. (Zahran, 1998)

The attempts to automate the software process are motivated by the need to improve the quality and productivity of development work. When we can reduce a task to a routine procedure and then mechanise it, we not only save labour but also eliminate a source of human error – which is the most effective way to improve productivity. Framing an automation strategy requires knowledge of what is needed, awareness of what is feasible, and a long-term commitment to investment in software process improvement. (Humprey, 1989) Understanding that there are different stages of maturity and understanding something of the conditions that determine where one is and where one can hope to be is often the key to growth – to turning the corner from chaotic software development to a more controlled and manageable process. (Humphrey, 1989)

2.1.2. Process Improvement

Most software problems are caused not by the lack of knowledge but by the lack of discipline to apply the best-known methods and an inability to effectively handle the myriad associated processes and product detail. Building the disciplined practices to perform every software task with precise correctness requires a painstaking improvement program. (Humphrey, 1989, pp.4-66)

Software process improvement in most general terms is described in (Pressman, 1992, pp.3-45). First, define the right processes, preferably using a model. Secondly, follow processes and refine them until you have an effective and efficient operation. Thirdly, continue to look for areas of improvement as part of your way of doing business.

More general definitions of process improvement have been provided by the two process models central to this research. Based on (SEI, 2002) process improvement is a program of activities designed to improve the performance and maturity of the organisation's processes, and the results of such a program. Based on (ISO/IEC 15504-1, 2004) process improvement is defined as actions taken to change organisation's processes to that they more effectively and/or efficiently meet the organisation's business goals.

Historically, attention has been largely focused on automating the middle part of the software process. At the same time, the front end of development process is one area where early attention can produce important benefits. Tools and methods can be used for precisely representing requirements and specifications and simple labelling techniques can help in tracking requirements through the development cycle. The quality of the early work in the software process often limits the success of the total project, so tools for helping this phase along can pay big dividends. As systems grow larger, it is easy for people to become confused, misunderstand, or forget. Since such problems with the requirements can have disastrous consequences for the rest of the program, even simple tool support for the initial process phases can pay big dividends later. The back end of the process needs automatic support because it typically involves the highest costs and has the greatest risk of lost control. This area should receive high priority also because it is so critical to product quality and because large resources are typically involved. As more tools and aids are used to support the development environment, it is also important to apply the same configuration management rigor to them, both to protect the tool assets themselves and to permit later determination of problem cause and prevention. (Humphrey, 1989)

If process improvement is not actively pursued, the process could lose its effectiveness. A process without a proactive effort to improve it will decay. Without process improvement, the process will fail to take advantage of new methods, new techniques and new tools. It will remain tied to outdated methods and techniques. (Zahran, 1998, pp.65-143)

Classical SPI techniques relate to software processes, standardisation, software metrics and process improvement. However, the field has also expanded to include other approaches and issues such as the personal discipline of software engineers and commitment. SPI stakeholders include SPI practitioners (responsible for improvement programs), software supplier organizations and the organizations they contract for, government bodies sponsoring research, academics and consultants. (Hansen et al., 2004)

Many of the major contributions to SPI originate from the Software Engineering Institute (SEI) at Carnegie Mellon University where Watts Humphrey has played a major innovative role. The institute is industry-facing and supported by the American Department of Defence, whose principal interests are to identify competent software suppliers and ensure the delivery of high quality software. Many consultancy, teaching and licensing activities are also associated with the SEI, and their directly-sponsored project work amounted to half their income. (Hansen et al., 2004)

The biggest problem in software process improvement work is the difficulty in economical justification of this activity. There are far too many interdependent factors to permit controlled studies. Even if we run a large number of carefully measured statistical tests, any measurements we take can only provide support for our own best judgment. Very often managers also ask for financial justification, when they do not want to do something. Most senior management decisions are actually based on intuition with a seasoning of financial judgement than sound statistical data. Unless management supports the process improvement, it is not worth conducting. (Humphrey, 1989)

There are a number of possible difficulties with SPI activities in software companies, some common ones are described below. First, people are against the idea – standards encourage too much bureaucracy and make organization rigid and inflexible, making it more difficult to find creative solutions to technical problems (Humphrey, 1989). Second, the SPI models for the small companies should be as simple as possible. They should offer guidelines for definition of the process, procedures and the documents used (Arent, 2000). Third, the documentation of the process and project improved the quality of the process and of the developed products. At the same time they represent a significant burden to the employees and as in the small companies there is usually a critical amount of human resource, the documentation is rarely complete (Arent, 2000). Fourth, the management often either does not understand the real issues or sees them as too technically trivial to be important (Humphrey, 1989). Fifth, the professionals see their problems as somehow immutable and incapable for solution. They don't consider them technically insoluble as much as organizationally impractical. They involve so much detail and procedure that all the existing standards, rules, facilities and attitudes seem too much to overcome (Humphrey, 1989). And finally, the improvement related work is always competing with other tasks in a software company and, like any other task, needs attention also from the management. If the management of the company is not seriously committed to improving the software processes why should the software expert in the company improve their behaviour? (Arent, 2000).

The following is a list of key points of a successful software process improvement plan according to (Humphrey, 1989).

1. To improve the software process, someone must work on it!
2. Unplanned process improvement is wishful thinking.
3. Automation of a poorly defined process will produce poorly defined results.
4. Improvement should be made in small, tested steps.
5. Train, train, train. (Training is expensive but not nearly as expensive as not training. Training needs to be planned, funded, scheduled and required).

In planning for change in an organisation, it is essential to recognise the natural inertia in the organisation. Not only are people generally reluctant to change their working habits, but the projects typically face challenging schedules that leave them little room to do studies or to migrate to new tools or environments. It is important that the technical professionals and their managers agree that a change is needed, that the strategy makes technical sense, that the plan meets their needs and that they are willing and able to do the required work.

True software process improvement requires that management, especially senior management, take an active role in process improvement. It also requires that the workers in the trenches participate in defining and implementing usable and effective processes. Process improvement is not, however, sufficient for success. Other issues are also fundamental, such as building the right product – one that customers want to buy; hiring, selecting and retaining competent staff; and finally, overcoming organisational barriers. (Paulk, 1998)

2.1.3. Process Assessment

The purpose of an assessment is to identify the highest priority areas for improvement and to provide guidance on how to make those improvements (Humphrey, 1989). Assessment helps an organization find out the true state of the effectiveness of the software process infrastructure and environment.

According to (Hunter and Thayer, 2001), software process assessment can be used for a number of reasons, the two principal ones being:

1. Capability determination – used by software procurers to determine the capability of potential contractors;
2. Software process improvement – used by software producers to improve their software processes in line with their business aims.

In addition, the results of process assessments are sometimes used to represent the state of the practice in software development, though this should only be done with care, as the sample used for this purpose is rarely representative of the industry as a whole. In order to define the state of current software process, there should be an evaluation standard and a measurement framework. An assessment method is usually based on a process model and an improvement roadmap. The assessment takes place by comparing the state of the organization's software process against the model and the improvement scale.

Both CMMI and ISO/IEC IS 15504 provide definitions of process assessment that are basically identical to Humphrey's definition above. Based on (SEI, 2002) process assessment (called appraisal) is an examination of one or more processes by a trained professional using an appraisal reference model as the basis for determining strengths and weaknesses. Based on (ISO/IEC 15504-1, 2004) process assessment is a disciplined evaluation of an organisational unit's processes against a Process Assessment Model.

Process assessment helps software organizations improve themselves by identifying their critical problems and establishing improvement priorities. (Humphrey, 1989) The basic assessment objectives are to learn how the organization works, to identify its major problems and to enrol its opinion leaders in the change process.

It is critical to understand that a software process assessment is not an audit but a review of a software organization undertaken to advise its management and professionals on how they can improve their operation. The assessment is typically conducted by a team of software professionals who have experience or training in process assessments. It is generally desirable for this group to be a mix of local and outside reviewers. (Humphrey, 1989)

One of the purposes of an assessment is to identify the highest-priority areas for improvement and to provide guidance on how to make those improvements. Assessments are based on the principle that the local managers and professionals want to improve their own operation and that their primary need is guidance on what to do and how to do it. While this principle generally applies, there are exceptions. Some organizations are under such extraordinary pressure, their managers are so inexperienced, or the professional skill level is so deficient that outside guidance and assistance are required. (Humphrey, 1989)

The assessment process described in (Humphrey, 1989) consists of four activities. First, identify the organisation to be assessed and the team to do it. The assessment team should all be experienced software developers, and one or more should have experience in each phase of the software process. The team members should come from projects other than the one under assessment. With an external assessment at least one professional from the organisation being assessed should participate as a full team member. Second, assessment ground rules form the basis of the contract for external assessment and are useful for distribution of roles and responsibilities in the internal assessment. Third, training for the assessment team familiarises the members with the assessment process and helps build a cohesive working group. At the end of the training there is a precise assessment plan made for the assessment. And finally, on-site assessment period usually starts with a presentation to the assessed company's management. An overview meeting is held with all the participants of the company that is going to be assessed, and the detailed schedule for the assessment period is presented.

As in many activities, the basic requirements for a good assessment are a competent team, sound leadership, and a cooperative organization. Because the software process is human-intensive, however, some special considerations should be kept in mind, described below and in greater detail in (Zahran, 1998, pp.145-163).

First, the need for a process model as a basis for the assessment – an assessment implies a standard. The organization's process is reviewed in comparison with some vision of how such processes should be performed. Without a process model or a standard, an assessment can easily degenerate into a loosely directed intuitive exploration. If the assessment team members have extensive software experience and good intuition, such studies can be valuable. Unfortunately, the members of such groups often focus on their own particular specialities. This generally means that no topic is covered in much depth and that many areas are overlooked. If such teams split into individuals or small units to probe particular areas, there is a better chance of covering all the key topics. Unfortunately, these separate probes result in many different views of the operation and reduce the likelihood of a coherent result. Splitting the team also destroys the synergistic power of the group's diverse experience and minimizes the likelihood of agreement on anything but platitudes. To avoid these problems, it is wise to base an assessment on a common view of the desired software process. Software process models provide basis for orderly exploration as well as a framework for establishing problem priorities. With such a focus, the entire team can work together on the key issues and recommendations. While agreement may take some time, the discussions invariably stimulate deeper understanding, and far better conclusions are reached than would otherwise be possible.

Secondly, the requirement for confidentiality – the assessment's purpose must be to support the organization's improvement program and not to report its problems to higher management. Confidentiality permits the assessors to talk to people at all levels of the organization. If managers suspect that the findings are reported to higher management, they will probably insist on being present on every interview. Unfortunately, when managers are present, professionals rarely say anything that their managers do not know already or with which they might disagree. There is then no reason to have an assessment. The managers could present this official view far more efficiently in a two-hour briefing. Confidentiality is required at all organizational levels. Several projects should be reviewed at once, ensuring that no single project or individual is identified with any specific problems.

Thirdly, senior management involvement – the senior manager sets the organization's priorities. This local manager typically gives final approval for software commitments and answers to corporate management when things go wrong. Without the support of senior management the assessment will likely be a waste of time. The lower-level people can generally handle their routine problems, but lasting improvements must survive the periodic crises. That is when the process is under most stress, when management is most likely to defer nonessential work, and when serious disasters are most likely. Since software crises are common, if the senior manager does not protect the process improvement efforts, they will not likely continue long enough to do much good.

Fourth, an attitude of respect for the views of the people in the organization being assessed – the local professionals will soon sense if an assessment team arrives thinking it has all the answers. This leads to an unspoken wish that the assessment will fail. Generally the local people work hard, are dedicated to doing a good job, and are trying to improve. They are thus properly sceptical of any brief study and doubt it can have any lasting impact. The distrust of outside experts is not only understandable but is quite proper. Complex problems rarely have simple answers, and the subtleties of most organizations are far too intricate for any group to fathom quickly. Also, a highly critical attitude or a lack of interest in local views by the assessment team can be deadly. When good work is found, it should be recognized and identified so other groups can take advantage of it. Surprisingly, for each software problem there is often someone in the organization who has already solved it. Making this capability visible can be one of the greatest and most immediate benefits of the assessment. Mistakes and oversights must also be identified, but they should be objectively reported without attribution, criticism, or blame. As difficult as it is to achieve, the proper attitude is one of open-minded and supportive professionalism.

And finally, an action orientation – the assessment must be directed toward improvement to have lasting effect. An action orientation keeps the questions focused on current problems and the need to solve them. If the assessment turns into a general exploration, it will not focus on the priority issues or produce recommendations that will be implemented.

The following subsection provides the description of various software standards and process models that can be used for process assessment purposes. Software standards and process models provide the basis for the process assessment.

2.1.4. SPI related standards and process models

This subsection describes the views of Humphrey (1989, pp.155-168), and Coallier and Azuma (1998) on standards related to Software Engineering, Software Process Improvement and on the standardization of the software development activities themselves.

Standards are needed when many people, products and tools must coexist. They are essential for establishing common support environments, performing integration, or conducting system test. The fact that everyone knows and understands a common way of doing the same tasks makes it easier for the professionals to move between projects, reduces the need for training, and permits a uniform method for reviewing the work and its status. (Humphrey, 1989, pp.155-168)

A standard is a rule or basis for comparison that is used to assess the size, content, value or quality of an object or activity. There are two different types of standards in software. One type describes the nature of the object to be produced, while the other defines the way the work is to be performed. (Humphrey, 1989)

Standards, in general, represent consensus. This representation means that a substantial majority of individuals, organizations and countries have reached an agreement. Standards are also an ideal medium to communicate terminology, procedures, models and benchmarks. (Coallier and Azuma, 1998)

Software standards have been invented in order to increase the quality of software products and the efficiency of software processes. Today all industries depend on software for competitive advantage. Growth will only be achieved if an industry meets and even exceeds international standards and the world's best practices. (Coallier and Azuma, 1998)

According to Humphrey, the software standards are essential for establishing common support environments, performing integration, or conducting system tests. They also promote the consistent use of better tools and methods.

While the standardisation of programming languages is generally recognised as necessary, the need for standards on documentation, error reporting, test plans, and estimating, for example, is just as great. A standard is appropriate when no further judgement is needed. Standardisation makes sense when items are arbitrary and must be done uniformly or when there is one clearly best alternative. The definition of coding or naming conventions, the selection of a programming language, and the use of common design methods are some examples.

Without standards most quality debates come down to generalised disagreement. Standards are most effective when the project manager personally implements them on a project basis. While standards alone will not make the difference between project success and failure, they clearly help.

Procedures are closely related to standards. The distinction between the procedure and a standard is that a review standard specifies review contents, preparatory materials, participants, responsibilities, and the resulting data and reports. The procedure for conducting the review describes how the work is actually to be done, by whom, when, and what is done with the results.

Before establishing an aggressive standards development program, it is wise to formulate an overall plan that considers the available standards, the priority needs of the organisation, the status of the projects, the available staff skills and the means for standards enforcement. In establishing a new standard, it is rarely wise to adopt one from another organisation without carefully examining its fit to the unique needs of the local users. Since standards reviews serve both a management and a technical purpose, they should involve all facets of the organisation. This involves wide distribution for comment and a fairly formal review process. Following the review period, the standard or procedure should be introduced on a trial basis with one or more projects.

Standards must be kept current. They should be modified and adjusted based on the experiences in using and enforcing them, on the changes in available technology, and on varying needs of the projects. If the standards are not maintained, they will gradually become less pertinent to working conditions and enforcement will become progressively less practical. If not corrected, the standard will ultimately become a bureaucratic procedure that takes time without adding value.

Standards maintenance should not involve a great deal of work. If a standard needs frequent changes, it probably covers a subject that is not ready for standardisation. Until the technology and methods for an area are well known and reasonably stable, standardisation should not be attempted. When standards are established too early, they can limit the creative process and impede technology.

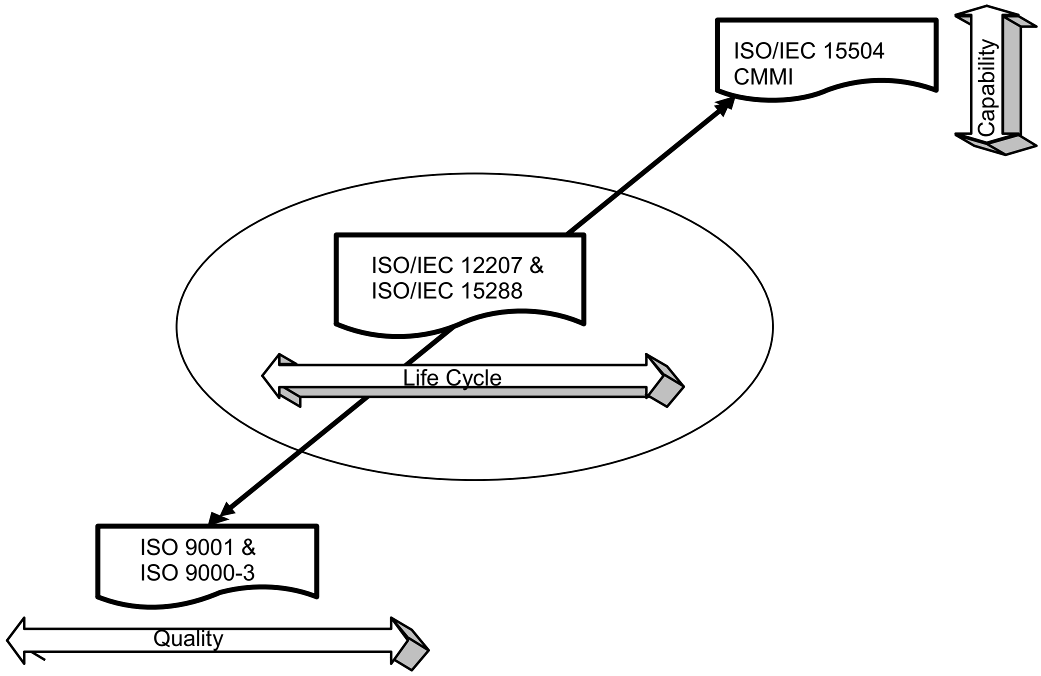


Figure 2-3. Process models and standards

There are a number of standards and process models with different goals and scopes of application. We can group the standards and process models described in this subsection into three groups based on their application, shown in Figure 2-3 below. ISO 9001 and 9000-3 are used for establishing a quality management system in the organisation, ISO/IEC 12207 and ISO/IEC 15288 describe the life cycle processes, and ISO/IEC IS 15504 and CMMI are used to assess or determine the capability of processes.

ISO/IEC 12207, ISO/IEC 15288 and ISO/IEC IS 15504 are closely aligned to each other having a common process repository. CMMI and ISO/IEC IS 15504 have the same purpose of process assessment and capability determination. The application of all the above-mentioned standards and process models help establish the organisational quality management system or to achieve the ISO 9001 certification.

The following subsections provide an overview of the standards shown in Figure 2-3. ISO/IEC IS 15504 and CMMI, applied extensively in this study have been described in great detail based primarily on the author's earlier publications. There are several reasons why these two process models have been studied in this research. Both ISO/IEC IS 15504 and CMMI are used extensively in software industry for process assessment purposes. They are both maintained and evolving through time. ISO/IEC IS 15504 is the only international standard for process assessment at the moment. CMMI has evolved from the concepts of software maturity framework and has therefore enduring underlying ideas behind it. The detailed description of the international standards and process models related to ISO/IEC IS 15504 and CMMI can be found in Appendix 1.

2.1.4.1. ISO/IEC 15504

This subsection provides a description of ISO/IEC 15504, one of the two process models extensively used in the current research. Most of the research prior to this thesis was carried out by the author when ISO/IEC 15504 was a Technical Report (TR), including the structural analysis of the reference model and measurement framework illustrated later in this subsection. The structural elements of the reference model and measurement framework have not changed significantly in the process of Technical Report becoming an International Standard (IS). The few changes concerning the structural elements that have taken place are primarily terminological and will be described. The structural analysis of the exemplar assessment model described in the end of this subsection was based on the draft documents of International Standard ISO/IEC 15504 that have remained the same until IS was published in 2006. Also, the information derived for this thesis comes from the International Standard of ISO/IEC 15504.

ISO/IEC TR 15504, also known as SPICE, started out in 1993 as an international initiative to support the development of an International Standard for Software Process Assessment. The term SPICE originally stands for the initiative to support the development of an international standard for software process assessment. SPICE is an abbreviation of Software Process Improvement and Capability dEtermination. In 1998-9 SPICE was published as Technical Reports of ISO/IEC 15504. The International Standard of ISO/IEC 15504 was published in 2003 (Part 2), 2004 (Part 1, 3 and 4) and the final part of the International Standard, ISO/IEC IS 15504-5 was published in 2006. The aim of the standard is to provide a shared approach for process assessment and lead to a common understanding of the use of process assessment for process improvement and capability evaluation. The standard provides the software development organisations with a continuous tool for process assessment and improvement while the software development is aligned with and supports business needs of the organisation.

The primary importance of ISO/IEC TR 15504 (ISO/IEC 15504-1, 1998) was that it set requirements for constructing an assessment process and a compatible assessment model that addresses unique needs of an industry or an organisation. The most significant requirements that the International Standard describes are the need to establish a complete and unambiguous mapping between the compatible model and the process reference model of ISO/IEC IS 15504-2, and to develop a mechanism for translating the outputs from an assessment into the standard process profiles defined in IS 15504 (Rout and Tuffley, 2002).

The Technical Reports of ISO/IEC 15504 consisted of nine parts, where Part 2 and Part 3 were normative. Part 2 was directly aligned to ISO/IEC 12207, providing an overall contextual framework for software life cycle processes, and the process dimension of the reference model was closely mapped to this framework. Part 5 provided an exemplar model for performing process assessments that was based upon and directly compatible with the reference model in Part 2.

In the International Standard of ISO/IEC 15504 there are only five parts, as a result of the substantial simplification and reduction of the earlier Technical Reports. The only normative part of the standard is part 2, which provides a framework for process assessment and sets out the minimum requirements for performing an assessment in order to ensure consistency and repeatability of the ratings.

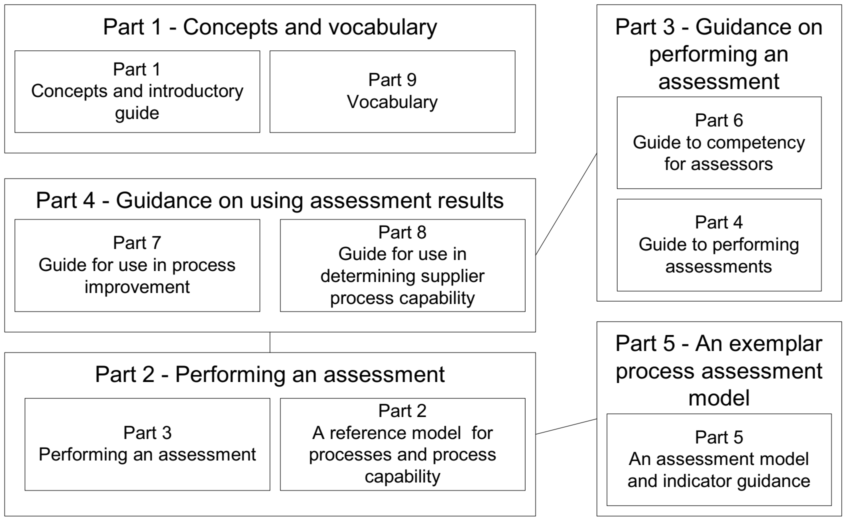


Figure 2-4. The integration of TR documents into a new document set of IS 15504 (Lepasaar et al., 2002)

Part 2 of ISO/IEC IS 15504 contains all normative components of the International Standard. Other parts contain guidance that will provide a more detailed understanding of the subject. Part 1 describes the concepts and vocabulary of the ISO/IEC IS 15504. Part 3 provides guidance on performing an assessment and Part 4 describes how the assessment results can be used. Part 5 is an exemplar process assessment model aligned with and satisfying all the requirements set in Part 2. The integration of the old documents into the new document sets is shown in Figure 2-4. The larger boxes represent the documents of the International Standard and the smaller ones the TR version of 15504 document sets.

15504 can also be divided into a set of guides and models. Part 2 describes the reference model and Part 5 an exemplar assessment model. The rest of the parts are guides of how to use and interpret these models.

ISO/IEC IS 15504 defines the minimum set of requirements for performing an assessment that will ensure assessment results are objective, impartial, consistent, repeatable and representative of the assessed process (ISO/IEC 15504-2, 2003). In order to increase the repeatable attribute ratings for assessed processes the ISO/IEC IS 15504 Part 2 sets out the requirements for assessment conformant with this international standard. The requirements help to ensure that the assessment output is self-consistent and provides evidence to substantiate the ratings. Figure 2-5 below shows the logical organisation of the major elements of the process assessment process. The process is same in TR and IS versions.

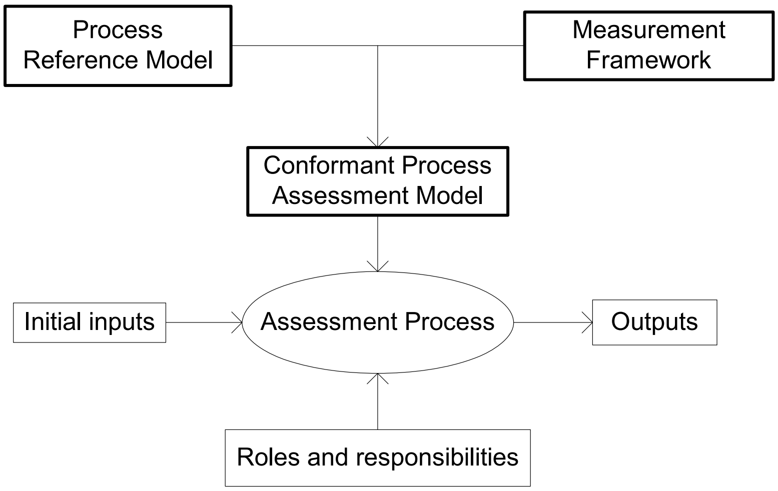


Figure 2-5. Major elements of the assessment process (Lepasaar and Mäkinen, 2002a)

An integral part of conducting an assessment is to use a process assessment model constructed for that purpose, derived from a process reference model and compatible with the requirements of measurement framework. The measurement framework for the assessment of process capability is defined in ISO/IEC IS 15504-2 (2003). A process reference model provides definitions of processes in a life cycle described in terms of process purpose and outcomes, together with an architecture describing relationships between the processes. One of the process reference models in accordance with requirements of ISO/IEC IS 15504-2 is ISO/IEC 12207. A conformant process assessment model embodies the core characteristics that could be expected of any assessment model, which claims to be consistent with ISO/IEC IS 15504-2. An exemplar process assessment model has been described in ISO/IEC IS 15504-5, containing good software engineering and management practices to be considered when interpreting the intent of the process reference model. One way to look for the conformity of an assessment model is to illustrate the structural elements of that model and compare them to the requirements of ISO/IEC IS 15504-2.

Process Reference Model

Here we describe the requirements of Process Reference Model in Unified Modelling Language class diagram notation (Figure 2-6). Process assessment model has two dimensions, a process dimension and a capability dimension. The process dimension is provided in an external Process Reference Model, which defines a set of processes, characterized by statements of process purpose and outcomes. The normative requirements for Process Reference Model have been described in ISO/IEC IS 15504-2.

The elements of Process Reference Model can be divided into two groups based on the nature of the requirements they describe: the elements describing the requirements for the reference model and those describing the requirements of process descriptions. The elements context and community of interest together with their associations illustrate the requirements for the reference model itself and elements process, purpose, and outcome with their subclasses and associations illustrate the requirements of process description. A model claiming conformity to IS 15504 must satisfy both of these sets of requirements.

Requirements for Process Reference Model are the declaration of domain and scope of the process reference model, a description of the relationship between the process reference model and the context of its intended use, actions taken to achieve consensus within the community of interest of the model. The descriptions of the processes are the fundamental element of Process Reference Model. There is another set of requirements for the processes. There has to be a description of the relationship between the processes defined in process reference model. Processes are described in terms of its purpose and outcomes, where the outcome statements describe either a work product, a change of state or meeting of specified constraints.

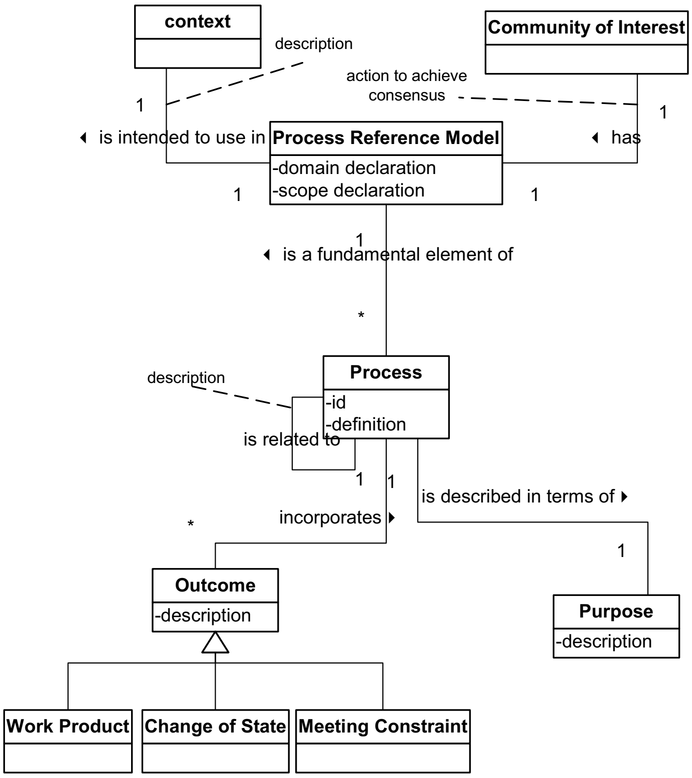


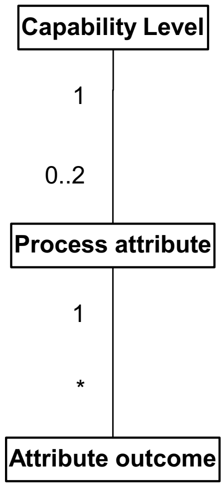
Figure 2-6. Elements describing the requirements of Process Reference Model (Lepasaar and Mäkinen, 2002a)

The elements of the reference model of the International Standard have remained the same as it was in the Technical Reports of ISO/IEC 15504, with the exception that instead of a "work product" the outcome statement should describe a "production of artefact".

Measurement Framework

The other dimension of the process assessment is the capability dimension. The capability dimension has nine process attributes that are grouped into six process capability levels that define an ordinal scale of capability that are applicable across selected processes. The measurement framework for process capability has been defined in ISO/IEC IS 15504-2 and has remained the same in IS as it was in TR version (Figure 2-7). The measure of capability is based upon a set of process attributes. Process attributes are used to determine whether a process has reached a given capability. The elements of the measurement framework have been given in

Figure 2-7 and an example of these corresponding elements has been given in Figure 2-8.



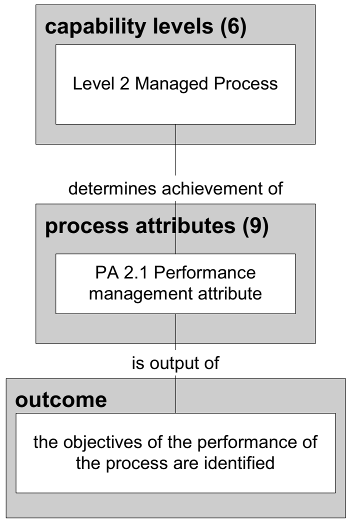


Figure 2-7. Elements and Figure 2-8. Example of the measurement framework described in TR 15504-2 (Lepasaar and Mäkinen, 2002a)

The measurement framework of the International Standard has remained the same as it was in the Technical Reports of ISO/IEC 15504.

Process Assessment Model

A process assessment model forms the basis for the collection of evidence and rating of process capability. Any process assessment model is related to one or more process reference models and should contain a definition of its purpose, scope, elements and indicators, mapping to relevant process reference model and mechanism for consistent expression of results.

The structure of the exemplar assessment model provided in ISO/IEC IS 15504-5 (2006) is given in Figure 2-9. The exemplar assessment model is compatible with the reference model defined in Part 2.

The process assessment model is based on the principle that the capability of a process can be assessed by demonstrating the achievement of process attributes. Each process in the process dimension has a set of base practices, which are the process-specific detailed practices. Base practices and work products are the process performance indicators that measure the degree of achievement of the process performance attribute for the process assessed.

Each process attribute in the capability dimension has a set of process attribute indicators, which provide evidence of the extent of the achievement of the attribute in the instantiated process. Generic practice indicators provide guidance on the implementation of the attribute's characteristics. The Generic resource indicators are associated with the resources used when performing the process. Generic work product indicator is a work product that is typically related to the performance of the process when it achieves the process attribute outcomes. This work product is a subset of the work product defined in process dimension. Process attribute is also related to processes as some of the processes support the achievement of process attribute of other processes.

In this research, we use elements of the exemplary process assessment model described in ISO/IEC IS 15504-5. The base practices of project management process from management process group are selected for the study. The base practices of processes that are related to project management process through work products are also selected. In addition, the generic practice indicators that support the achievement of process attributes of project management capability level 2 and no higher are included in the study.

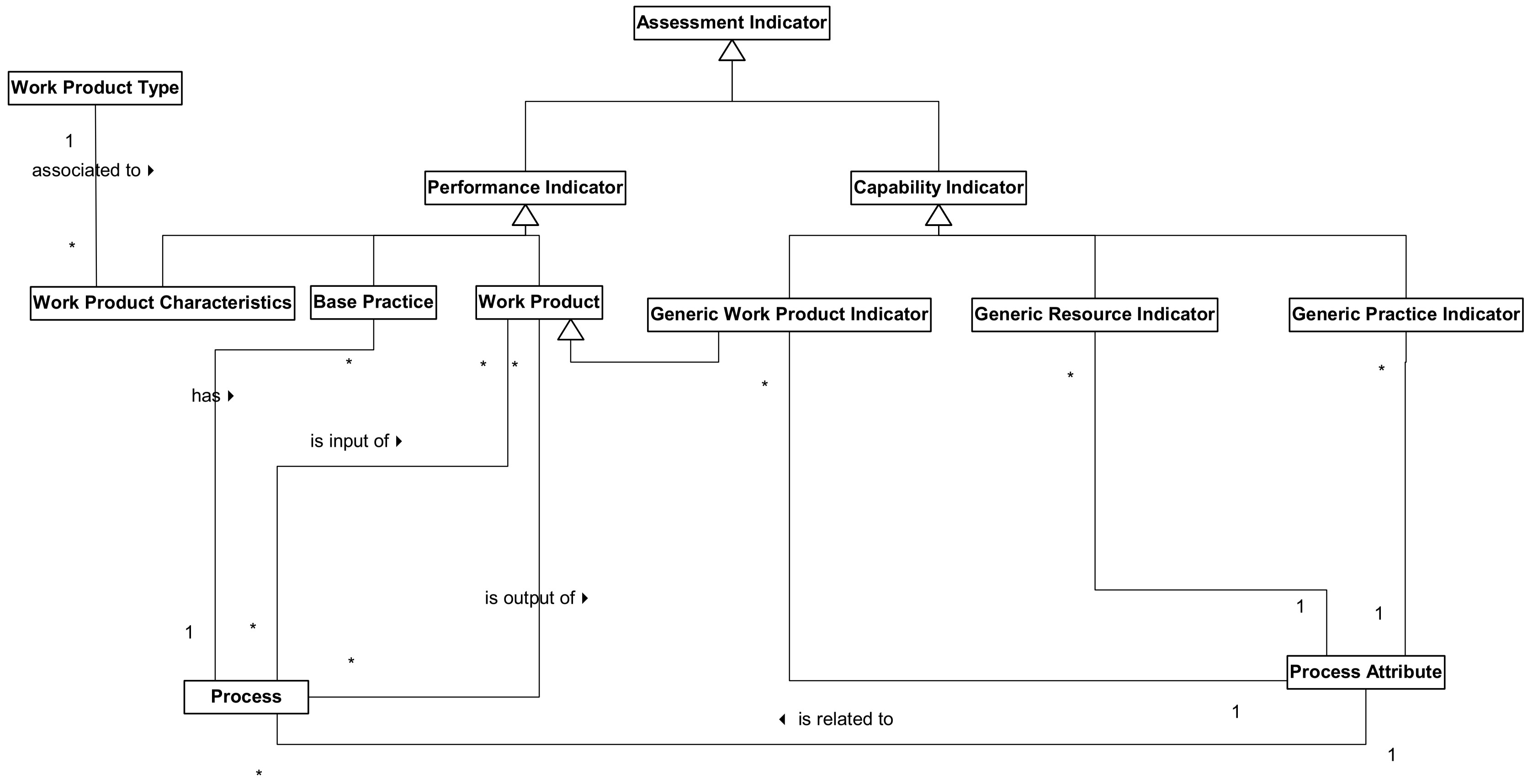


Figure 2-9. Structure of the exemplar assessment model described in ISO/IEC IS 15504-5 (Lepasaar and Mäkinen, 2002a)

2.1.4.2. Capability Maturity Model Integration

Both CMMI Continuous Representation and ISO/IEC IS 15504 are extensively used in the current research. This subsection describes the evolvement of CMMI Continuous Representation and its structure.

The development of the Capability Maturity Model Integration (CMMI) can be dated back to software maturity framework concept introduced by Software Engineering Institute (SEI) in 1986. In 1991 the SEI evolved the framework into a Capability Maturity Model v1.0 (Paulk, 1999). The CMM for Software v1.1 was developed with the stewardship by SEI and released in 1993. The CMMI project has been underway since February 1998. In December 2000 the CMMI project released the CMMI for Systems Engineering/Software Engineering, Version 1.02 and in 2002 Version 1.1.

The purpose of the Capability Maturity Model Integration (CMMI) is to provide guidance for improving the processes and the ability to manage the development, acquisition and maintenance of products and services. The CMMI project was formed to address the problem of having to use multiple Capability Maturity Models. CMMI aims to integrate three CMM models – CMM for Software, CMM for Systems, CMM for Integrated Product Development into a single model for use by organisations pursuing enterprise-wide process improvement (SEI, 2002).

Model representation is the way the process areas are presented in the certain process improvement model. In CMMI the two dominant representations are staged and continuous. (Bate and Shrum, 1998)

There are two representations of the CMMI – continuous and staged. With the staged representation one is able to measure the maturity of the entire software organisation. With continuous representation it is possible to assess every software process separately providing capability level for a process.

In the continuous representation of the CMMI (SEI, 2002) the organisation of the process areas are similar to that of ISO/IEC IS 15504 offering more freedom in the order of improvement and a measure for process capability. The staged representation of the CMMI provides a defined sequence of improvements and a measure for organisational maturity similarly to the SW-CMM.

In our research we focus on the guidance of the CMMI continuous representation (SEI, 2002). The continuous representation groups process areas by affinity categories and designate capability levels for process improvement within each process area. Capability profiles illustrate process improvement paths in terms of staging of process areas. Capability levels provide a recommended order for approaching process improvement within each process area, allowing flexibility for the order in which the process areas are addressed. The process dimension focuses on the best practices an organisation can use to improve processes in particular process areas.

Figure 2-10 illustrates the structure of the CMMI continuous representation. In CMMI, process areas are grouped into four process area categories. Process area includes a set of related practices that collectively aim at achieving specific goals. The specific practices describe the activities expected to result in achievement of specific goal of a process area. Specific practices at capability level 1 are called base practices and specific practices at higher levels are called advanced practices*,* which are built on the base practices. A typical work product is one of the outcomes of a specific practice. Subpractices are detailed descriptions that provide guidance for interpreting specific and generic practices. Discipline amplifications are also related to the specific practices and contain information relevant to a particular discipline. Generic and Specific Practices are descriptions of actions needed to enact the key elements of a process. The essence of CMMI model is in the practices.

In CMMI there are six capability levels that focus on maturing the organisation's ability to perform, control and improve its performance in a process area. Each capability level has one generic goal that prescribes what the organisation must achieve at that capability level. Generic practices relate to all process areas as they can improve the performance and control of any process. Generic practices are mapped to one generic goal. Generic practice elaborations provide guidance on how the generic practices, which apply to all process areas, should uniquely be applied to one certain process area.

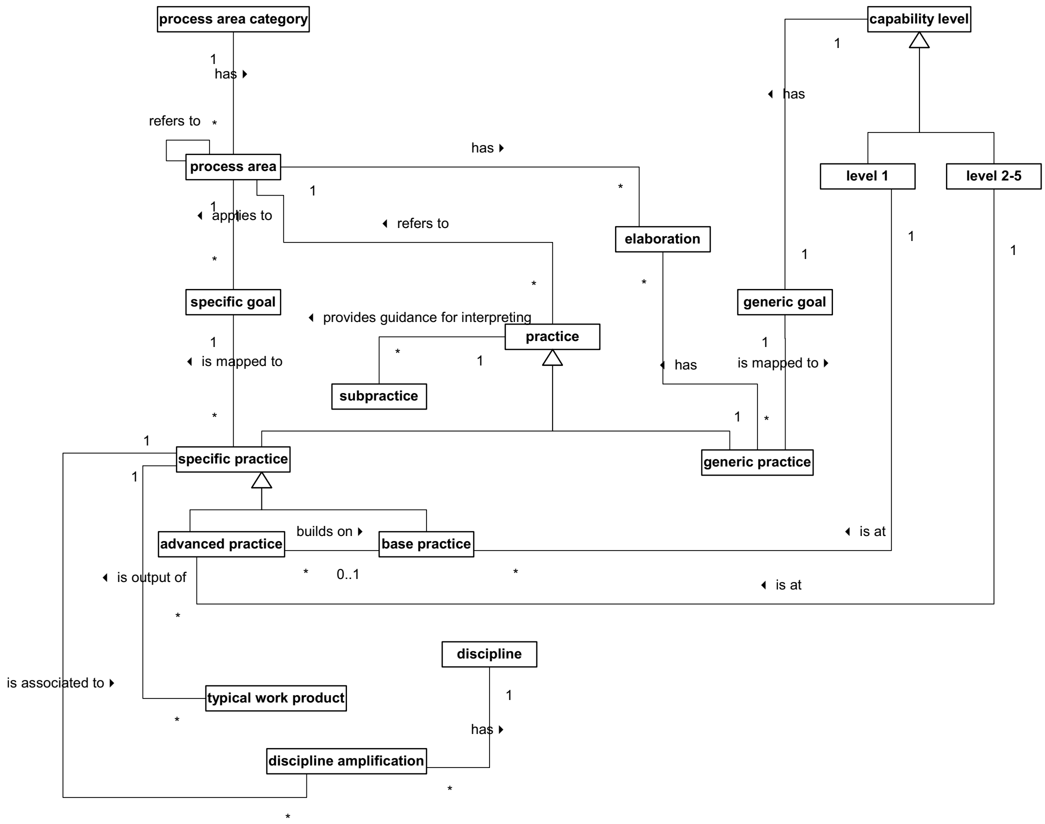


Figure 2-10. Structure of the CMMI continuous (Lepasaar and Mäkinen, 2002a)

There are 25 Process Areas grouped into four Process Area Categories in CMMI continuous representation – Process Management, Project Management, Engineering, and Support.

There is one Generic Goal on each of the five Capability Levels. Each Generic Goal has one to nine Generic Practices related to it. Generic Practices are activities that ensure that the processes associated with the Process Area will be effective, repeatable, and lasting. Generic Practices contribute to the achievement of the Generic Goal when applied to a particular Process Area.

In this research, the project management related activities described in the continuous representation of CMMI are used. The base practices of the Project Planning, and Project Monitoring and Control Process Areas, together with the Generic Practices that support the achievement of the Generic Goals of the Capability Level 2 of Project Planning, and Project Monitoring and Control are elements of CMMI applied in the study. The base practices of Process Areas that are related to Project Planning, and Project Monitoring and Control are also included in the study.

2.1.4.3. International Standards and Process Models related to ISO/IEC IS 15504 and CMMI

In this subsection a short overview of the related standards to ISO/IEC IS 15504 and CMMI, as shown in Figure 2-3, is provided. A more detailed description of each standard can be found in Appendix 1.

ISO 9000 family of standards

The ISO 9000 family of standards, listed below, has been developed to assist organisations, of all types and sizes, to implement and operate effective quality management systems: (ISO 9000, 2005)

1. ISO 9000 describes fundamentals of quality management systems and specifies terminology for quality management systems;
2. ISO 9001 specifies requirements for quality management systems for use where an organisation's capability to provide products that meet customer and applicable regulatory requirements needs to be demonstrated;
3. ISO 9004 provides guidance on quality management systems, including the processes for continual improvement that contribute to the satisfaction of an organisation's customers and other interested parties;
4. ISO 19011 provides guidance on managing and conducting environmental and quality audits.

CMM for Software

In November 1986, the Software Engineering Institute (SEI), with assistance from the Mitre Corporation, began developing a process maturity framework that would help organizations improve their software processes. This effort was initiated in response to a request to provide the federal government with a method for assessing the maturity of its software contractors. In September 1987, the SEI released a brief description of the process maturity framework and a maturity questionnaire. The SEI intended the maturity questionnaire to provide a simple tool for identifying areas where an organization's software process needed improvement. Unfortunately, maturity questionnaire was too often regarded as "the model" rather than as a vehicle for exploring process maturity issues. (Paulk et al., 1999) After four years of experience with the software process maturity framework and the preliminary version of the maturity questionnaire, the SEI evolved the software process maturity framework into the Capability Maturity Model for Software (SEI, 1993).

ISO/IEC 15288

The International Standard of ISO/IEC 15288 (2002) is called Systems Engineering – Systems Life Cycle Processes. It provides a common process framework covering the life cycle of man-made systems. This life cycle spans the conception of ideas through to the retirement of a system. It provides the processes for acquiring and supplying system products and services that are configured from one or more of three primary classes of system elements: hardware, software and humans. In addition, this framework provides for the assessment and improvement of the life cycle processes.

ISO/IEC 12207

In June 1989, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) initiated the development of an International Standard ISO/IEC 12207 on Software Life Cycle Processes. The international standard was published in August 1995. (Zahran, 1998, pp. 364-365) It is the first international standard to provide a comprehensive set of life cycle processes, activities and tasks for software that is part of a larger system, stand-alone software product, and software services. The standard provides common software process architecture for the acquisition, supply, development, operation and maintenance of software. The standard also provides the necessary supporting processes, activities and tasks, and organizational processes, activities and tasks for managing and improving the processes. (ISO/IEC 12207, 2004)

2.2. Software Project Management

This research describes the project management activities through the process models. This section first provides a short overview of the theoretical basis of project management, based on (Koskela and Howell, 2002). It then describes the importance of project management from an organization's perspective, and the meaning of a project and project management based on project management literature. We then describe the Project Management Body of Knowledge (PMBoK) as one of the sources of project management processes used extensively in industry

Koskela and Howell (2002) argue that project management has generally been seen without an explicit theory. They contend that it is actually possible to precisely point out the underlying theoretical foundation of project management as espoused in the PMBoK of Project Management Institute (PMI). This foundation can be divided into a theory of project and a theory of management. The product-oriented processes of the PMBoK that specify and create the project product refer to the theory of project. The processes of initiating, planning, executing, controlling and closing the project of the PMBoK refer to the theory of management.

In their description of the theory of project, Koskela and Howell refer to J. R. Turner's theoretical view of project management. First, Turner (1993) claims that project management is about managing work; secondly, work can be managed by dividing the total work effort into smaller chunks of work – these are called activities and tasks in the PMBoK; and finally, the divided tasks are related by sequential dependence. Koskela and Howell (2002) further argue that when project management is compared to the theories of operation management it is easily seen that project management rests on the transformation theory (view) of production that has dominated production thinking throughout the 20th century. In the transformation view, production is conceptualized as a transformation of inputs and outputs. The transformation view has its intellectual origins in economics, for example the popular value chain theory of Porter (1985) is one approach embodying this view. At the same time, the transformation view is so embedded in thinking and practice, Koskela and

Howell believe that it has formed the basis of an invisible, unspoken paradigm that shapes behaviour.

In describing the other theoretical basis of project management as a result of analysing the PMBoK, Koskela and Howell (2002) suggest that project management is based on three narrow theories of management: management-as-planning, the dispatching model and the thermostat model (model of management control). The first is evident from the structure and emphasis of the PMBoK. The second is apparent from the discussion of execution in the PMBoK. The third is very clearly embodied in the closed loop of planning, execution and controlling. The planning processes provide a plan that is realized by the executing processes, and variances from the baseline or requests for change lead to corrections in execution or changes in further plans.

The planning of the projects is thoroughly described in the PMBoK, with little offered in executing and controlling. The perspective of the theory of planning is that of management-as-planning that views a strong connection between the actions of management and outcomes of the organization. Management at the operations level is seen to consist of the centralized creation, revision and implementation of plans. (Koskela and Howell, 2002)

The underlying theory of execution turns out to be similar to the concept of job dispatching in manufacturing where it provides the interface between plan and work. Job dispatching is a procedure that uses logical decision rules to select a job for processing on a machine that has just become available. Dispatching consists of two elements: decision (for selecting task for a workstation from those predefined tasks that are ready for execution), and communicating the assignment (or authorization) to the workstation. In the case of project management, that decision is largely taken care in planning, and thus dispatching is reduced to mere communication: written or oral authorization or notification to start work. (Koskela and Howell, 2002)

The PMBoK divides the core processes of controlling into two sub-processes: performance reporting and overall change control. Based on the former, corrections are prescribed for the executing processes, based on the latter, changes are prescribed for the planning processes. Performance reporting, based on performance baseline, clearly corresponds to the cybernetic model of management control (thermostat model) that consists of the following elements: there is a standard of performance, performance is measured at the output (or input), the possible variance between the standard and the measured value is used for correcting the process so that the standard can be reached. (Koskela and Howell, 2002)

Koskela and Howell (2002) conclude that the silence on the theoretical basis of project management in project management literature is puzzling: it is either conceded that there is no theory of project management, or it reflects the opinion that the theoretical is not significant from the point of view of project management.

We continue the description of the meaning and importance of project and project management from organization's perspective, based on project management literature. Projects can be viewed as critical stepping stones for organizational growth and productivity. (Pinto and Kharbanda, 1995, pp. 11-86) Organizations worldwide are seeking ways to reduce bureaucracy and increase productivity and job satisfaction. Increasingly, project management processes are being used to create highly integrated organizations, controlled by project teams responsible for planning, controlling, coordinating and improving their own work. (Kezsbom and Edward, 2001, pp. 24-36) Based on the increasing interest in project management, there has also been an explosion in the literature on project management.

Although there is no single definition of a project, there are four dimensions of projects that most project management writers have described, based on (Pinto and Kharbanda, 1995, pp. 11-86).
These dimensions are:

1. Projects are constrained by a finite budget and time frame to completion; that is, they typically have a specific budget allocated to them as well as a defined start and completion date.
2. Projects comprise a set of complex and interrelated activities that require effective coordination.
3. Projects are directed toward the attainment of a clearly defined goal or set of goals.

4. To some degree, each project is unique.

A project can also be defined as an investment of resources for an objective, and also a cause of irreversible change. To get value from the investment, a project usually has defined data for completion. As a result, the work for a project is a period of intense engineering activities but short in its duration relative to the subsequent working life of the investment. (Wearne, 1995)

Project management is needed to look ahead at the needs and risks, communicate the plans and priorities, anticipate problems, assess progress and trends, get quality and value for money and change the plans if needed to achieve objectives. (Wearne, 1995)

Based on (Pinto and Kharbanda, 1995, pp. 11-86), project management is the dynamic process of leading, coordinating, planning and controlling a diverse and complex set of processes and people in the pursuit of achieving project objectives.

Excellence in project management is defined as a continuous stream of successfully managed projects. Any project can be driven to success through formal authority and strong executive meddling. But in order for a continuous stream of successful projects to occur, there must exist a strong corporate commitment to project management, and this commitment must be visible. (Kerzner, 2001, pp. 1-35)

The successful project consists of four factors, described in (Pinto and Kharbanda, 1995, pp. 11-86) – project being on time, on budget, performs as expected and is accepted by the customers. In order for the customer to accept the project, the project managers must devote additional time and attention to maintaining close ties with and satisfying the demands of the external clients. This requires the project managers to adopt an outward focus in their efforts. They are not just the managers of the project activities, but also the company's sales representatives to the client base.

When we begin to view project management as a technique for implementing overall corporate strategy, it is clear that the importance of project management and, hence, project managers cannot be underestimated. Project management becomes a framework for monitoring corporate progress as it further provides a basis on which the skilful manager can control the implementation process. No wonder, then, that there is a growing interest in the project manager's role within the corporation. (Pinto and Kharbanda, 1995, pp. 11-86)

In 1996, the first version of the body of knowledge in project management was published by the Project Management Institute. A body of knowledge describes the sum of knowledge within the procession that rests with the practitioners and academics that apply and advance it. Project Management Body of Knowledge (PMBoK) describes the sum of knowledge within the profession of project management. The full project management body of knowledge includes knowledge of proven traditional practices that are widely applied, as well as knowledge of innovative and advanced practices that have seen more limited use, and includes both published and unpublished material. The next subsection provides a more detailed description of the PMBoK.

Project Management Body of Knowledge

The purpose of the PMBoK (PMI, 2000) is to identify and describe the knowledge and practices applicable to most projects most of the time with a widespread consensus about their value and usefulness. It also provides a common lexicon within the profession and practice for talking and writing about project management.

Based on the PMBoK, projects are often implemented as a means of achieving an organization's strategic plan. Operations and projects differ primarily in that operations are ongoing and repetitive while projects are temporary and unique. In other words, a project is a temporary endeavour undertaken to create a unique product or service. Temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguishable way from all the other products or services. For many organizations, projects are a means to respond to those requests that cannot be addressed within the organization's normal operational limits.

In the PMBoK project management is defined as the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is an integrative endeavour – an action, or failure to take action, in one area will usually affect other areas. To help in understanding the integrative nature of project management, and to emphasize the importance of integration, the PMBoK describes project management in terms of its component processes and their interactions.

According to the PMBoK, projects are composed of processes. A process is a series of actions bringing about a result. Project processes are performed by people and generally fall into one of two major categories: project management processes – describe, organize, and complete the work of the project; and product-oriented processes – specify and create the project's product. Project management processes are applicable to most projects most of the time. Product-oriented processes are typically defined by the project life cycle and vary by application area. Project management processes and product-oriented processes overlap and interact throughout the project.

The PMBoK describes 36 project management processes that are grouped into nine knowledge areas – project integration management, project scope management, project time management, project cost management, project quality management, project human resource management, project communications management, project risk management and project procurement management. The same processes can also be organized into the following five process groups – initiating processes, planning processes, executing processes, controlling processes, and closing processes. Initiating processes authorize the project or phase. Planning processes define and refine objectives and select the best of the alternative courses of action to attain the objectives that the project was undertaken to address. Executing processes coordinate people and other resources to carry out the plan. Controlling processes ensure that project objectives are met by monitoring and measuring progress regularly to identify variances from plan so that corrective action can be taken when necessary. Closing processes formalize acceptance of the project or phase and bring it to an orderly end.

The core processes of planning, executing and controlling form a closed loop: the planning processes provide a plan that is realized by the executing processes, and variances from the baseline or requests for change lead to corrections in execution or changes in further plans. The planning processes are structured into core processes and facilitating processes. There are ten core processes: scope planning, scope definition, activity definition, resource planning, activity sequencing, activity duration estimating, cost estimating, schedule development, cost budgeting and project plan development. The output from these processes, the project plans, make up an input to the executing processes. In addition to the ten planning processes, there is only one executing process and two controlling processes. The emphasis is on planning, with little offered on executing especially. The only direct reference to the actual interface between plan and work is with regard to work authorization system. The PMBoK divides the core process of controlling into two sub-processes: performance reporting and overall change control. Based on the former, corrections are prescribed for the executing processes, and based on the latter, changes are prescribed for the planning processes. (Koskela and Howell, 2002)

The processes of the PMBoK have been listed in Appendix 4. They have been grouped both into nine knowledge areas as well as into five process groups.

The current research also studies the PMBoK and as shown further on in the research, the closing processes are included in the study. The closing processes include the generating, gathering, and disseminating of information to formalize phase or project completion, including evaluating the project and compiling lessons learned for use in planning future projects or phases.

2.3. SPI and Project Management

We have so far described the background to Software Process Improvement and Project Management. These areas form the basis of this study as shown in this section. The field of software process improvement has evolved from quality thinking in manufacturing (Hunter and Thayer, 2001): from Shewart's cycle of quality improvement, Deming's approach to continuous improvement and Juran's trilogy of quality improvement. The underlying theory of the present doctrine of project management is argued in (Koskela and Howell, 2002) to be based on the theory of management. Thus, the theoretical bases of the research lie in the disciplines of quality management, and the theory of project and of management, shown in Figure 2-11.

The aim of the research is to discover the relevance of process model guidance to industry projects and to the success of these projects. This research is limited to the software industry in Finland and Estonia, and to the model elements of the basic project management activities. The model elements of the basic project management activities are the base practices of project management and project management related process (areas) from CMMI and IS 15504. In CMMI continuous representation (SEI, 2002), the specific practices of capability level 1 are called base practices. In IS 15504-5 (ISO/IEC 15504-5, 2006), base practices address the purpose of the particular process representing the unique, functional activities of the process.

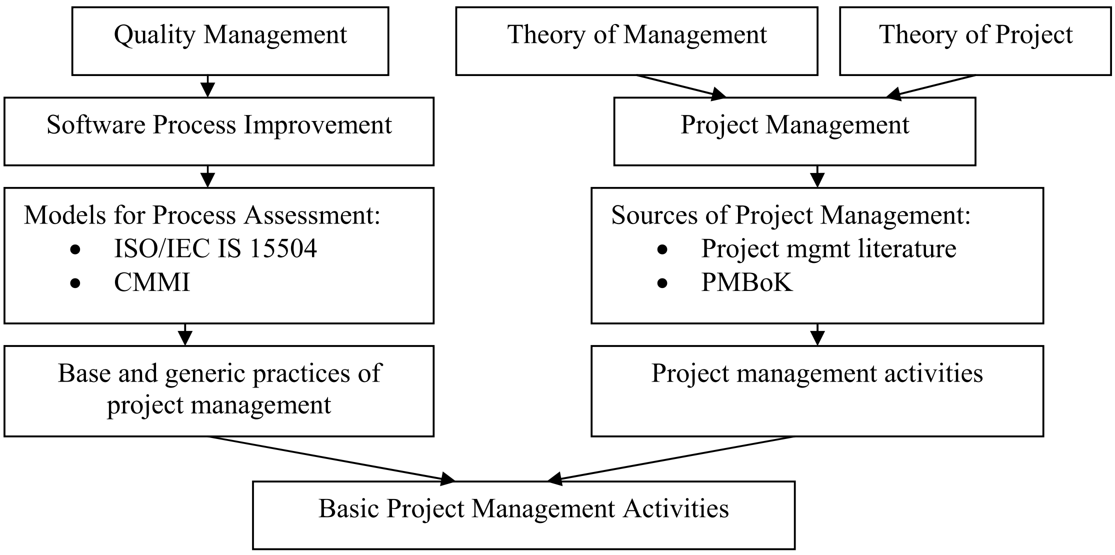


Figure 2-11. Theoretical background of the research elements

We also add generic practices and generic practice indicators that support the achievement of generic goal/process attributes of Capability Level 2 to the model. During the evaluation of the model, these should indicate that the industry project management activities are performed according to a plan and their performance is controlled against that plan as opposed to being accidental. The model includes pertinent project management activities from project management literature and the PMBoK. Most activities from the five process groups of the PMBoK were already derived from the process models. The activities focusing on finalizing the project have no similar practices among the selected practices of process models. These processes are added to the model from the PMBoK. Most activities from the project management literature had similar activities already listed in the scope of the selected practices from process models, except for the directing of people in the project. There are no direct activities focusing on the directing of people among the selected practices of process models, while various sources in literature find it crucially important for a well managed project. The detailed description of building the model is provided in Chapter 3 further on the thesis.

2.4. Related research

This section describes the related research conducted. The related publications have been described and analysed here. A short comparison to the aims of this research is provided, describing the uniqueness of the study. The related research also provides the underlying arguments that have led to the research questions of this study.

Although this research is related to quality management in general, there are three narrow areas of research that relate closely to this study: a) research conducted about SPI and process models; b) research conducted about Project Management and its practices that lead to project success; c) Project Management practices of process models that lead to project success. In the first two areas, there has been much research conducted. In the focused area of our research, only two closely related research publications were discovered. This research varies from the related research in its problem setting and research question, bringing new results through the original work.

2.4.1. Research on SPI and process models

There is extensive research conducted on Software Process Improvement, and on the methods (Komi-Sirviö, 2004; Kinnula, 2001; Järvinen, 2000) and models (Paulk, 1994) that are related to it. Much research has been conducted on the process models of CMMs and ISO/IEC TR 15504 (ISO/IEC 15504-1, 1998). There are many case studies published about their implementation and adoption in industry, mostly illustrating the industry success stories (O'Hara, 2000; Iversen, 2000; Herbsleb et al., 1994; Kinnula, 2001). Many of the well-reported success stories refer to relatively large, expensive projects in larger software firms connected to the American defence and aerospace industry (Hansen et al., 2004). There has also been much comparison of different Capability Models and SPICE, both by SEI (SEI, 2005) and ESI (ESI, 2005), primarily mappings of terminology and concepts (Paulk, 1999; Rout, 1998), with few analyses of conceptual relationships between the models (Mäkinen, 2004). Much research in SPI is focused also on the SMEs and how they can benefit from process models like SW-CMM originally created for the needs of large organizations. (Kautz, 1998; Baskerville and Pries-Heje, 1999; Varkoi, 2000; Ward et al., 2001)

2.4.2. Research on project management practices that lead to project success

Another area that is related closely to our research is project management concerning the software development projects. Most of the related research that has been conducted in this area is empirical, aiming to find the industry best practices as well as the project success factors.

An extensive survey of project management practices of 122 in-house software development projects in US organizations that rely heavily on software was described in (Verner and Evanco, 2005). Their underlying starting assumption was that a clear vision of the final product, good requirements, active risk management, and post-mortem reviews increase the project success. The findings of their study showed rather different results.

The experience of the project manager in software development was not significantly associated with project success, suggesting that project managers should have a broad managerial background rather than expertise in any particular technical area. Managing the project team through motivating the team members, coordinating the communication of team members and relating well with the team were significantly associated with project success. Managerial support of the development team was found to be the most essential factor that increases the motivation of the team to work effectively towards the organizational goals.

Although it is often argued that good project management necessitates complete and consistent requirements (Osmundson, 2003), the study by Verner and Evanco showed no significant association between project success and requirements elicitation and management. The developers admitted that it is important to have good requirements management for a project to succeed, but most projects began with incomplete requirements.

A mismatch also exists between risk identification and control. Most developers and project managers perceive risk management processes as creating extra work and expense. Although most project managers identified risks at the project's start, fewer than half followed through during development. This underscores that risk management is not routinely part of development.

Post-mortem reviews are important for process improvement, but companies seldom perform them. Most project managers viewed each project as a standalone entity and therefore did not perceive post-mortem reviews as important. Neither business nor project managers appeared to understand the specific causes of failed projects; consequently they are unlikely to improve their performance on subsequent projects.
The study concludes that the project manager's clear vision of the project, good requirements and adequate information for delivery were the most important factors of project success. The poor state of risk control, post-mortem reviews and requirements management in the projects is worrisome for the authors who claim that these are all vital for increasing software project management quality and success.

Similar study was carried out in Australia where 42 software development or maintenance projects were studied, described in (Verner and Cerpa, 2005). The results confirm the findings of the Verner and Evanco study.

Directing, managing and motivating the project team were found to be the crucial factors of project success. Risk monitoring, post-mortem reviews and requirements elicitation were not significantly associated with project success. The size of the project made no difference to whether or not risks were incorporated into their project plans.

The authors conclude that further study is needed to determine if the study represents all Australian software developers and to discover the underlying reasons for the poor project management processes in the software projects.

Goldenson and Herbsleb (1995) surveyed 61 CMM appraisals through contacting 167 individuals in USA and Canada over a one-year period. The study concludes that the higher organizational maturity increases the organizational performance. In their study, performance was defined in terms of six variables: customer satisfaction, ability to meet budget commitments, ability to meet schedule commitments, product quality, staff productivity, and staff morale.

El Emam and Birk (2000) have used the same variables defined in (Goldenson and Herbsleb, 1995) by defining them in the following way: ability to meet budget commitments, ability to meet schedule commitments, ability to achieve customer satisfaction, ability to satisfy specified requirements, staff productivity, staff morale/job satisfaction.

Kari Leppälä, who studied the techniques of project management in R&D organisation in (Leppälä, 1995) divides project success into three categories. If the project solves pre-defined problems or fulfils the specifications, the project is technically successful. If the project is executed according to the original budget and time schedule, it is a programmatic success. But the ultimate success, he argues, lies in the industrial innovation. He explains that a technical failure may actually have a positive impact, e.g. when a project that aims to study the feasibility of its object has a negative result it will prevent further investments into a weak innovation idea.

2.4.3. Research on process capability and project performance

The research conducted in this focused area usually aims to discover whether the higher capability of a certain process or process area has positive effects on project performance.

Goldenson and Herbsleb (1995) surveyed 61 CMM appraisals through contacting 167 individuals in USA and Canada over one year period. The study concludes that the higher organizational maturity increases the organizational performance. The results appear to be unaffected by the type and size of the organizations involved. Organizations from different sectors of software industry and the ones new to CMM benefit from the higher process maturity just like those from the defence contractors and federal government. Also, organizations with relatively few software employees appear to benefit from higher process maturity just as do larger organizations.

El Emam and Birk (2000) investigated the relationship between the capability of software requirements analysis (SRA) process as defined in the ISO/IEC TR 15504 and the performance of software projects. Altogether, they studied 70 assessments where 691 process instances had been assessed. Their basic assumption was that since process capability is defined through the implementation of practices, some correlation between process capability and process performance can reasonably be expected.

They considered the size of the organization as a context factor, where “small” was equal to or less than 50 IT staff. Previous studies provide inconsistent results about the effect of the organizational size. There have been some concerns that the implementation of certain processes or process management practices may not be as cost-effective for small organizations as for large ones. At the same time, there are several studies described in (Elemam and Birk, 2000) indicating that size of the organization and project does not affect the relationship between process maturity and project performance.

As was stated in (Elemam and Birk, 2000), the basic premise of software process assessment is that the practices defined in the assessment model are good practices and their implementation will therefore result in improved performance. Their results indicate that improving the SRA process may potentially lead to improvements in productivity of software projects in large organizations. This means that improvements in SRA process capability are associated with a reduction in the cost of software projects. However, no relationship was found with other measures of performance, nor was there any relationship between SRA process capability and any of the performance measures that were used for small organizations.

An article by J.J. Jiang et al. (2004) describes a study that examined the relationship between SW-CMM software process development activities and project performance. Jiang et al surveyed 154 software organizations familiar with or adopting the activities of the SW-CMM for managing their software development. As a result of their study they conclude that the process maturity is positively associated with the project performance, while the basic project management process activities were not significant to the performance at all. Although this article is closely related to this study, the aim and the level of detail varies a lot between the two. In (Jiang et al., 2004) the focus is mainly on how well SW-CMM practices support the achievement of higher maturity levels and less on how well the SW-CMM practices correspond to the practices in software industry. In other words, (Jiang et al., 2004) examines the associations within the SW-CMM model, while this study aims to find an association between models and the software industry.

2.4.4. Conclusions on the related research

There is evidence that the higher organization maturity or process capability supports increase in the project performance. In (Jiang et al., 2004) the question remained about the significance of basic project management practices to project performance. We focus only on basic project management and its related practices – the processes that support the achievement of capability levels 1 and 2 in CMMI Continuous and ISO/IEC IS 15504. We aim to discover whether the implementation of processes on project level supports the project success?

There is also confusing evidence on whether the size and type of the organization and of the project affect the relationship between higher process capability and project success. Furthermore, there is evidence that the experience of the project manager in software development has no association with project success. Thus, we aim to find out whether the intensity of implementing process model practices depends on the characteristics of the project, organization and project manager.

As was stated in (Elemam and Birk, 2000), the benefits of process improvement cannot be posited to an individual process but to a combination of processes. Based on this argument, we study a combination of related processes instead of studying the relationship of an individual process capability and project success. The process success factors used in the study reflect the six success variables described in (Goldenson and Herbsleb, 1995) and applied in (Elemam and Birk, 2000).

Various online libraries, online databases of technical literature, and project management and standardisation related community sites were scoured for the keywords of this research until no more relevant new results were found. Based on the literature studied, we conclude that the project management practices, project success factors, process capability and project performance have been studied for decades. At the same time, the author did not find earlier published works that study the intensity of implementing a specific set of process model practices in industry projects, e.g. the basic project management practices in this research, and finding the relationship between the implementation of these practices and project success.

3. BUILDING THE MODEL OF BASIC PROJECT MANAGEMENT ACTIVITIES

In this chapter, illustrated in Figure 3-1 below, the first part of the research conducted has been described in detail.

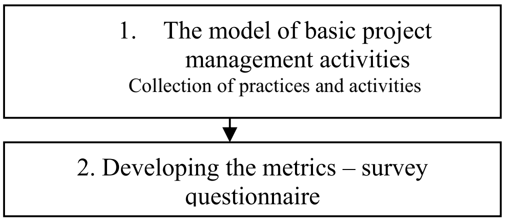


Figure 3-1. Structure of model building chapter

The following are the details about constructing the model of basic project management activities. To evaluate the model, the model elements need to be measurable. Metrics are developed and a survey questionnaire is built for that purpose, described together with the sampling method in this chapter. Since the industry data was gathered from software companies in Finland and Estonia, a description of software industry in general and of SPI in particular in these countries has been provided. The data received and the preparation of the data for analysis is also described here.

3.1. Constructing the model

The model of basic project management activities was constructed based on the process models, the Project Management Body of Knowledge (PMI, 2000) and other sources of project management literature (Figure 3-2). The process models used in this research are ISO/IEC IS 15504 and CMMI, both developed for process assessment purposes, having a theoretical basis in Software Process Improvement and, by that extension, in quality thinking. Project Management Body of Knowledge of Project Management Institute provides generally accepted knowledge and practices of project management and is based on project management discipline which is based on the theory of project and theory of management.

In the survey that was developed, in addition to the questions of project management activities implemented in practice, also the questions about the background of the respondents were asked. The questions about the background of the company, the project, the project manager and the project success factors were derived from a similar questionnaire of a PhD thesis defended in Oulu (Huisman, 2000). Huisman studied the deployment of systems development methodologies in practice. She analysed a number of factors to determine whether they explain the organizational deployment of systems development methodologies. The factors can be loosely grouped into four: background information of the software development organization and of the individual respondent, the methodology used in software development on the organization level and on the project level. Although this research focuses on the implementation of basic project management activities in practice, we are also studying the possible influence that the organizational background and project manager might have on the implementation of basic project management activities. Similar factors describing the organization on a cultural level and the project manager on individual level are therefore applied in this study.

The project success factors reflect the areas of project performance described in (Goldenson and Herbsleb, 1995) explained in greater detail in Section 2.4.2. Goldenson and Herbsleb described six success factors reflecting customer satisfaction, ability to meet budget commitments, ability to meet schedule commitments, product quality, staff productivity, and staff morale. In this research we have the following project success factors, the success factors of Goldenson and Herbsleb added in brackets: project was completed on schedule (ability to meet schedule commitments), project was completed within budget (ability to meet budget commitments), project was accepted by the customers (customer satisfaction), project achieved its goals / product satisfied all the stated requirements (product quality), high speed of developing the product (staff productivity), project represents excellent work (staff morale). There are also two verification questions to check the adequacy of the responses: developed product was a success (verifying the success factor of product satisfying the stated requirements) and the project was a success (verifying the success factor of project achieving its goals) – both reflecting the quality of work.

In the following subsections (illustrated in Figure 3-2), we describe how the basic project management activities were derived to the model from the process models – CMMI for Software and Systems Engineering Continuous Representation and ISO/IEC IS 15504-5. The lists of model practices selected for the study from CMMI and ISO/IEC IS 15504 are provided in Appendices 2 and 3, respectively. These basic project management activities that form the basis of the research are then grouped together and re-phrased for the survey questionnaire for model evaluation purposes in software industry.

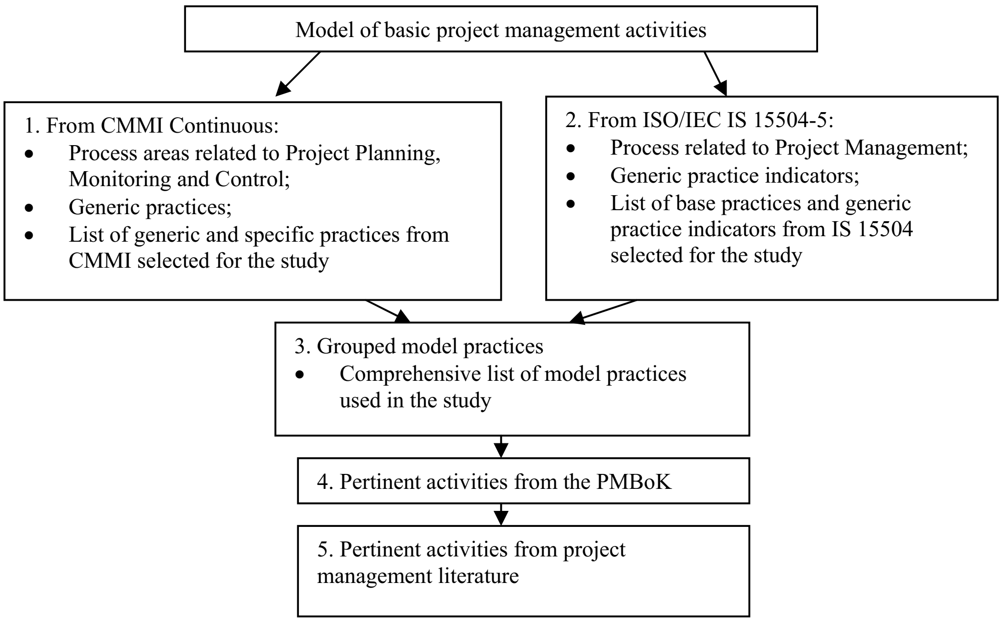


Figure 3-2. Description of the model of basic project management activities

Pertinent project management activities are selected from the PMBoK and other sources of project management literature. The purpose of these project management activities in the research is to find out whether there are activities that industry implements and regards as valuable for success, but that are not included in the scope of practices selected from the process models. The comprehensive list of all the basic project management activities selected to this study from the process models, the PMBoK and project management literature is provided in Appendix 5.

3.1.1. Selection of model practices

The CMMI Continuous Representation and ISO/IEC IS 15504 assessment model both have two dimensions: capability dimension and process dimension. Process dimension describes activities through process (areas) and base or advanced practices. Capability dimension describes the capability levels through generic goals or process attributes that consist of generic practices or generic practices indicators, in CMMI and IS 15504 respectively.

The current research focuses on the basic project management practices for process models. These are the base practices of project management and project management related process (areas) from CMMI and IS 15504. In CMMI Continuous Representation (SEI, 2002), the specific practices of capability level 1 are called base practices. In IS 15504-5 (ISO/IEC 15504-5, 2006), base practices address the purpose of the particular process representing the unique, functional activities of the process.

We also add generic practices and generic practice indicators that support the achievement of generic goal/process attributes of Capability Level 2. This should indicate that the processes that have been implemented in the project described in the survey are performed according to a plan and their performance is controlled against that plan as opposed to being accidental.

Next, we describe how the basic project management practices were derived from the CMMI for Software and Systems Engineering Continuous Representation model. The final list of model practices selected for the study from CMMI is given in Appendix 2.

3.1.1.1. Basic Project Management Practices from CMMI SE/SW Continuous Representation

This subsection provides information about the basic project management practices that were selected for the research from CMMI Continuous Representation. Basic project management practices are the base practices of Project Planning, and Project

Monitoring and Control Process Areas and of the Process Areas related to them. First, the relationship between the process areas has been described and the selection reasoned here. Secondly, the Generic Practices of Generic Goals 1 and 2 have been selected for the research. The list of base and generic practices selected from CMMI Continuous for the study is provided in Appendix 2.

Specific Practices Selected from CMMI Continuous

There are seven Project Management process areas in CMMI Continuous Representation (SEI, 2002): Project Planning, Project Monitoring and Control, Supplier Agreement Management, Integrated Project Management for IPPD[1], Risk Management, Integrated Teaming and Quantitative Project Management.

We considered Project Planning and Project Monitoring and Control Process Areas the core project management activities for our study. The IPPD related Process Areas have been excluded from our research, since we cannot assume that the surveyed companies know or use such a specific development approach. Our study focuses only on basic project management related practices and therefore we also excluded the advanced project management process areas of Integrated Project Management for IPPD, Risk Management, Integrated Teaming, and Quantitative Project Management.

In CMMI Continuous Representation, the Process Areas that are related to each other have been described within each Process Area description. The following are the related Process Areas of Project Planning, and Project Monitoring and Control.

The Process Areas related to Project Planning are Requirements Development, Requirements Management, Risk Management, Supplier Agreement Management, Technical Solution, Project Monitoring and Control, Organizational Training, and

[1] Integrated Product and Process Development (IPPD) is a systematic approach that achieves a timely collaboration of relevant stakeholders throughout the life of the product to better satisfy customer needs, expectations, and requirements. The processes to support an IPPD approach are integrated with the other processes in the organization. The IPPD process areas, specific goals, and specific practices alone cannot achieve IPPD. If a project or organization chooses IPPD, it performs the IPPD-specific practices concurrently with other specific practices used to produce products (e.g., the Engineering process areas). That is, if an organization or project wishes to use IPPD, it chooses a model with one or more disciplines in addition to selecting IPPD. (CMMI 2002)

Process and Product Quality Assurance. The Process Areas related to Project Monitoring and Control are Project Planning, Measurement and Analysis, Risk Management, and Configuration Management.

Before identifying the base practices that are related to the Project Planning, and Project Monitoring and Control Process Areas, we exclude the Process Areas that are not basic, based on CMMI continuous representation or that support the achievement of higher than maturity level 2, based on CMMI staged representation.

Based on CMMI continuous representation (SEI, 2002), Process Areas are grouped into two groups – basic and advanced Process Areas, where Project Planning, Project Monitoring and Control and Supplier Agreement Management are the Basic Project Management (BPM) Process Areas. The Engineering Process Areas of Requirements Development, Requirements Management and Technical Solution are all considered to be on project level in CMMI, i.e. they are the basic Process Areas. Configuration Management, and Measurement and Analysis of Support Process Areas are also basic Process Areas. Risk Management of Project Management Process Area is considered advanced, whereas the Organizational Training of Process Management Process Area is the basic Process Area.

Staged representation of CMMI (SEI, 2002a) illustrates similar groupings, but also lists the Process Areas into groups based on the Maturity Levels they support in achieving. Project Planning, Project Monitoring and Control, Supplier Agreement Management, Requirements Management, Measurement and Analysis, Configuration Management support the achievement of Maturity Level 2. While, Requirements Development, Technical Solution, Risk Management and Organizational Training support the achievement of Maturity Level 3.

The model under construction includes only the basic project management practices. Thus, we selected only these Process Areas that were grouped as basic in CMMI Continuous and supported the achievement of Maturity Level 2 and not higher, based on CMMI Staged Representation.

We then selected the Basic Project Management (BPM) and the base practices of the Process Areas related (to the BPM) Process Areas for our study. The specific practices selected were SP 1.1-1 – SP 3.3-1 from the Project Planning, SP 1.1-1 – SP 2.3-1 from the Project Monitoring and Control, SP 1.2-1, SP 1.3-1, SP 2.3-1 from the Supplier Agreement Management, SP 1.1-1 – SP 1.3-1, SP 1.4-2, SP 1.5-1 from the Requirements Management, SP 1.1-1 – SP 2.4-1 from the Measurement and Analysis, and SP 1.1-1 – SP 3.2-1 from the Configuration Management. The full list of specific practices selected from the CMMI is provided in Appendix 2.

Generic Practices Selected from CMMI Continuous

The capability levels of process areas are achieved through the application of generic practices. Reaching capability level 1 for a process area is equivalent to saying that the specific goals of the process area are achieved. A capability level 1 process is characterized as a performed process. It is a process that satisfies the specific goals of the process area. Reaching capability level 2 means that the performance of the process area is managed, i.e. level 2 process is called managed process. A managed process is thus a performed process that is planned and the performance of the process is managed against the plan. The control provided by a managed process helps ensure that the established process is also retained during times of stress. (SEI, 2002)

In our research, we aim to study the intensity of the implemented project management practices in industry projects. This should also include the details of performing and managing the processes in project management area. In other words, we include the Generic Practices of Generic Goals 1 and 2 of the selected Project Management Process Areas from the CMMI in our research.

The entire list of Specific and Generic Practices selected from CMMI Continuous for the study is provided in Appendix 2. The list consists of Specific Project Management related Practices of CMMI Continuous, where the related Specific Practices are selected based on the information these practices provide to support the Project Planning, and Project Monitoring and Control Process Areas. The list describes the basic project management practices derived from CMMI Continuous for the study.

The following is an explanation how the basic project management practices were derived for the research from ISO/IEC IS 15504.

3.1.1.2 Basic Project Management Practices from ISO/IEC IS 15504

This subsection provides information about the basic project management practices that were selected for the research from ISO/IEC IS 15504. Basic project management practices are the base practices of project management and its related processes. First, the relationship between the processes has been described here and the rationale is provided for the selection of the processes for the study. Secondly, the generic practice indicators of project management have been selected for the research. The entire list of all base practices and generic practice indicators selected from ISO/IEC IS 15504 for this study is provided in Appendix 3.

Base practices selected from ISO/IEC IS 15504

Project Management (MAN.3) process is in the Management (MAN) process group. Stated in (ISO/IEC 15504-5, 2006), the Management process group consists of processes included in the Process Assessment Model that contain practices that may be used by anyone who manages any type of project or process within a software life cycle. These six processes are organizational alignment (MAN.1), organizational management (MAN.2), project management (MAN.3), quality management (MAN.4), risk management (MAN.5), and measurement (MAN.6).

In ISO/IEC IS 15504-5 another indication to which processes are related to each other can be viewed in Notes. The base practice MAN.3.BP4 – determine and maintain estimates for project attributes NOTE2 suggests looking at Quality Management (MAN.4) and Risk Management (MAN.5) for details in quality goals and risks that should be included in estimates of project attributes.

Capability of a process can be assessed by demonstrating the achievement of process attributes. Process attributes are related to processes as some of the processes support the achievement of certain process attributes. In our study, we focus only on practices that support the achievement of process attributes of capability level 2 and not higher. We can therefore exclude processes that support the achievement of process attributes of higher levels. Table 13 in ISO/IEC IS 15504-5 (ISO/IEC 15504-5, 2006) indicates the processes that support the achievement of the capabilities addressed by a process attribute. Organizational alignment (MAN.1) supports the achievement of process measurement attribute (PA 4.1) and above, organizational management (MAN.2) supports the achievement of process definition attribute (PA 3.1) and process deployment attribute (PA 3.2), project management (MAN.3) supports the achievement of performance management attribute (PA 2.1) and PA 3.2, quality management (MAN.4) supports the achievement of PA 3.2, PA 4.1. and process control attribute (PA 4.2), risk management (MAN.5) supports the achievement of PA 2.1 and PA 4.1, and measurement (MAN.6) supports the achievement of PA 3.2 – PA 5.1 (process innovation attribute).

As stated before, we are focusing on basic project management practices, supporting the achievement of PAs on Level 2 and not higher. Based on this, we can select only project management and risk management processes from the six processes described above.

The base practices, input and output work products and their associated characteristics relate to the processes defined in the process dimension of the process assessment model, and are chosen to explicitly address the achievement of the defined process purpose. Work products are either used, produced or both, when performing the process. The performance of a process produces work products that are usable in achieving the purpose of the process. The associated work products are provided as guidance for potential inputs and outputs to look for, and provide objective evidence supporting the assessment of a particular process. (ISO/IEC 15504-5, 2006)

In finding project management related processes, we can use the input and output work products – one process can be related to another process through sharing the same work products. For example, the project management input work products that are at the same time products of another process (their output work products) allow us to assume that these processes are closely related. Also, some project management output work products produce data necessary for other process input or output work products and also these processes are related to each other.

Project management input work products are the contract, process performance data, cost estimate, estimate, change request, customer request, problem report, project measure, human resource management plan, project plan, risk management plan, request for proposal, progress status report, schedule, tracking system, work breakdown structure, project activity network, customer requirements, software development methodology.

Some of the listed input work products are produced by project management base practices themselves. Needless to say, all project management base practices are related to each other since they are activities that contribute to achieving the same specific process purpose. The processes that produce (output work products) the project management input work products are supplier tendering, contract agreement, change request management, requirements elicitation, problem resolution management, measurement, human resource management, risk management and organisational management.

As stated earlier, we focus only on processes that support the achievement of PAs on Level 2 and not higher. Based on that, we excluded measurement, human resource management and organisational management processes as they support the achievement of PAs on Level 3 and higher. The remaining project management related processes and their base practices selected for our study are supplier tendering (SPL.1.BP3, BP4, BP7, BP8), contract agreement (ACQ.3.BP1-BP3), change request management (CFG.4.BP2, BP3, BP5-BP9), requirements elicitation (ENG.1.BP1, BP3-BP.4), problem resolution management (CFG.3.BP4-BP6), and risk management (MAN.5.BP1-BP7).

Project management output work products are the cost estimate, estimate, change request, project plan, risk management plan, training plan, communication record, progress status record, review record, corrective action register, schedule, work breakdown structure, project activity network, and project status report. Some of the project management output work products are produced by project management base practices themselves. The processes to which project management output work products contribute to are human resource management, training, quality assurance, change request management, supplier tendering, organisational alignment, knowledge management and process improvement.

Again, as we focus only on processes that support the achievement of PAs on Level 2 and not higher. We excluded human resource management, training, organisational alignment, knowledge management and process improvement processes as they support the achievement of PAs on Level 3 and higher. The remaining project management related processes and their base practices selected for the study are quality assurance (QUA.1.BP4), joint review (QUA.4.BP3), change request management (CFG.4.BP2, BP3, BP5-BP9), supplier tendering (SPL.1.BP1–BP2). The entire list of project management related base practices can be found in Appendix 3.

Generic practice indicators selected from ISO/IEC IS 15504

The generic practice indicators of IS 15504 are activities of a generic type and provide guidance on the implementation of the attribute's characteristics. They are designed around the achievement of the process attribute and many of them concern management practices, i.e. practices that are established to support the process performance as it is characterised at Level 1. For this study, the generic practice indicators of the process attributes of Level 1 and Level 2 have been selected. The entire list of all the project management and related process base practices and generic practice indicators selected from ISO/IEC IS 15504 for the study is provided in Appendix 3.

Next, we will group the selected model practices from CMMI (Appendix 2) and ISO/IEC IS 15504 (Appendix 3) to get a comprehensive list of basic project management practices from process models for our study.

3.1.2. Grouping the model practices

Model practices are drawn from two different models that need to be grouped for evaluation purposes. Since integrating practices of different models is an approach that lacks objectivity, we will use the differentiation of known and unknown factors (Figure 3-3) (Järvinen, 2001, pp.37-39).

This classification is used to select factors or variables into a research model. The unknown factors are excluded from the research model. In Figure 3-5, the known variables belong to the theoretical framework, and the unknown variables are either consciously excluded from the study or forgotten. The known variables are further divided into two groups, adjustable and restrictions. In constructive research where the previous practices are changed it is important to know on which variables we can influence (adjustable) and on which ones we cannot (restrictions). (Järvinen, 2001, pp. 37-39)

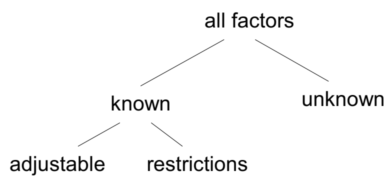


Figure 3-3. Differentiation of the known and unknown factors (Järvinen, 2001, p. 38)

While comparing process models, we can group their practices into known and unknown factors (Figure 3-4). The practices that are both in IS 15504 and in CMMI are the known variables, while practices only in IS 15504 and not in CMMI (the practices that have been excluded or forgotten from CMMI) are the unknown factors of CMMI. And, the practices only in CMMI and not in IS 15504 are the unknown factors of IS 15504. In our research all the practices from IS 15504 and CMMI are used. This model is used to build the questionnaire – the known practices (similar practice from IS 15504 and CMMI) are combined together into one question and the unknown practices are all listed in the questionnaire by themselves.

This differentiation helps to see the similarities and differences between the two process models. It also allows an easier industry practice comparison to practices of only one of the process model. Since we do not aim to change previous practices, our differentiation does not include the grouping into adjustable and restrictions variables.

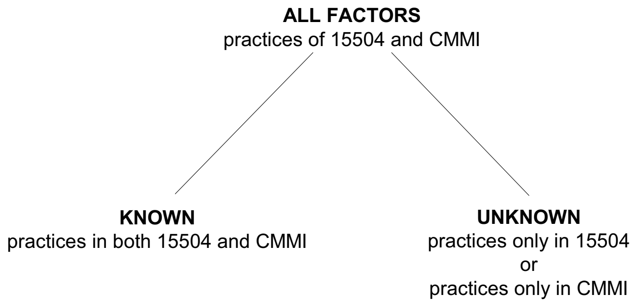


Figure 3-4. Model practices grouped based on differentiation of known and unknown factors

Table A5-1 in Appendix 5 groups the basic project management practices from CMMI and IS 15504, which serve as the basis of the survey used for data gathering from industry. The base practice without a corresponding practice in the other process model is the unknown practice.

The project management practices have been grouped into the following groups for the survey questionnaire (Table A5-1, Appendix 5): Project Planning (practices from project management of IS 15504 and project planning of CMMI); Project Estimation (practices from project management of IS 15504 and project planning of CMMI); Project Monitoring and Control (practices from project management of IS 15504 and project monitoring and control of CMMI); Requirements Management (related practices from requirements elicitation of IS 15504 and of requirements management of CMMI); Supplier Tendering (related practices of IS 15504); Change Request and Configuration Management (related practices from change request management of IS 15504 and from configuration management of CMMI); Supplier Agreement Management (related practices from contract agreement of IS 15504 and from supplier agreement management of CMMI); Risk Management (practices from risk management of IS 15504 and one from project planning of CMMI); Problem Resolution Management (related practices from problem resolution management of IS 15504); Quality Assurance (related practice from quality assurance and from joint review of IS 15504); Measurement and Analysis (related practices from measurement and analysis of CMMI); Process Performance Management (generic practices of CMMI and generic practice indicators of process performance attribute of IS 15504); and Process Work Products Management (generic practice indicators of process work product attribute of IS 15504).

An extensive literature survey was conducted to find project management activities that are unknown to the selected scope of practices of both process models. The following subsections describe the selected project management activities of the model, derived from the PMBoK and other sources of project management literature. Only the factors unknown to the selected process model practices are selected to the model of basic project management activities from literature. The purpose of these pertinent project management activities in the research is to find out whether there are activities that industry implements and regards as vital for success but are not described on project level related to project management in the process models.

3.1.3. Pertinent project management activities from the PMBoK

This subsection describes pertinent project management activities of the PMBoK (PMI, 2000) that are not described as project level project management related activities in the process models but which, being relevant to project management, are included in the study. There are five groups of processes related to project management. Each group consists of core and facilitating processes that are comparable to the selected practices of process models.

Project management process groups in the PMBoK (PMI, 2000): Initiating processes – authorizing the project or phase; planning processes – defining and refining objectives and selecting the best of the alternative courses of action to attain the objectives that the project was undertaken to address; executing processes – coordinating people and other resources to carry out the plan; controlling processes – ensuring that project objectives are met by monitoring and measuring progress regularly to identify variances from plan so that corrective action can be taken when necessary; and closing processes – formalizing acceptance of the project or phase and bringing it to an orderly end.

Most processes described in the PMBoK have already been derived for the study from either one or both of the process models. Initiating process that is a part of the scope management has corresponding practices in both ISO/IEC IS 15504 project management and the CMMI project planning practices in estimating and defining the scope of the project work. The planning processes of the PMBoK have most of the corresponding practices in the project management of IS 15504 and project planning of CMMI with risk management planning of the PMBoK corresponding to risk management practices of IS 15504.

Executing process group of the PMBoK describes activities that correspond to various selected practices of process models including practices from project management, quality assurance and contract agreement of IS 15504; supplier agreement and data management related practices of project planning and project monitoring process areas in CMMI.

Controlling process group of the PMBoK describes two activities where performance reporting corresponds to project monitoring practices of CMMI and progress reviewing practice of project management in IS 15504. Change control activities of the PMBoK correspond to change request management practices of IS 15504 and configuration management practices of CMMI.

The last group of processes in the PMBoK focusing on finalizing the project consists of two activities: contract closeout and administrative closure of the project. Of the closing processes of the PMBoK, contract closeout activities are related to contract agreement practices of IS 15504. Administrative closure has no similar practices in the selected scope of practices from the process models. The following activities are therefore derived from the "closing processes" process group of the PMBoK into the mode of basic project management activities:

1. Information to formalize project completion is gathered and disseminated;
2. The project is evaluated after closing;
3. The lessons learned are compiled for future projects

These three activities of project closing were selected into the model of basic project management activities.

3.1.4. Pertinent activities from project management literature

An extensive literature survey was conducted to find relevant project management activities that were not described in the scope of the selected practices from the process models. The project management related activities described in literature can be viewed in groups of a) project planning and estimation activities (Kerzner, 2001 pp.231-325; Royce, 1998 pp. 139-154; Sommerville, 2004 pp. 96-98; PRINCE, 2005; Dean, 1985; Gupta and Taube, 1985; Keen, 1987; Kezsbom, 2001; Andersen et al., 1990; Archibald, 1992, pp. 178-339; Lientz and Rea, 1995 pp. 98-100), b) project directing activities focusing on directing people (Kerzner, 2001; PRINCE, 2005; Dean, 1985; Gupta and Taube, 1985; Andersen et al., 1990; Lientz and Rea, 1995 pp. 98-100; Sommerville, 2004 pp. 34-35; Smith and Thompson, 1995; Wearne, 1995), c) project administration related activities like documentation and contract management (Kerzner, 2001; Sommerville, 2004 pp. 93-95; Keen, 1987; Kezsbom, 2001; Andersen et al., 1990; Archibald, 1992, pp. 178-339; Lientz and Rea, 1995 pp. 98-100), d) project monitoring and control activities (Kerzner, 2001; Sommerville, 2004 pp. 94-96; Royce, 1998 pp.187-207; PRINCE, 2005; Dean, 1985; Gupta and Taube, 1985; Keen, 1987; Kezsbom, 2001; Andersen et al., 1990; Archibald, 1992, pp. 178-339), e) human resource management related activities (Gupta and Taube, 1985), f) quality assurance activities (Andersen et al., 1990), g) risk management activities (Sommerville, 2004 pp. 105-111), and h) project completion related activities (PRINCE, 2005; PMI, 2000). Most activities from project management literature had similar practices already described in the scope of selected practices from the process models (project planning, estimation, monitoring and control, human resource and risk management) or in the PMBoK (project completion). Activities about directing people were added to this study as a result of the literature survey conducted. There are no project level practices related to project management in the process models that focus on directing people, while various sources in literature (Kerzner, 2001 pp.231-

325; PRINCE, 2005; Dean, 1985; Gupta and Taube, 1985; Andersen et al., 1990; Lientz and Rea, 1995 pp. 98-100; Sommerville, 2004 pp.92-113; Smith and Thompson, 1995; Wearne, 1995) find it crucially important for a well managed project. Project directing includes areas like giving directions to people, supervising the team, motivating people, coordinating interaction, decision-making and resolving conflicts.

The activities derived for the model are the following:

1. Give directions to the project team;
2. Supervise the project team;
3. Motivate the people in the project team;
4. Coordinate the interaction between the people in the project team;
5. Explain the reasons behind the decision-making to the project team;
6. Resolve the conflicts within the project team.

These six activities were added to the model of basic project management activities and re-phrased for the model evaluation purposes. The comprehensive list of all basic project management activities is described in Appendix 5.

3.2. Providing the metrics – developing the survey questionnaire

As Nardi (2003, pp. 64-79) points out, questionnaires are ideally suited to assess what people report they believe, because opinions are not readily observed and easily measured with other research methods. In this study, we aim to find out the intensity of application of basic project management activities in industry projects. More precisely, the constructed model of basic project management activities is now being developed into a survey questionnaire where the questions describe the basic project management activities. The basic project management practices from process models can also be viewed as best practices, the application of which can lead to project success. Thus, the industry projects described in the survey should also be successful. The questionnaire is addressed to software industry project managers, who will then describe a recent successfully completed project that they managed by rating the questions provided in the survey. The questionnaire can be divided largely into five parts, where the first three parts focus on the background of the company, the project manager and the project in question. The fourth part asks the project manager to describe the success of the project he or she has chosen for detailed description. The fifth and the largest part of the survey lists the basic project management activities, and provides an intensity scale to find out how well these activities were implemented in industry projects. The survey questionnaire used in the study can be viewed in Appendix 6.

In the survey, we have mainly used closed-ended questions, which give respondents standardized answers to select from, similar to questions on a multiple-choice test. Although the closed-ended questions give fewer variations in people's responses than open-ended questions, it is easier and quicker for the respondents to complete, and the coding of responses is more efficient for the research. (Nardi, 2003, pp. 64-79) Each set of questions from the project management activities section onwards has an open-ended question to elicit from the respondent comments and additional activities that were not listed. This option aims to get additional activities that the industry projects apply that aren't described in the scope of selected practices from process models or literature.

A Likert-type scale, a rating scale from 1 to 5, is applied in the survey for measuring the intensity of project success and application of model practices, where 1 is "totally disagree" and 5 is "totally agree". The five-point Likert scale is the most frequently used response scale (Conger, 1994) An ordinal scale assigns numbers to objects, which are rank-ordered with respect to some characteristics, in this case with respect to the degree of agreement. This scale contributes also to a straight-forward coding of questions for the data analysis purposes.

The questionnaire was constructed so that all the closed-ended questions about the project success and the application of activities were compulsory for the respondents to rate. Even though the questionnaire also asks the name of the company of the respondent, the name of the respondent and his/her email address, it was not compulsory to fill that in. This option has been given to get responses also from highly confidentiality-conscious companies.

The following subsections describe how the appropriateness and validity of the questionnaire was tested, the selection of the sampling method used in the study and how the validity of the entire research was established. Also the environment from where the data was gathered has been described here, along with a short overview of the data received and the coding of the questionnaire for the data analysis purposes.

3.2.1. Pilot testing the questionnaire

Once the questionnaire was completed, its layout was designed for a web survey. After finalizing the structure and outlook of the survey, it was ready for pilot testing. The survey was sent to a software project manager who also provided comments on the survey after filling it in. Based on the comments received from the pilot testing, a number of terms were explained in the online glossary linked to the survey to minimize possible misunderstandings. The web survey can be viewed at http://www.lepmets.com/survey.htm, and the glossary can be viewed at http://www.lepmets.com/glossary.htm.

3.2.2. Sampling

The study used the nonprobability sampling method (Fowler, 2002, pp. 53-57), and as such the sample is likely to be biased in the direction of companies interested in software process improvement and in their willingness to contribute to the research. Also, the normal assumptions for calculating sampling errors and applying inferential statistics do not apply. Thus, the data resulting from the study apply only to those who responded to the survey.

Reasons for nonprobability sampling

In order to find out if model practices are similar to practices applied in companies where no process models are used, we needed two different groups of respondents – one group that is familiar with SPI and the other, with no continuous experience in that area. At the beginning, simple random sampling was used where the survey was sent to 118 Finnish software companies. Only 1 response was received from this sample.

There are several possible reasons why only one response was received, and why nonprobability sampling instead of random sampling was used in this research. We conclude that the companies most likely to respond to the survey questionnaire are the companies interested in quality-related issues in software development. It is impossible to determine the population of companies interested in quality and the companies knowledgeable about software process improvement. Instead, we contacted the companies familiar with SPI through FiSMA (SPI expertise centre in Finland). And we also sent out the questionnaire to companies through a national organization in Estonia that unites the active software companies in the country. This provided us with responses where SPI models have been used (from Finland), and responses from quality-aware companies where SPI models are not being used (from Estonia). The survey was online for half a year (from late February until end of August in 2005) and the organizations informed the companies about the survey repeatedly during that time period.

Even though the resulting nonprobability samples often look rather similar to probability sample data (to the extent that they can be compared) it is important to remember two things: first, the respondents are likely to be biased; and second, even though the sample may spread around the population in a reasonably realistic way, probability theory and sampling error do not apply, meaning that we cannot infer the population. (Fowler, 2002, pp. 53-57)

3.2.3. On research validity

In (Järvinen, 2001, p.51), it is said that research lacks external validity if its results cannot be generalized to groups other than those that participated in the study. Research lacks internal validity if its results are ambiguous or can be explained by factors other than those explicitly incorporated in the research design.

Due to the nonprobability sampling method being used, the results of the current research can only be generalized to the respondents of the study. On the other hand, the internal validity is increased by the detailed background description of each response, minimizing the possibility of the unknown factors influencing the results. Also, verification techniques have been used by asking same questions a number of times in order to achieve higher reliability.

As to the validity of the research results, the results achieved through the data analysis also provide the answers to the research questions. Data was triangulated by three data analysis methods. Results achieved using these methods were in compliance with each other, indicating that using any other method will not provide new results of the received data. We can therefore conclude that the methods used validate the research results and answers to the posed research questions.

3.2.4. Data gathering environment

The countries that are involved in the study are Estonia and Finland, two neighbouring northern European countries. There are a number of cultural similarities between the two but the economic situation differs greatly as a result of recent historic events. Estonia (pop. 1.4 million) is a former Soviet republic that has been independent for 15 years and a member of the European Union since 2004, while Finland (pop. 5.2 million) has been a member of the European Union from 1995. (Lepasaar et al., 2001a)

IT in Estonia

As many other nations, Estonia has seen information technology (IT) as an important tool for further accelerating the extremely fast recovery of the Estonian economy. (Kalja and Oruaas, 1999) Based on (Klaamann, 2005) there were around 400 ICT companies in Estonia in 2004 that together with the public sector employed around 11,000 people. The four largest IT companies in Estonia are Skype, Playtech and the IT departments of two major commercial banks that employ over 100 people each. In comparison, the size of a typical software company is only around 25 to 50 people.

The 2004 turnover of the telecom companies was 8.9 billion EEK, 8.3 billion of which was on the local market. The IT market can be divided into three groups based on the type of IT company: distributors (with turnover of 2.0 billion EEK in 2004), dealers for the large Western companies (turnover 0.8 billion EEK in 2004) and the rest – these being IT companies primarily involved in integration, system development and resale with a turnover of 4.8 billion EEK in 2004. (Klaamann, 2005) The turnover of the IT sector increased 5% in 2005, with a 7% increase in the number of employees, and 13% increase in labour costs. There is a growing trend of labour shortages which will lead to even higher labour costs in the future. (Klaamann, 2006) Although there are many innovative ideas and great IT experts in Estonia, leading to companies like Skype and Playtech, the increasing lack of IT specialists has not allowed the overall ICT sector to develop as fast as expected. (Klaamann, 2005)

Based on the cluster analysis of European Commission's Innovation Scoreboard (European Commission, 2006), Estonia is classified in the "losing ground" category because of its negative trend. Public expenditures have increased from 0.47% in 1998 to 0.53% in 2003, but are still only 80% of the EU average. As of 2000, only 2.4% of firms received public support for innovation. Estonia is lagging behind most EU member states primarily due to the lack of knowledge creation. Estonia's weakness in knowledge creation is due to its insufficient levels of business research and development (R&D). Estonia is among those countries that are relatively weak at transforming their innovation assets into innovation results (sales of new products, high tech employment, patents, etc).

SPI activities in Estonia

There has been no national SPI initiative in Estonia, but there are a couple of companies that are using international models to increase their product quality. The following is a description of what has been done so far in Estonia in the SPI area.

The Software Engineering Institute's Capability Maturity Model for software process assessment, improvement and capability determination was the first methodology that was learned and applied in Estonia. The ISO 9000 certificate is becoming more and more popular today and most large software companies in Estonia are striving for readiness to achieve certification. The customers often consider the ISO 9000 certificate as material evidence that decreases their risk upon software product quality they will receive.

SPICE was introduced to Estonian software companies as a result of co-operation between the Estonian Software Engineering Centre and Tallinn University of Technology in Estonia, and Software Engineering Centre OY, Software Technology Transfer Finland OY in Finland.

SPI-related training with the aim to introduce international experiences and international software assessment and improvement models and methods took place in April 1998, focusing on SPICE. Similar training took place half a year later with more participants of whom many are quality managers or employed in related positions in their software companies in Estonia. One of the participating companies has started to use the SPICE model for software process improvement.

The Initiative for Software Process Improvement - Régions Extérieures (INSPIRE) was a project in the COPERNICUS programme of European Commission and was conducted in Estonia in 1997. COPERNICUS itself is a part of the European System and Software Initiative (ESSI) framework. The project was fully funded by the European Commission. (INSPIRE, 2000)

The aim of the project was to increase the use of international software standards among the national software organisations in four Eastern and Central European countries (Estonia, Poland, Hungary and Romania). The project focused on providing access to the experience and knowledge of various software process assessment, improvement and certification methods currently available in Western Europe.

The INSPIRE project activities comprised mainly of training and consultations on the usage and implementation of international methods in practice. Four software companies from Estonia participated in this project. The companies were targeted to identify their critical business or development processes and make improvement plans. Every one of these companies performed the required tasks and reported their results to the Estonian Information Technology Society, who then sent them on to INSPIRE project group for analysis.

Although all the companies found the project useful and necessary, only one of these companies is using an international software process improvement standard today.

We can hereby conclude that SPI awareness in Estonia is very low. Even if some software organizations developing for the Western customers know about software process models that could improve their development quality, there are no organizations actively and continuously applying the process models to improve their processes.

IT in Finland

The Finnish IT related businesses have been evolving for a hundred years and today they form an attractive and vigorous industrial system on the international level. Finland is also known for the outstanding devotion to research and development. (Paija, 2000)

Based on the services offered, the Finnish software/data processing sector can be divided into six segments (Ylikorpi, 2005):

1. Computer hardware consultations
2. Software development and consultations
3. Data processing related services
4. Databases and networking related services
5. Computer and office equipment manufacturing and maintenance
6. Other data processing related services

The software development and consultation related services can roughly be divided into three categories illustrated in Figure 3-5 below: software products, customer tailored software (or customized software), and embedded software. (Ylikorpi, 2005)

1. The software products sector primarily includes the off-the-shelf software products that are not planned and developed according to any one specific

customer. They are marketed and sold to hundreds of users. They include anti-virus programs, text editors, etc.

2. Customer-tailored or customized software is typically developed to meet the requirements of one specific customer through close cooperation with that customer.
3. Embedded software is developed for use in computer hardware, e.g. software that is used in mobile phones.

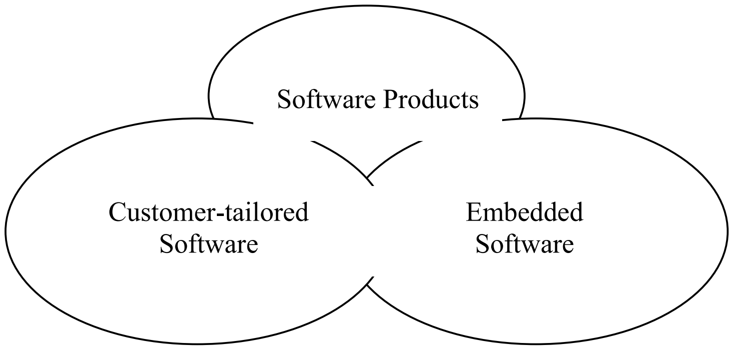


Figure 3-5. Description of Finnish software sector based on services provided (Ylikorpi, 2005)

The total revenues of the Finnish software sector in 2003 were over €4.2 billion. Over 37,000 people were employed in this sector in over 4,800 companies in Finland. Of the three categories described above, the customer-tailored software development is the largest in the software sector. With constant growth in the number of software companies in Finland, more and more people are being employed by the software sector. (Ylikorpi, 2005)

Despite the challenging economic situation in the 1990s, Finnish software development companies have been able to adjust to the economic situation. As companies are rather small, their capability to modify business operations in the short term in order to keep the business running is relatively good. As the downturn of the economy makes growth plans more difficult, it also forces companies to improve their processes and efficiency. (Lamberg, 2004)

SPI activities in Finland

The software process improvement standard ISO/IEC TR 15504 was released in May 1998. The SPICE Trials aim to validate the developing standard, specifically in terms of its coverage, applicability and usability. The participation of software companies in the trials allow them to influence the standard, get support in conducting their own software process assessments, and access the SPICE Trials results to see their positions towards other companies assessed. Finland was involved in the empirical trials of ISO/IEC TR 15504, also known as the SPICE Trials already in their first phase in 1995.

Based on my experience in cooperation between Estonian and Finnish software companies, my involvement in standardisation work in Estonia and observation of FiSMA activities in Finland, I have noticed that ISO/IEC 15504 is known among the majority of software companies in Finland today. There might be many reasons for that, such as the activeness of people who participate in developing the standards and of course the need for software process improvement in industry. ISO/IEC TR 15504 has been extremely helpful in implementing process improvement plans in software companies in Finland. (Lepasaar et al., 2001a)

In autumn 1998, Finnish Software Measurement Association (FISMA) together with one of the Finnish software-developing companies Tieto Corporation OY, developed a tailored SPICE model, now widely called FISMA SPICE. It is a detailed SPICE-compatible model for process assessment providing a questionnaire for evaluating any process instance. (FISMA, 2007) In the beginning of 2000, FISMA also started the initiative of collecting the SPICE assessment results all over Finland into one national results database.

SPICE has found an especially wide usage in the Satakunta region of Western Finland, as an initiative of the Tampere University of Technology (TUT) in Pori. A project to establish a software process improvement network started in August 1998. This project was called SataSPIN and its aim was to help the small and medium sized software enterprises in the software business to develop their operations using SPICE. The operative management of the project was delegated to the Centre of Software

Expertise (CoSE) within TUT Pori. The further goal of the CoSE is to provide comparison data regarding a company's capability towards other software organisations assessed in the country and establishing improvement guidelines for organisations to follow. In addition to the aforementioned activities, there is much research conducted based on the results of the project. The ongoing research and analysis assure the participants that the project is developing in time and thus is relevant also in future.

The idea of the SataSPIN project stemmed from the wish to form a group of software companies whose interest would not only lie in finishing a software project in time but who also want to improve their software processes. The aim of the SataSPIN project was to help the smaller software companies improve their processes with the help of the international software process models that the large companies have already been using for years for that purpose (Varkoi, 2000).

The SataSPIN project started in August 1998 and by the end of 2000 the first phase was over. By that time the eight participating software organisations had received various consultations, the largest and the most important part of which are the software process assessments. There had also been many training courses targeted to support the improvement of software processes and to enhance the competencies of the personnel.

The companies that were involved in the SataSPIN project have between two to fifty employees in software engineering related positions. All of the companies were eager to develop their operations dynamically and most of them are expanding their businesses. From the viewpoint of the participating companies, the benefits of the project included the following: improvement of customer satisfaction and competitiveness; management of growth of the business; improvement of competence and motivation of the personnel; development of working methods and improvement of knowledge and skills by software engineering training (Varkoi, 2000).

Although SPICE is getting better known among the software related businesses, the ISO 9000 certificate is still considered by many customers as a necessary material evidence of a mature organisation reliable enough to become their software supplier.

The process improvement work in the companies will also support the achievement of ISO 9000 certificate, in case that is the goal of the company.

To summarize, we can say that there is extensive knowledge and experience of software process improvement in Finland. Many companies apply process models continuously to improve their processes; Finland is actively participating in the standardization work and carrying out research concerning the standardization issues in industry.

3.2.5. Data received

The following is a short overview of the data received from the survey. A short description of the respondents is given and the coding of the variables of the survey is described so that the results of the data analysis would be more understandable.

After the attempted random sampling where one response was received, the nonprobability sampling was used and there were altogether 29 responses to the survey. 11 of them from Estonia, 16 from Finland and 2 remained anonymous as to the origin of the respondent company. Of the 16 respondents from Finland, there were two companies that responded to the survey more than just once. From one of them two project managers responded and from the other three project managers responded. Thus, there were 13 unique company responses from Finland.

Applying the following scale to company size, where a company with less than 9 employees is "micro", from 10 to 49 employees is "small", from 50 to 249 employees is "medium" and over 250 employees is "large" in size, the respondents can be divided into four groups. 4 respondents are micro, 7 small, 9 medium and 9 large companies.

Applying the same scale to the size of the software department in the company, the respondents can be divided into the following four groups: one respondent from a company with large software development department, seven from medium, 11 from small and 10 from micro software development departments.

The respondents could describe their company type through the activities to which it has devoted most of the time – either to the development of a new system, system maintenance or customization of packaged software. The majority of respondents (18) were from companies primarily developing new systems, seven responses came from companies primarily maintaining systems and four from companies customizing packaged software.

The respondents also described the usage of software standards and process models in their organizational and project level. On the organizational level, nine responses were received from companies that apply ISO 9000 series of standards, two from companies applying ISO/IEC IS 15504, four from companies applying CMM or CMMI, and one from a company applying ISO/IEC 12207. Among Finnish companies, the ISO 9000 series was applied in five responses and in three of the responses from Estonian companies. ISO/IEC IS 15504 was only applied in the responses from Finnish companies. CMM or CMMI was applied in three responses from Finland and one from Estonia, and ISO/IEC 12207 was applied in a response that came from Estonia.

Standards and process models used on the project level indicate the usage of the standard during the project that was described in great detail in the survey. On the project level, standards and process models were used much less than on the organizational level. The ISO 9000 series was applied in eight projects (responses), two of which were from Estonian companies. Only one project from a Finnish company used CMM or CMMI and one project from an Estonian company used ISO/IEC 12207.

The project managers responding to the survey could describe their project either as the development of a new system or enhancement of an existing system. Twenty responses described projects developing new systems and six responses described the projects enhancing existing systems. The distribution country-wise was rather equal – nine responses from Estonia and 11 from Finland were describing projects of new system development; enhancement of existing systems was the goal of two projects from Estonia and of five projects from Finland. Two anonymous responses described projects enhancing the existing systems.

The project lifecycle models used in the projects described in the survey was also under study in the research. Based on the data received, the most popular lifecycle model was the evolutionary lifecycle model, meaning that the system was developed and delivered incrementally through subsystems. Out of the 28 responses, twelve applied the evolutionary lifecycle model. The usage of phased, prototyping and concurrent development were evenly distributed across the responses.

Of the eleven responses received from Estonian companies, six described very successful projects. Out of the 16 responses received from Finnish companies, there were only six responses describing the very successful projects.

3.2.6. Coding the questionnaire

This subsection describes the preparation of data for data analysis through coding of all the questions of the survey questionnaire. The questions in the survey can be viewed as variables belonging to different groups (Appendix 6). The variables in group A describe the company background, explained in Table 3-1 below.

Table 3-1. Company background variables

Variable	Company background description
A1	Company's core business area
A2	Local/multisite company
A3	Size of the company
A4	Size of the software department
A5	Percentage of effort expended by the company on new application development
A6	Percentage of effort expended by the company on systems maintenance
A7	Percentage of effort expended by the company on customising packaged software
A8	Standards used in the company

The variables in group B describe the background of the project manager who responded to the survey. It mostly describes in terms of percentage where the effort and time of the project manager is devoted as well as the experience of the project manager, illustrated in detail in Table 3-2 below.

Table 3-2. Background of the project manager variables

Variable	Project manager's activities and experience
B1	Percentage of effort and time devoted to project management work
B2	Percentage of effort and time devoted to software analysis
B3	Percentage of effort and time devoted to design
B4	Percentage of effort and time devoted to programming
B5	Percentage of effort and time devoted to testing
B6	Percentage of effort and time devoted to user training
B7	Percentage of effort and time devoted to something else entirely
B8	Experience of project manager in developing software
B9	Experience of project manager in managing projects

The variables in group C describe the background of the project, which the project manager describes in greater detail throughout the survey. The variables are described in Table 3-3 below.

Table 3-3. Background of the project variables

Variable	Description of the project
C1	Project type - development of a new system or enhancement of an existing system
C2	Number of staff in the development team of the project
C3	Number of end-users of the project
C4	Duration of the project in months
C5	Target users of the project – in house or external
C6	Phased life cycle model used in the project
C7	Prototyping life cycle model used in the project
C8	Spiral life cycle model used in the project
C9	Evolutionary life cycle model used in the project
C10	Concurrent life cycle model used in the project
C11	Other life cycle model used in the project
C12	Standards used in the project

The variables in group D describe the project success factors, which the project managers evaluated on the scale from one to five, where 1 was unsuccessful and 5 was successful. The project success factors are illustrated in Table 3-4 below.

Table 3-4. Project success factors

Variable	Project success factor
D1	Project on schedule
D2	Project on budget
D3	Project accepted by customers
D4	Project that achieved its goals
D5	High speed of development of the project – high productivity
D6	Product satisfied the requirements
D7	Project represented excellent work
D8	Developed product was a success
D9	Overall. the project was a success

From groups E to S, the variables indicate the project management practices derived from CMMI and ISO/IEC IS 15504 base practices and PMBoK activities. Each group from D to S has one “summarizing variable” that seeks the overall success of the entire group of variables. The correlation between each variable in the group and the summarizing variable will show us the relevance of every single base practice for the success of the whole process area (group of variables). For example, the last variable of group D (project success) summarizes the entire group (“the project was a success”) and the correlation of each variable in the group D (D1-D8) with the summarizing variable of D9 shows us what project success depends on the most. The rating scale of variables from D to S was a Likert-type scale from 1 to 5, where 1 was “totally disagree” and 5 “totally agree”.

4. EVALUATING THE MODEL OF BASIC PROJECT MANAGEMENT ACTIVITIES

This section describes the evaluation of the model constructed. The model is triangulated by three different data analysis methods. First, data analysis methods used in the study are described in the chapter and the reasons for triangulation are explained. The research and the additional questions asked in the research are then answered through the thorough data analysis illustrated.

4.1. Triangulation of data

The aim of this section is to describe the data analysis methods used in the research. Triangulation of data refers to using more than one method on the same set of data. The validity of the results increases as the findings of the data analysis are the same using any of the methods. The triangulation of data is used in this research also to visualise the results.

The statistical analyses suitable for cases where the number of dependent variables exceeds the number of independent variables, are factor, multi-regression and correlation analyses. (Järvinen, 2001, pp.150-151) In this research, the dependent variables are the variables describing the implementation of model practices, and the independent variables are the background characteristics. As such, the factor, multi-regression and correlation analyses are suitable for this research.

Correlation analysis (2005) is the starting point of the factor analysis, describing a linear relationship between variables. Factor analysis (2005) is intended to condense information, in other words, to describe the same phenomenon with fewer dimensions. Both above-mentioned analysis methods fit this study. Multi-regression analysis aims to find a linear combination of two or more independent variables best explaining a variation of a dependent variable. Since finding the variations of dependent variable is not the aim of our study, the multi-regression analysis is not conducted. Cluster analysis is intended to group observations in such a way that the observations located in the same cluster are more similar between each other and differ from other observations. (Järvinen, 2001, pp. 152-153) Self-organizing maps (SOM, 2005) are used for clustering the responses, and for describing and visualizing the non-linear relationships between the variables. SOM analysis was conducted in MATLAB environment.

4.1.1. Correlation and Factor Analysis

Correlations were calculated using MS Excel in this research. Factor analysis was conducted using Principal Component Analysis (PCA) method. The main idea of PCA is to replace a large set of variables with a smaller set of variables which best summarises the larger set. PCA combines correlated variables into one factor. The two steps of PCA that can also be viewed as the outputs (total variance explained and rotated component matrix) are the following:

First, total variance between factors was calculated. Factors that accounted less and less variance were extracted. The variances extracted by the factors are called "eigenvalues". Using the Kaiser criterion, only factors with eigenvalues greater than 1 are retained, i.e. they are the retained factors (principal components). Secondly, the rotated component matrix is calculated using varimax rotation method. The goal of rotation is to obtain a clear pattern of the loadings, i.e. factors that are clearly marked by high loading for some variables and low loading for others shows the classification of the variables.

The factor loadings, also called component loadings in PCA, are the correlation coefficients between the variables (rows) and factors (columns). The squared factor loading is the percent of variance in that variable explained by the factor. The sum of the squared factor loadings for all factors for a given variable (row) is the variance in that variable accounted for by all the factors, and this is called the *communality*. In a complete PCA, with no factors dropped, this will be a 1.0, or 100% of the variance. The ratio of the squared factor loadings for a given variable (row in the factor matrix) shows the relative importance of the different factors in explaining the variance of the given variable. Factor loadings are the basis for imputing a label to the different factors.

4.1.2. Self-Organizing Maps

The Self-Organizing Maps can be used for clustering and visualizing multidimensional data and for reducing the dimensionality by mapping the data into a two-dimensional output grid, also known as a map. The Self-Organizing Maps (SOM) in a neural network that uses unsupervised learning algorithm. It means there is no prior information presented to the learning algorithm, as to how input and output are connected. (Kohonen, 2000)

Algorithm behind SOM is mathematically rather complex and we will not describe it in great detail. Only a general view of how a self-organizing map is created is given below. The algorithm of self-organizing maps has two basic steps – finding the best match or winner node and the value of the neighbourhood size. (SOM, 2005)

The first step is finding the best match or winner node. First, raw data is converted into vectors. The value of each vector or an input node is then compared with the weight value of each output node, i.e. the minimum Euclidean distance between an input node (raw data) and an output node (representation of randomised vector value or weight) is then worked out. Input and output nodes are representatives of vector values of same dimensionality. Whichever weight value is closest to the input node is considered to be the winner node, meaning that the output node that gives the shortest distance is the winner. When the winner node has been identified, the weight of that node is modified so that it becomes more similar to the input node.

The second step is finding the value of the neighbourhood size. The neighbourhood value defines an area around the winner node such that surrounding nodes will also be modified. The neighbourhood value defines a function whereby the algorithm decides to what extent those surrounding weights will be modified according to their distance from the winner node.

Once the winner node and neighbourhood nodes have been found, the algorithm jumps to the next input node and repeats the process until it has gone through all the input nodes. The iteration continues with the learning values decreasing each time until the resolution of the map does not change sufficiently to warrant further calculations. During the iterations the final location of the input nodes (raw data) is registered on the map so that the user can see how elements have been clustered.

Not only do SOMs give an idea of clustering but they are also spatially sensitive. Therefore one can not only tell what cluster a variable is from but also determine its relatedness to that cluster or cluster centre. All this information can be visualised in a 2-dimensional way using colours – called unified distance matrix (U-matrix). The U-matrix presents the distances between each map unit by colour coding. The light colours correspond to small distances between two map units and dark colours illustrate larger distances between the map units. The points on the output map that are on the light area belong to the same group or cluster and the dark area shows the borders between various clusters. (Kohonen, 2000)

4.1.3. Reasons for data triangulation

The reason for triangulating the data in this thesis is simple – while correlation is the most straight-forward form of relations between two variables, we cannot find clusters of variables from correlation tables very easily. Factor analysis is of help here – we can find the clusters of variables that have similar trends of behaviour. On the other hand, the reasons behind classifying variables under a certain component are not explained through factor analysis. Here, we can use SOM (SOM, 1999), which also visualises clusters of multi-dimensional data in its diagrams and in addition, explains the reasoning behind clustering of different variables.

4.2. Results

This subsection describes the results of the data triangulation conducted. Each research question is addressed separately, with all three analysis methods being used to find answers to the question. Each question will be provided with a short conclusion after the analysis, which summarizes the findings.

Due to the high data-volume of the correlation and factor analysis tables, the correlation tables of the analysis are in Appendix 7 and there is a reference to them each time the correlations have been calculated. Only fragments of the factor analysis rotation tables have been included in the thesis material. All factor analysis tables are available on the web at (Lepmets, 2005).

Question 1: what is the relationship between the implementing the basic project management activities and the type of the project and the company?

The correlation between the type of the project (factor C1) and the basic project management activities (factors from E-S, especially in group Q, particularly Q1 and Q13) was looked for. Also, the correlation between the type of the company (factors A5, A6 and A7) and basic project management activities was looked for. All correlation tables can be found in appendix 7. The answers to question F2 were not used because of the incorrect formulation of the question.

Table A7-1 in appendix 7 shows us the calculated correlation coefficients between variables C1 and variables from group E to S. As we can see from Table A7-1, there was no significant correlation found between C1 and Q1 (-0.14) or Q13 (-0.06). In fact, no significant correlation was found between C1 and any variable from E-S. The strongest correlation coefficient was found between C1 and E14 (-0.55), which stands for a moderate negative correlation between the type of the project and how well the commitments were obtained to project plan. In other words, when the type of the project was about enhancing an existing system, the commitments to the plan were not obtained well. The next strongest correlation coefficient was -0.37 with G8, which stands for a low negative correlation between the type of the project and analysing problems and issues in the project. We can conclude that the project type did not correlate strongly with any of the basic project management activities.

In classifying variables using principal component factoring for ***factor analysis*** there were altogether 27 components clustering all the variables. In explaining the results of the data analysis, only fragments of the rotation tables have been used in the text to illustrate the clusters that were formed. Due to the large size of the tables, the entire factor analysis results are not included in the text of the thesis. Instead, they have been made available on the web at (Lepmets, 2005). It is important to remember that the larger the number of the component (1-27), the less important is the component in the whole data set. In Table 4-1 below, C1 does not group with any basic project management activities. Instead, it grouped together with variables describing the background of the company, i.e. the type of the company (A5, A6) and the target users of the project (C5). Enhancement of an existing system (C1) correlates strongly with the systems maintenance company (A6). Both of them are negatively correlated to the type of company mostly developing new applications (A5). The latter correlates moderately also with projects where target users are external to the company (C5).

Table 4-1. Variables classified together with C1

		component
	variable:	**9**
Sys maintenance (%)	A6	-0.881
Type of project	C1	-0.680
Dev of new apps (%)	A5	0.675
Target users of the project	C5	0.462

Next, the ***correlation*** between the type of the company (factors A5, A6 and A7) and the applied basic project management activities was looked for. Table A7-2 in Appendix 7 shows us the calculated correlation coefficients between factors A5, A6 and A7 with factors from group E to S.

As we can see from Table A7-2, there was no significant correlation found between the type of a company (A5, A6 and A7) and any factor from E-S. The strongest correlation coefficient was calculated between A6 and G8 (-0.55), which shows a moderate negative correlation between system maintenance company type and project were issues and problems were well solved. The next strongest correlation coefficient was calculated between A5 and H1 (0.46), which indicates a moderate positive correlation between company developing new applications and the project where customer requirements were well obtained. Nevertheless, no significant correlation between the type of a company and any of the basic project management activities was found.

The same was confirmed by ***factor analysis*** where two indicators of company type (A5 and A6) were classified together with the project type (C1) and the target users of the project (C5), as we already saw in Table A7-2. Table 4-2 below shows us that also the type of company that focuses more on customisation of packaged software (A7) was not classified together with any model practices, but instead with the size of the software development department (A4). There was a negative correlation between the two, i.e. the smaller the size of the software department the more probable it was that the company was also customizing packaged software products.

Table 4-2. Variables classified together with A7

		component
	variable:	**24**
Custom of packaged sw (%)	A7	0.885
Sw dept size (% of sw people in company)	A4	-0.500

Self-Organizing Maps

In order to find relationships between the background of the project and the company, and the basic project management activities, all responses were clustered based on a) all the variables from A to S (Figure 4-1) and b) the variables indicating model practices from E-S (Figure 4-2). All self-organizing map figures in this thesis include two items – on the right there is a unified distance matrix and on the left there is a table of numbers illustrating the location of all responses.

For the visualization of the self-organizing map, a Unified distance matrix (U-matrix) is used. The U-matrix represents the distances between each pair of map units by color coding. A light color corresponds to a small distance between two map units and a dark color represents a bigger difference between the map units. The points on the output map that lie in the light area belong to the same group or cluster, while the dark area shows the borders between the clusters. The main idea for interpreting the results is to search the map for lighter areas and darker borders that separate them. A light area corresponds to a group of data that are similar and behave in the same way.

The tables of numbers left of the u-matrices represent the location of all responses. The responses illustrated on the u-matrix are the first responses of the input map that are connected to one specific map unit. The tables provide all responses connected to the map units, including the ones provided on the u-matrix. Although it is possible to provide all the responses also on the u-matrix, it would make the figure very difficult to read since there can be many responses connected to one map unit. That is the reason for describing the responses in tables next to the u-matrices.

There are three main clusters of responses described on both the u-matrix and the table in Figure 4-1: one in the upper part, a second on the lower left and a third on the lower right side. The clusters have been separated from each other by dotted lines in the tables next to the figures. Numbers inside one area of dotted lines in the tables indicate the closest related responses, corresponding to the light area of the u-matrices that indicates the group of data that are similar and behave in the same way. The darker colour on the u-matrix that runs between the grey areas separates the different clusters. Clusters are clearly seen when you compare the numbers on u-matrix and on the table at its left, considering that the dotted line of the table illustrates the dark colour of the u-matrix that separates the clusters. There are no light white units on the edge of the u-matrices outside the grey map units in Figures 4-1 or 4-2.

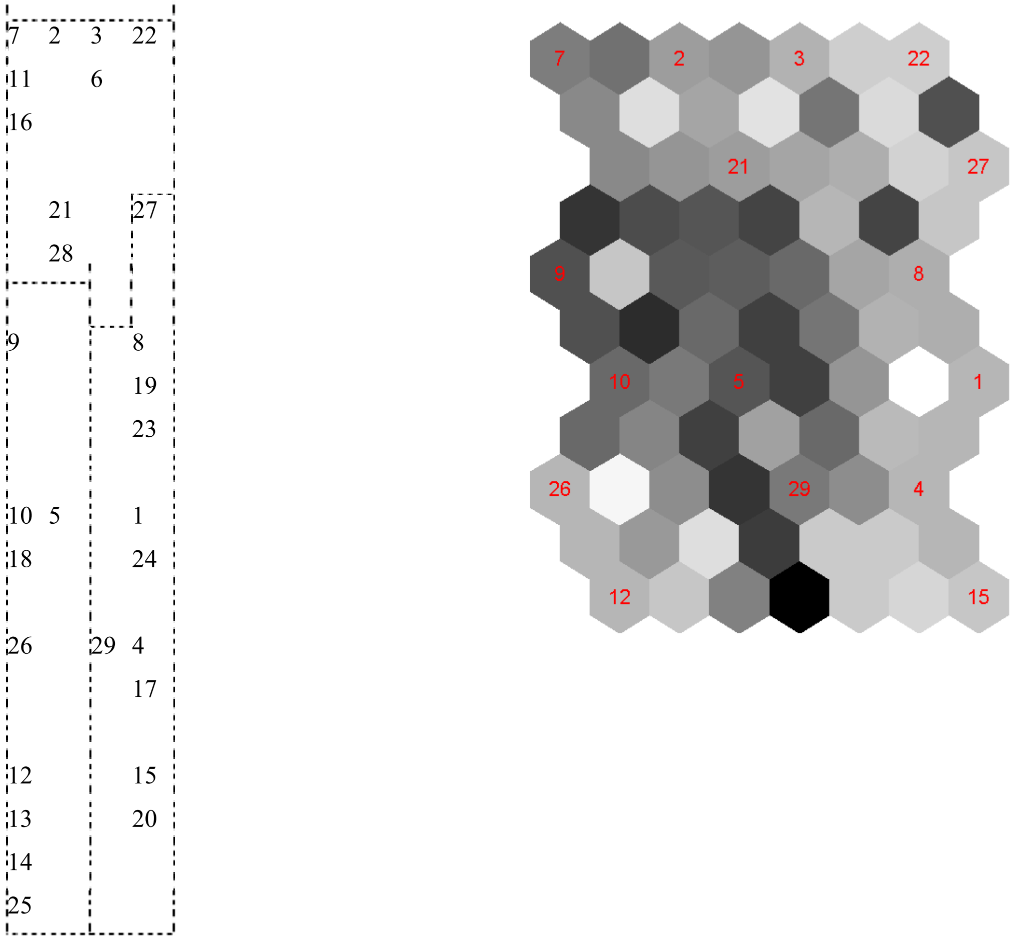


Figure 4-1. Clustering responses based on variables A-S

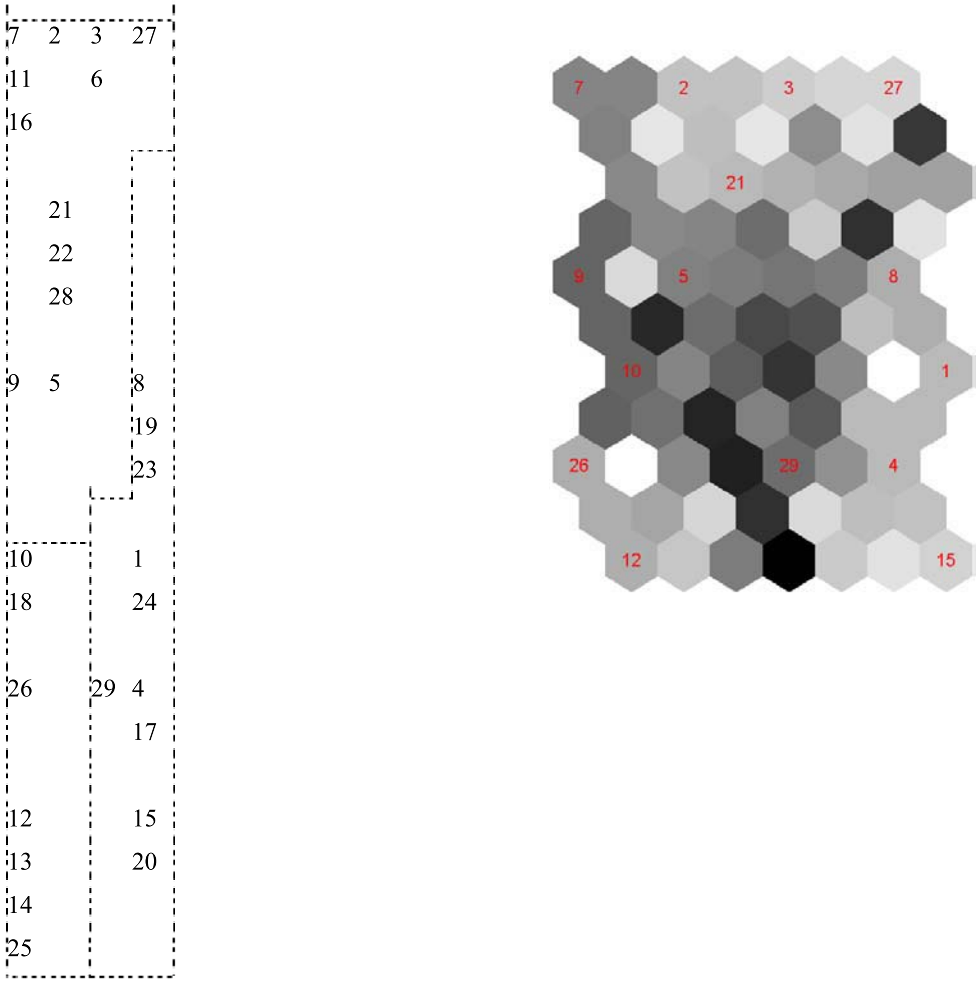


Figure 4-2. Clustering responses based on variables E-S

Although there are more variables used in the analysis described in Figure 4-1, the comparison of Figures 4-1 and 4-2 shows rather similar clusters of responses. This allows us to conclude that relationships between responses are stable and supported by the values of the company and project background variables.

To describe relationships between the characteristics of the company and of the project with the application of basic project management activities, we will refer to the Figure 4-1 for visualise explanations. Figures 4-3 and 4-4 illustrate the values of the selected variables used for clustering the responses (Figure 4-1), providing us with the information about the relationship between these variables.

In Figure 4-3, the summarizing variables from E-S have been illustrated, where darker colours indicate higher values and lighter colours indicate smaller values of the summarizing variables. First item on the figure titled U-matrix illustrates the size and shape of all the following u-matrices that indicate the values of the summarizing variables. This information helps to interpret the u-matrices in the cases where the light white map units are located on the edges of the u-matrix.

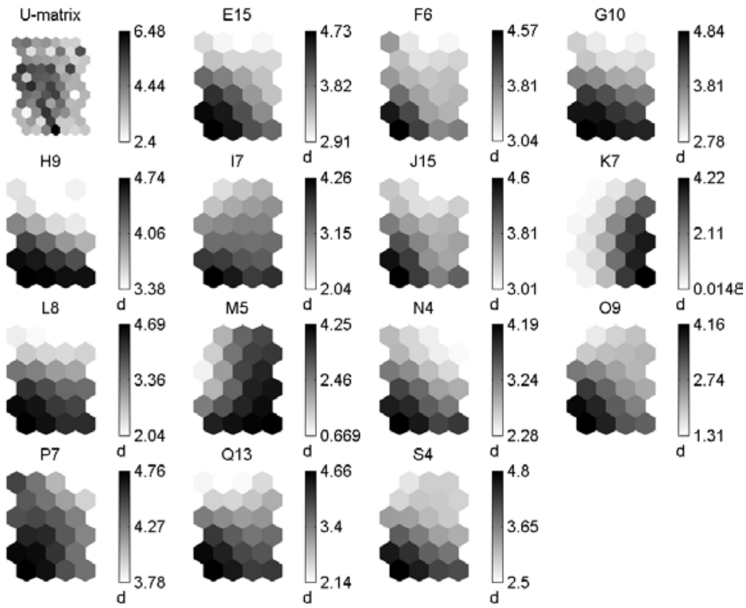


Figure 4-3. Description of summarizing variables in clustering responses based on variables A-S (Figure 4-1)

The variables in Figure 4-3 summarize the basic project management activities. We can see that highest values of summarizing variables tend to fall into one cluster in the lower left side, with the exception of variables K and M. The reason for K and M to distinguish is their higher value variance due to only few responses rating these variables.

In Figure 4-4, the values of variables from A-D, indicating the values of the background of the company, project and project manager with project success factors have been illustrated. While the highest summarizing variable values of E-S (Figure 4-3) fall clearly into the lower left side cluster, then the higher values for background variables A-C (Figure 4-4) are quite evenly distributed over the clusters.

Closer observation tells us that software houses (lower values in A1) with large software development departments (high values in A4) primarily developing new applications (high values in A5) are grouped together into the lower left corner, where most of the model practices have also been grouped (Figure 4-3).

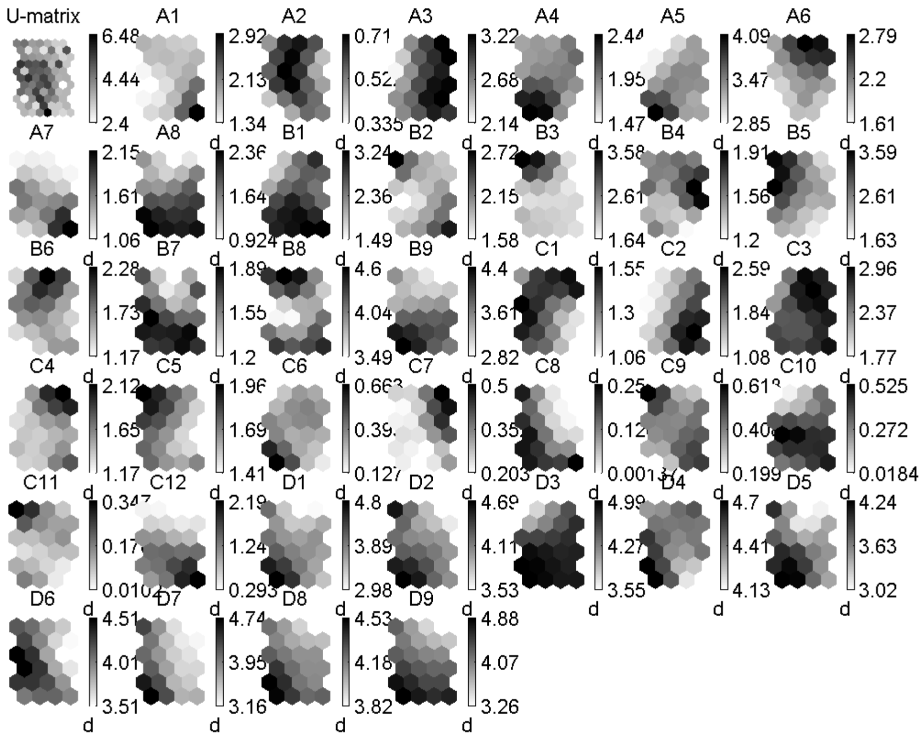


Figure 4-4. Description of variables A-D in clustering responses based on variables A-S (Figure 4-1)

A company working on systems maintenance (A6) and the projects about enhancing an existing system (C1) group together into the upper right side, and company customising packaged software (A7) into the lower right side. Although the type of the project grouped together with most other background variables, the basic project management activities (Figure 4-3) and the type of the company that primarily develops new applications (A5) was grouped together into one cluster. The same cluster describes responses from software houses, large software development departments with experienced project managers (B9) and successful software projects (D9).

Conclusions

Question: what is the relationship between implementing the basic project management activities and the type of the project and the company?

Answer: As an answer to the first research question, we can say that implementation of the basic project management activities does not depend on the type of the project. Although there was also no significant correlation found between the basic project management activities and the type of the company, it is more likely that a company developing new applications will implement more of the basic project management activities than the ones mostly maintaining or customizing packaged software.

Question 2: what is the relationship between the implementing basic project management activities and the size of the project and/or the company?

The ***correlation*** between the size of the company (factor A3), the size of the software development department in the company (factor A4), the size of the project through the number of staff in the development team (C2), the number of end-users (C3), and the duration of the project (C4) with the basic project management activities (factors from E-S, especially in group Q, particularly Q1 and Q13) was looked for.

The correlation coefficients between the size of the project and company, and the application of basic project management activities were calculated and can be viewed in Table A7-3 in Appendix 7. The strongest correlation was found between C4 and F5 (-0.70), which is a strong negative correlation between the duration of the project and the accurate estimation of the project schedule. In other words, the longer the project lasted, the less accurate was the estimation of the project schedule. The next strongest correlation was below 0.5, which indicates only a moderate correlation between the size of the project and company and the application of model practices. The strongest correlation with Q1 was -0.31 with C4, which indicates a weak negative correlation between the duration of the project and performance of the base practices. We can therefore say that almost no significant correlations were found between the size of the project and of the company and the application of basic project management activities.

Factor analysis gives a bit more information about classifying the variables describing the size of the company and the project, as can be seen in Table 4-3 below. From the first section of Table 4-3, we can see that the size of the company (A3) is related to activities dealing with directing the project staff (P1, P3, P4, P5, P7), to planning stakeholder involvement in the project (E9), to accurate estimation of the project (F6). The size of the project was also related to some of the project success factors, like project being on schedule (D1), on budget (D2), project representing excellent work (D7) and the overall success of the project (D9). All these activities have a negative correlation with the size of the company, which means that the smaller the sizes of the company, the more these activities were applied. Also, the smaller the size of the company, the more successful was the project described. There was a positive correlation between the size of the company and its locations (A2), meaning that the larger the size the more likely it was that the company was located in multiple sites.

The next section of Table 4-3 shows that the size of software development department did not classify together with any basic project management activity. Instead, it correlated with the type of the company (A7). The smaller software development departments were more devoted to the customisation of packaged software, as opposed to the development of new applications or maintaining the software.

The third section of Table 4-3 describes the classification of the size of the project through the number of staff in project development team (C2) and its related variables. The smaller the project in the number of developers, the more likely was the developed product a success (D8) and without conflicts in the project team (P6).

The fourth section of the table describes the classification of variables together with C3, the number of end-users that the project had. A rather interesting finding was made here about the size of the project being related to the use of the process models in the company. The table shows us that the smaller the number of end-users in the project, the more the company used the software process models (ISO/IEC IS 15504, CMMI, and ISO 12207).

The last section of the table describes the classification of variables together with the duration of the project (C4). The most interesting finding here is that the longer the project lasted, the less the basic project management activities were performed, i.e. there was a negative correlation between the length of the project and performing the activities (Q1). Also, the shorter the duration of the project, the better the project management work product management (R5). It also shows us that the shorter projects had more project planning and estimation than the ones that lasted longer, i.e. a negative correlation between length of the project and defining project life cycle (E2), planning project resources (E6) and data management (E7), implementing the project plan (E11), and estimating the project schedule (F5). The shorter the project, the less time the project manager devoted to user training (B6).

Table 4-3. Classification of variables A3, A4, C2, C3 and C4

	Variable:	Component 3
the project was on schedule	D1	0.840
the project was a success	D9	0.820
the project was on budget	D2	0.692
the project staff committed well to directions	P1	0.656
project's staff interaction well coordinated	P4	0.647
project was carried out in positive environment	P7	0.590
stakeholder involvement in project was planned	E9	0.577
people in project were motivated	P3	0.571
reasons of decision-making understood by staff	P5	0.545
location of company	A2	-0.540
project represented excellent work	D7	0.520
size of the company	A3	-0.496
project was accurately estimated	F6	0.456
	Variable:	**Component 24**
Custom of packaged sw (%)	A7	0.885
Sw dept size (% of sw people in company)	A4	-0.500
	Variable:	**Component 12**
conflicts in project team didn't emerge	P6	0.854
No. of staff in development team	C2	-0.467
developed product was a success	D8	0.436
	Variable:	**Component 7**
standards used in the company	A8	0.885
project measurement data collected	O5	0.598
No. of end-users in the project	C3	-0.569
	Variable:	**Component 5**
project schedule was estimated	F5	0.783
project commitments were monitored	G1	0.779
duration of the project	C4	-0.761
project's data management was planned	E7	0.704
WPs identified, documented and controlled	R3	0.684
project manager devoted to user training	B6	-0.650
WPs reviewed and adjusted to meet defined req-s	R4	0.631
project data management were monitored	G3	0.599
process work products were well managed	R5	0.555
project resources were planned	E6	0.543
project plan was implemented	E11	0.481
project risks were monitored	G2	0.479
base practices were performed	Q1	0.428
project life cycle was defined	E2	0.383

Although the factor analysis results shown in Table 4-3 classified the variables describing company and project size together with other variables, it is important to realise that mostly we were dealing with moderate correlations, with only a few correlations being significant (over 0.7).

SOM analysis

In order to find the relationships between the size of the company (A3), the size of software development department (A4), size of project development team (C2), number of end-users of the project (C3) and the duration of the project (C4) with the basic project management activities, we can refer once again to Figure 4-4 for a detailed description.

From Figure 4-3 we know that most of the variables describing basic project management activities (E-S) grouped into one cluster in the lower left corner. From Figure 4-4 we see that the higher values of variables A3 and C3 are distributed rather evenly on the right side of the diagram. The higher values for variable A4 are in the lower left corner, for variable C2 in the lower right corner, and for variable C4 in the upper right corner.

Applying the basic project management activities grouped together with responses from larger software development departments (A4). Other variables indicating the size of the company and project were grouped into other clusters.

Conclusions

Question: what is the relationship between the implementing basic project management activity and the size of the project and/or the company?

Answer: As an answer to the second research question we can conclude, based on the data of this research, that implementing the basic project management activity in projects is not significantly related to the size of the company or the size of the project. SOM analysis suggests that the larger software development departments implement more basic project management activities than smaller ones. Additional findings tell us that respondents from smaller companies had more successful projects than those from larger companies. The smaller development teams had fewer conflicts in their teams during their projects with a more successful product being developed as a result of a project.

Question 3: what is the relationship between implementing the basic project management activities and the success of software projects?

The ***correlation*** between the project success (D9) and basic project management activities (E-S, Q1 andQ13 in particular) was looked for. The correlation coefficients calculated between factors D9 and E-S can be seen in Table A7-4 in appendix 7.

We can see in Table A7-4 that there is a moderate correlation between project success and performing the basic project management activities, i.e. correlation coefficient between D9 and Q1 (0.49) as well as between project success (D9) and process performance management (0.45).

Significant correlations were found between D9 and E9 (0.71), P2 (0.75), P3 (0.78), and moderate correlations between D9 and E15 (0.61) and P7 (0.69). The successful projects were well planned for (E15) and also had stakeholder involvement planned within the project (E9). The most critical factors for project success came from the project directing group, i.e. successful projects were carried out in a positive environment (P7), where staff responded well to supervision (P2) and people in the project were motivated (P3).

In Table 4-4, ***factor analysis*** results for classifying variables together with D9 can be seen. First of all, factor analysis tells us that the success of a project depends highly on project being on schedule (D1) and on budget (D2). The successful projects were the ones where people were well directed (P1) and motivated (P3), where staff interaction was well coordinated (P4), reasons behind the decision-making were well understood by staff (P5), and the project was carried out in a positive environment (P7). A successful project was also an accurately estimated project (F6), where stakeholder involvement was planned (E9). An interesting finding here is that the successful projects were carried out in smaller companies at a single location, i.e. negative correlations between D9 and A2, and D9 and A3.

Table 4-4. Classification of variables with D9

model practices:	variable:	component 3
the project was on schedule	D1	0.840
the project was a success	D9	0.820
the project was on budget	D2	0.692
the project staff committed well to directions	P1	0.656
project's staff interaction well coordinated	P4	0.647
project was carried out in positive environment	P7	0.590
stakeholder involvement in project was planned	E9	0.577
people in project were motivated	P3	0.571
reasons of decision-making understood by staff	P5	0.545
location of company	A2	-0.540
project represented excellent work	D7	0.520
size of the company	A3	-0.496
project was accurately estimated	F6	0.456

SOM analysis

In order to see if there is a the relationship between the application of basic project management activities (E-S) and success of software project (D9), we can refer to Figure 4-4, which describes the values of variables A-D in clustering responses based on all variables.

From Figure 4-3 we learned that most basic project management activities were clustered into the lower left corner of the diagram and the success of the software project (D9) also has higher values in that part of the diagram (Figure 4-4).

Figure 4-5 describes the clustering of variables (D-S) based on the 29 responses. There are two distinct clusters in the diagram, separated from each other by dotted line in the table. The cluster in the upper right side of the diagram groups primarily the variables of K and M, which had highly varied values due to the low number of responses. The rest of the values for variables D-S were clustered evenly throughout the responses. Figure 4-6 confirms similar clustering even when the background variables (A-C) are added in the analyses. The highest variance in variables remains in the uppermost right corner of the diagram, the small variance in variable values is next to it on the upper left corner of the diagram (illustrating mostly background of company, project and project manager where value scale was mostly 0-1). The largest cluster groups variables with similar, rather small variance. The lowest part of the diagram describes the variables with the smallest variance and the highest values over all responses (Figure 4-7).

High values in project success (D) are in the lower right side of the diagrams together with high values in people management (P) and customer request management (J). We can therefore conclude that the successful projects depend on good people management and customer request management in the project.

H7 I3 O4 O9	J13 L1	L2		K1 K2 K3 K4 K5 K6 K7 M1
		M2 M3 M4 M5		
O1 O2 O3 O5 O6 O7 O8	I2 Q6		L6	
S2	I5 I7 Q11 R1 R2	L5 Q9		E12 E13 Q12
J12	I4	I1 I6	G4 N2	G7 Q7 Q8
S1 S3 S4	L4 Q13			F1 F2 G6 H8 Q5 Q10
J4 J10 J11 N4 Q3 Q4	L7 L8 Q2	E15	G2 G3 G9 G10	E3 F6
J9	J15 N3	R3 R5	R4	E2 E5 E9 F3 G8 H5
J2 J8 J14 L3		G5 N1	E8 E11 G1	D5 E7 Q1
H6	H9		E4	D1 D7 E1 E6 E14 P4
J1 J3 J5 J6 J7	H3	D3 E10 F4 H1 H2 H4	D4 D6 D8 F5	D2 D9 P1 P2 P3 P5 P6 P7

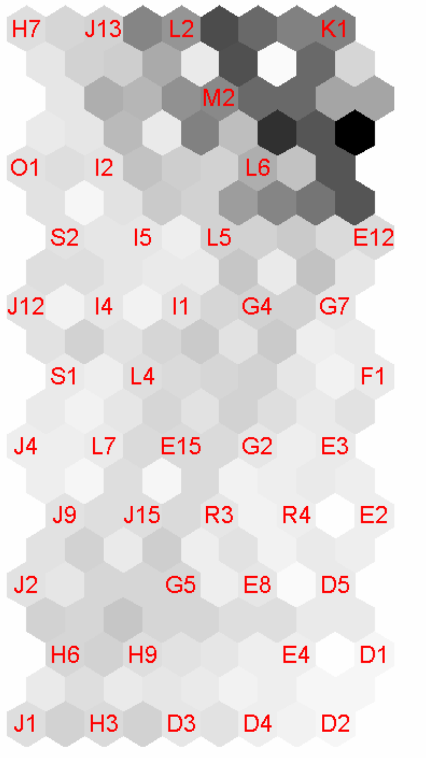


Figure 4-5. Clustering variables D-S

A2 C6 C7 C8 C9 C10 C11 K1 M1	C12	A7 C2		K2 K3 K4 K5 K6 K7
C1	B4 B7 C4	A1		
B3 B6 C5	A4 A6 A8 B2		C3	
B5		A3 B1 J13	L2	M2 M3 M4 M5
O5 O7	O6 O8 O9	O4	I3 L1 L6	
	O1 O2 O3	H7 Q6	L5	I2 I5 I7 Q9
J4 J9 J10 N4 Q3 Q4	S1 S4	S2 S3	Q11 R1 R2	J12
L7 L8 Q2	Q13	E13 G4 N2		A5 I1 I4 I6 J11
E15 J15 N1 N3 R5	G2 G9	G7 Q10 Q12	E12 Q8	L4
F6 G3 R3 R4	E3 E9 F2 G10	Q7		J2 J3 J7 J8 L3
B9 D5 E2 E7		E5 F1 F3 G8 H5	E8 G5 G6 H8 Q5	H6 J14
E6 P2 Q1	E14 G1			H3 J1 J5 J6
B8 D1 D2 D7 D8 D9 P1 P3 P4 P5 P6 P7	E1	D6 E4 E11 F5 H4	D4 E10 F4	D3 H1 H2 H9

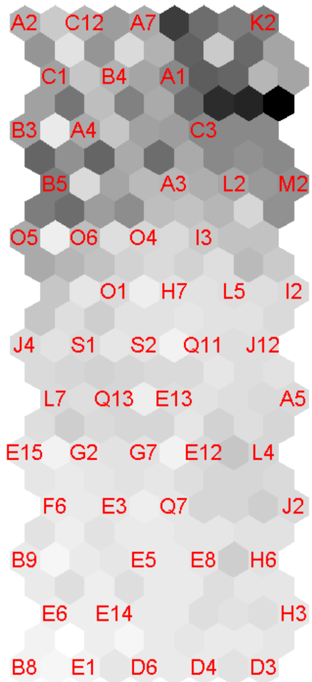


Figure 4-6. Clustering variables A-S

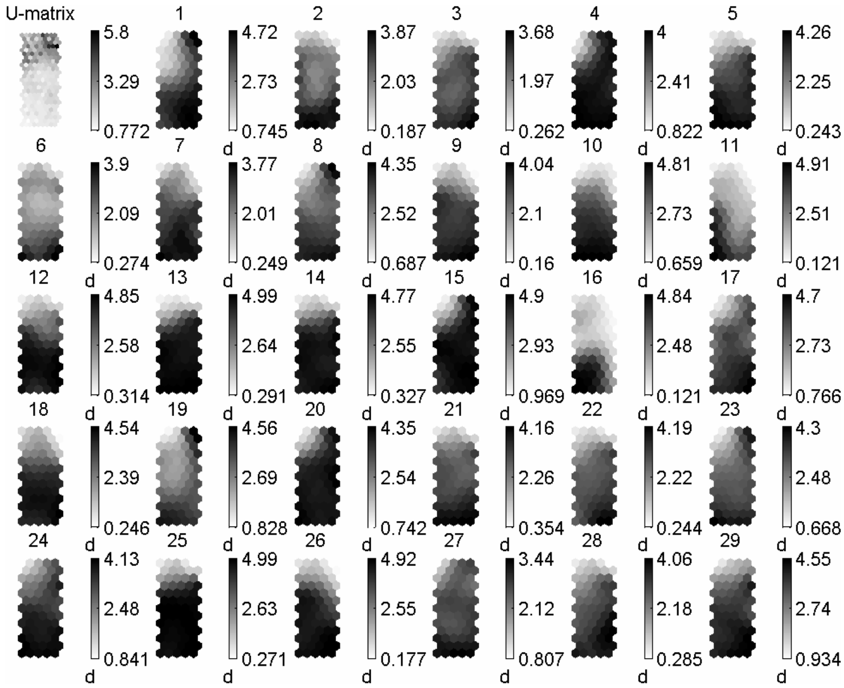


Figure 4-7. Values of all variables over all responses

Conclusions

Question: what is the relationship between implementing the basic project management activities and the success of software projects?

Answer: We can conclude that the factors that most affected the success of the project were the activities related to directing and managing the people in the project. Also, successful project planning and accurate estimation with defining the project scope, planning of the project resources and stakeholder involvement were important for project success. Smaller projects were more successful than the larger ones and a project manager with more experience in developing software was of importance for a project to succeed.

Although we cannot argue that implementing the basic project management activities are significant for a project to succeed, we can say that directing and managing the people and their interactions well in the project is crucial for project success.

4.3. Additional Findings

This subsection aims to give more information about the application of basic project management activities in industry software projects. There are altogether five questions, four of which are explained by triangulating the data as was done before. The last question is explained only by providing the correlation calculations. Each question is provided with a short summary of findings, as in the last subsection.

1. What constitutes project success for project managers?

In the survey used for data collection, the project managers were asked whether the project they described in detail was a successful one or not. There were eight project success variables (D1-D8) and one summarizing variable (D9) in the group of variables describing project success. We hereby aim to find out what constitutes a successful project to the project managers. In order to find that out, we seek relationships between the variables describing project success (D1-D8) and their summarizing variable (D9).

Correlation

Table 4-5. Correlations between variables describing the project success (D1-D9)

		D1	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*	*D8*	*D9*
On schedule	D1	1.00								
On budget	D2	0.63	1.00							
Accepted by customers	D3	0.09	-0.10	1.00						
Project achieved its goals	D4	0.24	0.24	0.13	1.00					
High speed of development	D5	0.28	0.23	-0.18	-0.06	1.00				
Product satisfied requirements	D6	0.07	0.04	0.00	0.13	0.07	1.00			
Project represented excellent work	D7	0.58	0.51	-0.15	0.40	0.36	0.20	1.00		
Developed product was a success	D8	0.27	0.51	0.03	0.11	0.13	0.05	0.42	1.00	
The project was a success	D9	0.71	0.60	0.06	0.15	0.22	0.05	0.64	0.47	1.00

In the Table 4-5 above, the correlation coefficients have been calculated between the variables in the group describing project success.

The significant correlation coefficient (0.71) was calculated between a project being on schedule (D1) and the success of the entire project (D9). Project being on budget (D2) and project representing excellent work (D7) were both moderately correlated with the project success (D9). Curiously enough, the least important things for project success were the project being accepted by the customers (D3) and the product satisfying its requirements (D6).

Factor analysis

Factor analysis results confirm the findings of the correlation coefficients. Namely, that project on schedule (D1), on budget (D2), representing excellent work (D7) and having an overall success (D9) grouped together into one cluster under the third component (Table 4-6). The other variables describing project success were distributed separately over the clusters.

Table 4-6. Classification of variables with D9

	Factor:	**Component 3**
the project was on schedule	D1	0.840
the project was a success	D9	0.820
the project was on budget	D2	0.692
the project staff committed well to directions	P1	0.656
project's staff interaction well coordinated	P4	0.647
project was carried out in positive environment	P7	0.590
stakeholder involvement in project was planned	E9	0.577
people in project were motivated	P3	0.571
reasons of decision-making understood by staff	P5	0.545
location of company	A2	-0.540
project represented excellent work	D7	0.520
size of the company	A3	-0.496
project was accurately estimated	F6	0.456

Self-Organizing Maps

In Figure 4-8 below we can see the grouping of variables in group D.

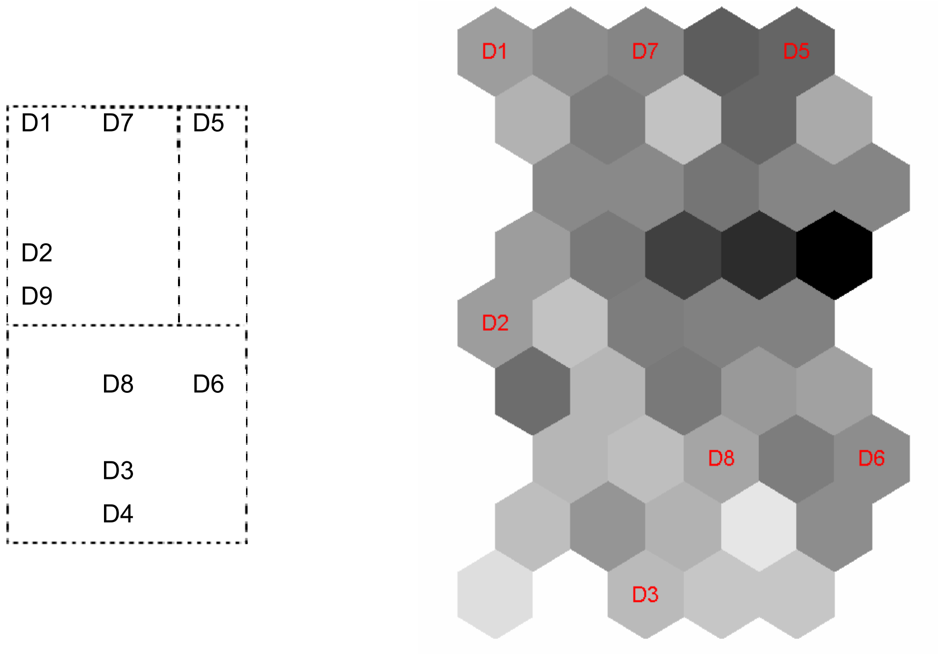


Figure 4-8. Grouping variables describing project success (D1-D9)

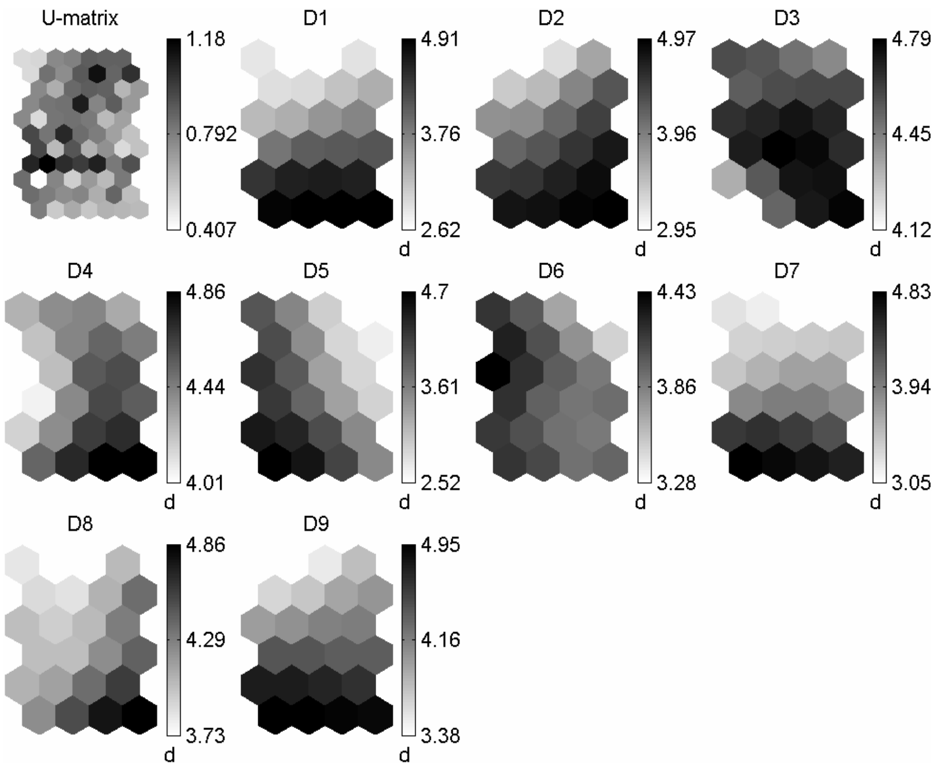


Figure 4-9. Variable D1-D9 value diagrams over all responses

In the more detailed diagram of variables (Figure 4-9) we can see the values for each variable over all responses, where the similar value distribution indicates the connection between the variables. Thus, SOM confirms the findings that project on schedule (D1), on budget (D2) and representing excellent work (D7) group together with the overall success of a project (D9).

Figure 4-9 illustrates that the highest values for D1, D2, D7 and D9 fall into the lowest end of the diagram, while the smallest values are in the upper part of the diagram. The distribution of values over the diagram is most similar between D1 and D9, followed by D7 and D2 respectively.

Conclusions

Question: What constitutes project success for project managers?

Answer: Based on the data collected in this survey, we can conclude that project managers regarded the overall project success as depending on the project being on schedule and on budget. Paradoxically, the project managers believed that customer acceptance of the project and the satisfaction of product requirements were not at all important for the project to succeed.

2. Which background variables affect project success?

In the three research questions of the study we looked for some relationships between the background of the company and project, and the model practices applied in the project. This time, we are interested in whether any of the variables describing the background of a company, project or project manager has an effect on the success of the project. To do that, we seek relationships between the background variables (A-C) and success variables (D1-D9).

Correlations

Table 4-7. Correlations between background variables and variables of project success

		D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**
Core business area	A1	-0.23	-0.34	0.22	-0.16	-0.25	0.03	-0.02	-0.13	0.00
Multi-site	A2	-0.47	-0.41	0.02	-0.09	-0.09	0.22	-0.38	-0.30	-0.41
Company size	A3	-0.34	-0.46	0.08	-0.02	-0.12	0.07	-0.44	-0.27	-0.41
Sw dept size	A4	0.22	0.09	0.10	0.03	0.33	0.17	-0.10	0.01	-0.09
Dev of new apps	A5	0.16	0.14	0.23	0.02	-0.07	0.00	0.21	0.28	0.28
Sys maintenance	A6	-0.18	-0.04	-0.01	-0.15	0.02	-0.12	-0.51	-0.14	-0.44
Custom of packaged sw	A7	-0.18	-0.25	0.06	0.04	-0.05	0.08	0.03	-0.08	0.01
Standards used	A8	0.18	0.32	0.24	-0.15	0.03	0.05	0.23	0.25	0.21
% devoted to PM	B1	-0.07	-0.08	0.34	-0.30	-0.19	-0.13	-0.13	-0.20	-0.04
% devoted to sw analysis	B2	0.06	0.22	-0.11	0.18	0.13	0.06	0.14	0.05	0.23
% devoted to design	B3	0.11	0.35	-0.39	0.18	0.03	0.31	0.25	0.14	0.09
% devoted to programming	B4	0.02	0.04	-0.16	0.44	0.09	-0.20	0.11	0.21	0.13
% devoted to testing	B5	0.20	0.28	-0.20	0.26	0.10	0.27	0.26	-0.16	0.07
% devoted to user training	B6	-0.13	0.15	0.06	0.21	-0.23	0.08	-0.18	0.07	-0.05
% devoted to sth else	B7	0.03	-0.24	0.06	-0.25	0.15	0.09	-0.11	0.09	-0.08
Experience in dev sw	B8	-0.04	0.18	-0.32	0.04	-0.03	-0.27	0.12	0.24	0.17
Experience in PM	B9	0.28	0.08	0.02	-0.25	0.23	-0.09	0.29	0.09	0.38
Type of project	C1	-0.07	-0.32	0.11	-0.05	0.01	0.07	-0.26	-0.10	-0.36
No. of staff in dev team	C2	0.02	-0.22	0.13	-0.19	0.08	-0.13	-0.39	-0.24	-0.21
No. of end-users	C3	-0.11	-0.18	0.13	0.07	-0.16	-0.37	-0.21	0.18	0.07
Duration of the project	C4	-0.07	-0.22	0.03	-0.26	-0.14	-0.04	-0.11	0.08	-0.09
Target users of the project	C5	0.03	0.28	-0.19	0.00	-0.13	0.00	0.31	0.19	0.21
Life cycle model used - phased	C6	0.25	0.17	0.23	0.20	-0.20	0.15	0.27	0.09	0.15
Life cycle model used - prototyping	C7	-0.31	-0.28	-0.03	0.13	-0.09	-0.24	-0.23	-0.40	-0.11
Life cycle model used - spiral	C8	0.06	-0.07	-0.05	-0.32	0.31	0.00	0.17	-0.26	0.26
Life cycle model used - evolutionary	C9	-0.12	-0.15	-0.21	-0.17	-0.02	0.00	-0.26	-0.05	0.01
Life cycle model used - concurrent	C10	-0.10	0.11	0.41	0.13	0.06	-0.31	-0.06	0.01	-0.02
Other life cycle model used	C11	0.06	0.24	-0.35	0.04	0.21	-0.21	0.17	0.30	0.00
Standards used in the project	C12	0.12	0.13	0.36	-0.08	0.07	0.24	0.11	0.04	0.28

Correlation coefficients were calculated between variables A-C and D1-D9 (Table 4-7 above) to find the related variables.

There were no significant correlations found between background variables and variables describing project success. The strongest correlation coefficient in the whole table was -0.51 between excellent work in the project (D7) and company maintaining systems (A6), which is a moderate negative correlation. The strongest correlation with the overall project success (D9) was found with company maintaining systems (A6), where there was a weak negative correlation (-0.44) with project success. Also the company size (A3) had a weak negative correlation (-0.41) with project success. Project manager with lots of experience in project management (B9) had a weak correlation (0.38) with the overall success of the project.

We can thus say that the larger the company, the less successful projects they described in the survey. This can partially be due to higher project requirements in larger companies.

Factor analysis

Table 4-6 also illustrates the clustering of project success variables with other variables, including background variables. We can see that the four project success variables (D1, D2, D7 and D9) group together with the company size (A3) and location (A2). The size and location variables are negatively correlated to the success variables, confirming the finding in correlation tables that the larger companies described a less successful project than the smaller ones.

Table 4-8 – classification of variables with D8

	Variable:	**Component 12**
conflicts in project team didn't emerge	P6	0.854
nr of staff in development team	C2	-0.467
developed product was a success	D8	0.436

The only other variable describing the project success grouping together with a background variable is D8 – developed product was a success, illustrated in Table 4-8. There is a negative correlation between the size of development team (C2) and the successful product. Although the correlation is not significant between these two variables, it is interesting to see that the smaller teams had more successful products than the larger ones.

Self-Organizing Maps

Figure 4-10 illustrates the grouping of variables A-D and Figure 4-11 illustrates the values of these variables over all the responses. There are altogether three groups – the upper left side corner describes the responses with little variance (0-1), the group of variables in the middle of the diagram describes responses with great variance in values, and the lower end describes responses with small variance and higher values of variables.

We can see that most variables describing project success have grouped into the lower end of the diagram. Only a few background variables fall into the same cluster. Experience of project manager in both software development (B8) and project management (B9) and the type of the company developing new applications (A5) are related to the project success.

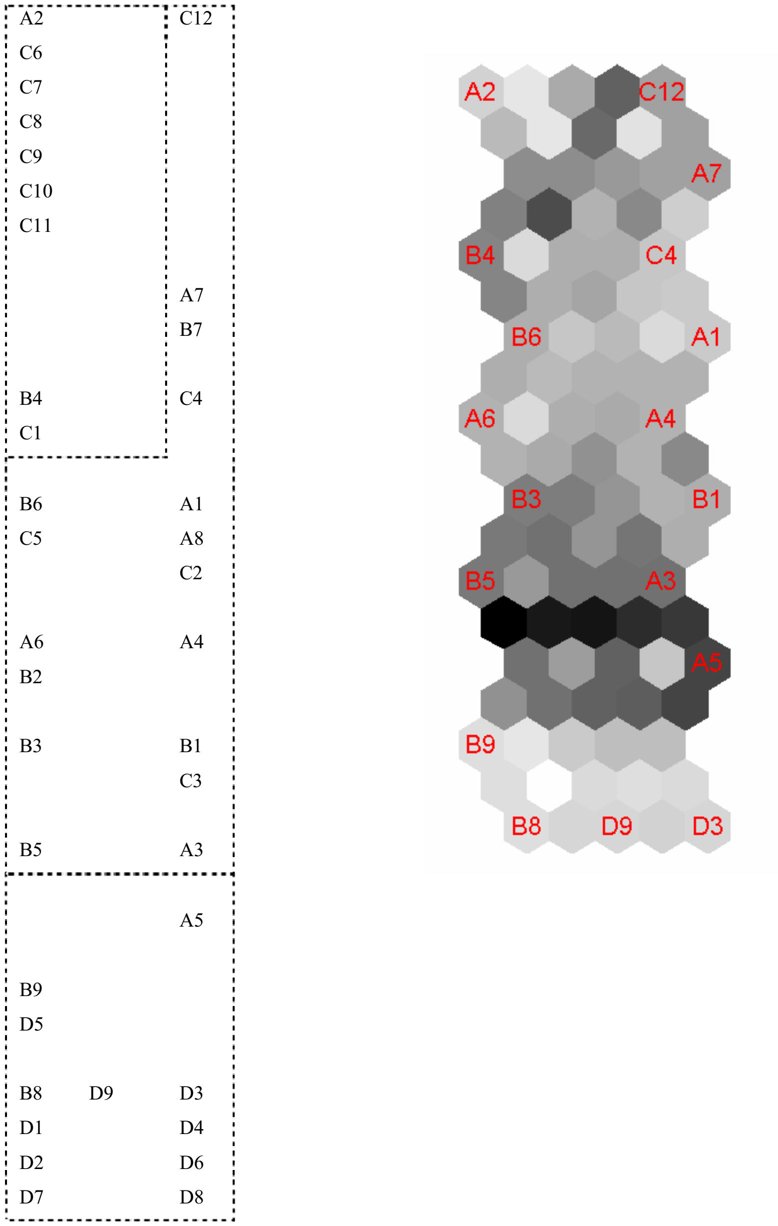


Figure 4-10. Grouping of variables A-D over all responses

From Figure 4-11, we can also see that projects developing new systems were more successful than projects that were enhancing the existing systems, i.e. C1 is negatively correlated with D9. SOM analysis also confirms the finding of the correlations, where the smaller sized local companies described more successful projects than the large multisite companies, i.e. there is a negative correlation between A2 and A3, and D9.

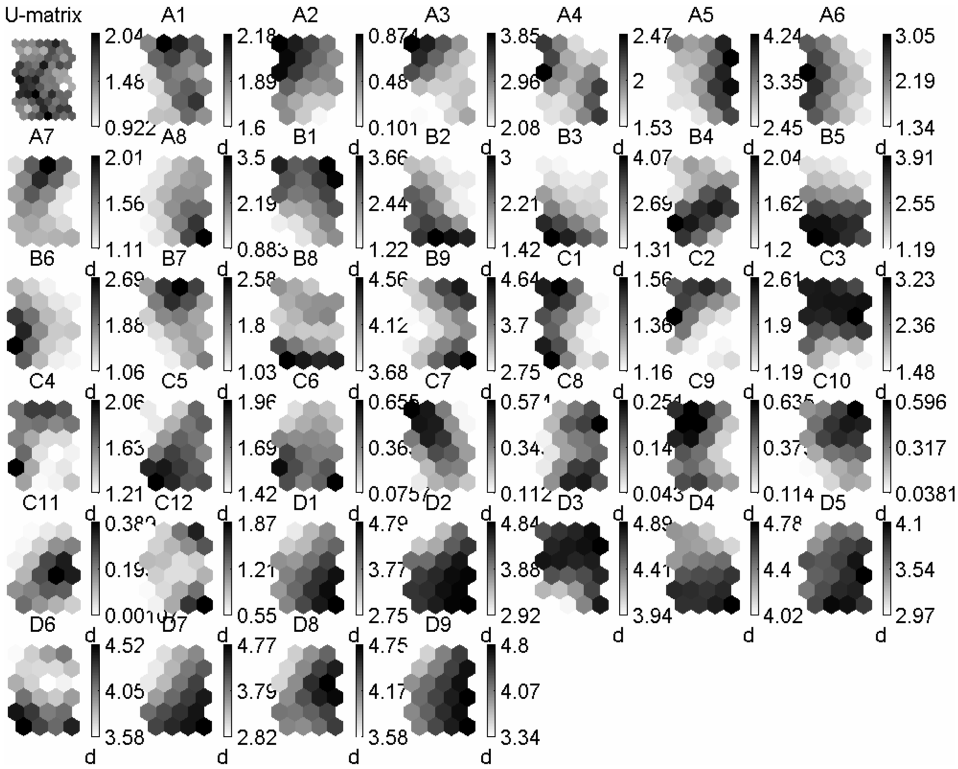


Figure 4-11. Values of variables A-D over all responses

Conclusions

Question: Which background variables affect project success?

Answer: The data suggests that smaller development teams and smaller local companies rated their projects more successfully than larger companies and teams. The smaller teams also developed products that were more successful than those of the larger teams. Experience of the project manager in both software development and project management helps the project to succeed. The projects aiming to develop new systems were more successful than projects enhancing an existing system.

3. **Do companies and projects that use software process models implement more basic project management practices in their project than the companies and projects that are not using standards?**

The basic project management practices that are being validated in this research are derived primarily from ISO/IEC IS 15504 and CMMI. It would be obvious that companies that apply one of these two process models in their projects also apply similar practices in their industry projects. On the other hand, the model practices should be generic enough for any company to apply them that wants to assure better process and product quality, regardless of the standards that they use or do not use in their company. We hereby aim to find out if there is a connection between the application of standards on company and project level with the application of model practices, in this case the basic project management practices.

In the background questions about both the company and the project, there was a question about the application of software standards, A8 and C12 respectively. The higher values of the variables indicate the application of ISO/IEC IS 15504 and CMMI, process models from which the activities (E-S) had been derived.

Correlations

To see whether the standards used on company and project levels also mean application of more basic project management practices, we calculated correlation coefficients between standards used in company (A8), standards used in the project (C12) and all the basic project management activities (E-S). The correlations can be seen in Table A7-5 in Appendix 7.

The strongest correlation between any basic project management practice and standards/process models used on the company level (A8) was a moderate correlation (0.62) with O5. This means that project measurement data was collected more in projects that were using standards on the company level. Measurement results were also communicated (O8) and stored (O7) more in the responses where standards were used in companies.

The strongest correlation between any basic project management practice and standards used in the project (C12) was a moderate correlation (0.57) with L1. Project risk management scope was established in projects where software standards were used. The bi-directional traceability of requirements (H7) was better managed, data measurement analysis procedures were established (O4), and risk management strategies were defined (L2) in the projects where standards were used. All these correlations were moderate, i.e. the correlation coefficient was between 0.5 and 0.6.

Factor analysis

Table 4-9 shows the classification of variables A8 and C12 together with other variables of the survey. There is a correlation between the size of the project and the standards used in the company – the companies that applied software standards (A8) had projects with a larger number of end-users (C3). Also, the companies applying standards were collecting the project measurement data (O5).

Table 4-9. Classification of variables together with A8 and C12

		component
model practices:	**variable**	**7**
standards used in the company	A8	0.885
project measurement data collected	O5	0.598
No. of end-users in the project	C3	-0.569
		component
	variable	**16**
phased life cycle model used	C6	0.862
concurrent life cycle model used	C10	-0.588
standards used in the project	C12	-0.395

The second section of the table PCA7 illustrates the cluster where the application of standards on project level (C12) was grouped. Only three variables describing the project grouped together here. The responses indicate that concurrent and phased life cycle model are not used in the same project (negative correlation between C6 and

C10), and we also see that projects where standards are used apply the concurrent life cycle model instead of the phased life cycle model.

Self-Organizing Maps

From Figure 4-3 we know that most of the variables describing model practices (E-S) grouped into one cluster in the lower left corner of the diagram. Figure 4-4 illustrates the values of variables A-D in clustering of responses based on all variables (A-S). When we take a closer look at the value distribution of the variables A8 and C12, we see that the higher values of A8 fall evenly into the lower end, and the higher values of C12 into the lower right corner of the diagram. There is no straight-forward correlation between the application of basic project management practices and the application of standards. This may suggest that companies that do not apply software standards or process models still apply the same practices described in process models.

Conclusions

Question: Do companies and projects that use software process models implement more basic project management practices in their project than the companies and projects that are not using standards?

Answer: Although there is no significant correlation between the use of standards and application of basic project management practices, there is an indication that companies and projects using process models also apply processes of measurement and analysis, and risk management. Companies using process models collect measurement data (O5), and communicate and store the measurement results (O8, O7). The projects where standards are used have also established the data measurement analysis procedures (O4), and some practices of risk management (L1, L2). Other than that, it appears that the basic project management practices are generic enough for all companies to apply, regardless to whether they use standards on project or company level or not.

In addition, the companies that used standards on company level had larger projects (C3) and the projects where standards were used applied concurrent life cycle models.

4. Is implementing the basic project management activities related to life cycle models used in the project?

In the survey, there were six variables (C6 – C11) describing the life cycle models used in the project the respondents described. The respondents could select more than one variable since life cycle models are often not purely applied. The choices of life cycle models used in the project were the following: phased (C6), prototyping (C7), spiral (C8), evolutionary (C9), concurrent (C10) and some other life cycle model (C11). Unfortunately, even when another model option (C11) was selected, the respondents did not specify what kind of a model it was. We aim to find out if life cycle models (C6-C10) relate to basic project management activities (E-S).

Correlations

Table A7-6 in Appendix 7 illustrates the correlation coefficients calculated between C6-C10 and E-S. No significant correlations were found between any variables. The strongest correlations of each life cycle model are described below.

The project using phased life cycle (C6) model had the strongest correlation coefficient (0.41) with project risk management scope was established (L1), which is a moderate correlation. Project using prototyping life cycle model (C7) had the strongest negative correlation (-0.42) with J2 status of change requests tracked (J2) in requirements management, followed by negative correlations with measurement data analysed (O6), customer request for change recorded (J1) in requirements management and measurement data collected (O5). Although the correlations were not significant, the findings suggest that the few more complex and time-consuming practices from the requirements management and measurement are not applied when the prototyping life cycle model is followed in the project. Projects using spiral life cycle model (C8) correlated strongest (0.39) with project staff responding well to supervision (P2) having a weak correlation between these variables. C8 had also a weak negative correlation (-0.37) with status of change requests tracked (J2).

Projects using evolutionary life cycle model (C9) had a weak correlation 0.31 with stakeholder involvement planned (E9) and a weak negative correlation (-0.36) with customer inquiry screening performed (I2).

Projects using concurrent life cycle model (C10) had moderate correlations (0.52 and 0.51, respectively) with work and resource level reconciled (E13) and reviewing the plans that affect the project (E12) from project planning. A moderate correlation was found also between agreeing on requirements (H3) and establishing customer requirements baseline (H5) with correlation coefficients 0.47 and 0.45, respectively. Thus, the concurrent life cycle model seems to require more from project planning than the other models.

Factor analysis

In factor analysis illustrated in Table 4-10, the variables describing the life cycle models did not classify together with any basic project management activity, except for the variable describing the other life cycle model (C11) that grouped together with obtaining commitment to the plan (E14) of project planning.

Table 4-10. Classification of variables with life cycle models (C6-C11)

		component
model practices:	**variable**	**10**
pm's time devoted to programming	B4	-0.896
other life cycle model used	C11	-0.652
commitments to plan obtained	E14	0.550
pm's time devoted to project mgmt	B1	0.543
model practices:	**variable**	**16**
phased life cycle model used	C6	0.862
concurrent life cycle model used	C10	-0.588
standards used in the project	C12	-0.395
model practices:	**variable**	**20**
prototyping life cycle model used	C7	0.856
spiral life cycle model used	C8	0.572
model practices:	**variable**	**21**
evolutionary life cycle model used	C9	0.857

Self-Organizing Maps

Using Figures 4-3 and 4-4, we see that while most basic project management activities (E-S) are located in the lower left corner of the diagram, the values for variables C6-C11 illustrated in Figure 4-4, do not exhibit such a clear pattern. Thus, we have no indication of relationships between the life cycle model and application of basic project management activities.

Conclusions

Question: Is implementing the basic project management activities related to life cycle models used in the project?

Answer: As a result of data analysis conducted, there was no evidence found for a connection between life cycle models and application of basic project management activities.

Correlation analysis suggests that when prototyping life cycle model is used, some of the more time-consuming practices of requirements management, and measurement and analysis are not applied in the project. Moreover, following the concurrent life cycle model demands more from project planning than do the other life cycle models.

5. Validation of each basic project management activity group – correlation between the variables of the group with the summarizing variable of that same group.

In the survey, each group of variables describing basic project management activities had one summarizing variable. The summarizing variable was created to find the relevance of the basic project management activities to the overall success of the area that the activity group focused on. We have already seen the correlations between the overall success of a project (summarizing variable D9) and all the variables in the group of project success (D1-D8). We now wish to conduct a similar study with all the basic project management activities. This should show us the relevance of each basic project management activity in the eyes of the industry project managers.

To answer this particular question, the data was analysed using only correlation coefficients, which shows the most straightforward connection between variables. Since all the variables are connected to their summarizing variable, the other analysis methods will not give much additional information about this particular question.

Correlations

Correlations between each group and its summarizing variable can be viewed in Table A7-7 in Appendix 7. The highest correlations have been illustrated in light colour. If no significant correlation between the basic project management activity and its summarizing variable was found, the highest correlation has been indicated. The correlations between variables in groups K and M are very high due to only few responses rating these variables.

In project planning, there were no significant correlations with the good project planning (E15). The most important activity was the allocation of responsibilities (E10) for a successful project planning. For accurate project estimation, the project's attributes (F1) need to be estimated. For a well monitored and controlled project, the stakeholder involvement was monitored (G4) and the deviations from plans were corrected and managed (G9). In good requirements management the commitment to requirements had to be obtained (H4). Most supplier tendering practices were important to manage the whole process well. The most important was the preparation of supplier proposal response (I5). In change request and configuration management there are two summarizing factors. For good change request management, the changes need to be approved before implementation (J5). For good configuration management, the configuration items need to be identified (J8). Taking corrective actions (L7), analysing risks (L4), and defining and performing risk treatment actions (L5) are most important for good project risk management. For good product quality assurance, the problems of the developed product need to be identified (N1) and for good process quality assurance, the product quality needs to be well assured (N3). Project measures need to be specified (O2), measurement data analysed (O6) and the results of measurement communicated (O8) for good measurement and analyses process. In order to have a positive project environment (P7) people in the project need to be motivated (P3). For good process performance management the process needs to be monitored and controlled (Q6) and for good work product management the work products need to be identified, documented and controlled (R3). Information about the project and its end needs to be formalized (S1) for a good project completion.

Conclusions

Question: what is the correlation between the variables of each group with the summarizing variable of that same group?

Answer: From earlier analysis results, we learned that in order for a project to be successful, a positive environment for development is required. From the correlation analysis, we can see that in order to have such an environment, the people in the project need to be motivated. Also project planning and project estimation were of relevance for project success.

5. DISCUSSION AND CONCLUSIONS

This chapter provides conclusive analysis of the research results and describes them from the perspective of the aim and scope set in the beginning of the study. The findings of this research are then interpreted and compared to the results of the related research described in detail in chapter 2 of the thesis. The ideas for the future research are also described here.

5.1. Summary of findings

The aim of the research was to find the relevance of basic project management activities to industry projects and to the success of these projects. We constructed a model of basic project management activities and evaluated it against the surveyed industry data. The data was received from 29 software projects in software companies in Finland and Estonia. Due to the nonprobability sampling used, we can only generalize the findings of our research to the respondents of the survey. The model was evaluated by triangulating the data with three data analysis methods to reach the aim and illustrate the answers to the research question.

The model of basic project management activities consisted of the base practices of project management and of its related processes, the generic practices and generic practice indicators of project management that support the achievement of generic goals and process attributes of up to Level 2, derived from the CMMI continuous representation and ISO/IEC IS 15504 respectively. Few activities were also added to the model from the PMBoK and from other sources of project management literature. The model elements were grouped based on the differentiation of known and unknown factors.

We looked for a relationship between the implementation of the basic project management activities and the project success. We also aimed to find whether the characteristics of the project, the project manager and the company affect the intensity with which the basic project management activities are implemented in industry projects.

We first studied the relationship between implementing the basic project management activities and the type of the project and company. As a result of the research, we found that implementation of the basic project management activities did not depend on the type of the project. Although there was no significant correlation found, more basic project management activities were implemented by companies that developed new applications than the ones that were engaged in maintaining or customizing packaged software.

We then looked for the relationship between implementing basic project management activities and the size of the project or company. Based on the data of this research, there was no significant relationship found between implementing the basic project management activities and the size of the project or company. The results suggested that the larger software development departments implemented more basic project management activities than the smaller ones. Additional findings told us that respondents from smaller development teams had fewer conflicts in their teams during their projects with more successful products being developed as a result, than those from larger companies.

Thirdly, we searched for the relationship between implementing the basic project management activities and the success of software projects. Although we could not argue that implementing the basic project management activities were significant for a project to succeed, we could say that directing and managing the people and their interactions well in the project was crucial for project success.

As a result of the research, we conclude that the activities related to managing and directing the people in the project developing team were most important from the standpoint of the project succeeding. Planning the project resources and stakeholder involvement, and estimating the project accurately were also relevant for the project success. The more complicated activities related to project data measurement and analysis; risk control and post-mortem reviews through project closing activities were rarely implemented in the projects studied in the research.

This finding suggested that the organizations improving their processes with the help of process models may not experience much benefit to their improvement work until the processes reach a higher capability level than level 2. The basic project management activities may form the necessary foundation for project success, but their implementation alone did not deliver observable benefits based on this study.

Project managers believed that project success depends first and foremost on the project's ability to meet schedule and budget commitments. It is worrisome, to say the least, that the project managers participating in the research did not find the customer acceptance of the project nor the product satisfying the set requirements important for the overall project success. Good project management requires the developers to be in constant contact with the customer throughout the project in order to fully understand and manage the customer requirements and expectations for the project and the product under development.

A project manager with a broad managerial background led projects to success more easily than a project manager with expertise in any particular area of software development. Our results also suggested that dividing large projects into smaller sub-projects that are more easily planned, estimated and managed, where there was a smaller development team, would result in fewer conflicts and a more successful product being developed as a result of the project.

The findings remind us of two important points. First, even though the higher project management process capabilities are likely to increase the success of the project, it is clear that the human aspects of the project management and process improvement are vitally important for their success. Successful process improvement relies heavily on human factors, skills and teamwork competencies. A project manager has to motivate the team members, coordinate their interaction and supervise them when necessary to create the positive environment for the development that supports the overall project success.

Secondly, although each project is different and the process model guidance should be tailored to fit the needs of each specific project, the findings of the study suggest that smaller projects and development teams develop more successful products than the large projects and teams. Sub-dividing a large project into smaller projects allows for easier planning and more accurate estimation, which in turn support the overall success of the project.

5.2. Interpretation of findings

There is evidence from literature that the higher organization maturity or process capability supports increased project performance. In (Jiang et al., 2004) the question remains about the significance of basic project management practices to project performance. We focused only on basic project management and its related practices – the processes that support the achievement of capability levels 1 and 2 in CMMI Continuous and ISO/IEC IS 15504. We aimed to discover whether the implementation of processes on project level supports the project success.

In addition, there is confusing evidence (Elemam and Birk, 2000; Goldenson and Herbsleb, 1995) on whether the size and type of the organization and of the project affect the relationship between higher process capability and project success. There is evidence (Verner and Evanco, 2005) that the experience of the project manager in software development has no association with project success. We aimed to find out whether the intensity of implementing basic project management activities depends on the characteristics of the project, organization and project manager.

In our research, we constructed and evaluated the model of basic project management activities. To see how well the model performs, we evaluated the model in industry. We studied the relationship between the intensity with which the basic project management activities have been implemented in industry projects and the background characteristics of the company, the project and the project manager. Also, the relationship between implementing the basic project management activities and project success was studied. The key success factors that lead to project success have also been described here based on the perspective of project managers.

Next, we describe the answers to the following three questions that this research provided:

1. What defines project success?
2. Which basic project management activities support project success?
3. What affects the intensity of implementing the basic project management activities?

1. What defines project success?

First of all, we describe the findings concerning the project success factors as the overall project success is being used extensively in the study. In our study, project success was described through a number of factors that reflect the areas in (Goldenson and Herbsleb, 1995) – the project's ability to meet budget commitments, ability to meet schedule commitments, ability to achieve customer satisfaction, ability to meet the defined goals, productivity in the project, and the product's ability to satisfy specified requirements. Based on our study, the project managers regarded the overall project success as depending on the project's ability to meet the schedule and budget commitments. Curiously enough, the project's ability to achieve the customer satisfaction and the product's ability to satisfy specified requirements were not important for the overall project success. As stated in (Pinto and Kharbanda, 1995, pp. 11-86), project managers too often make the mistake of believing that if they handle the budget and schedule commitments, the customer will accept the project. In fact, the customer acceptance has to be managed just like any other project aspect.

In (Verner and Evanco, 2003) the practitioners' view on project success is described as consisting of two parts – the personal factors associated with the work and the customer/user factors. Personal factors include a sense of achievement while working on the project, a good job being done, the project work was satisfying, and the project resulting in professional growth. The customer/user factors include whether the customer/user was involved, if they had realistic expectations, and whether the project met all of their requirements.

Based on the explanation given in (Verner and Evanco, 2003), it appears that the project managers were mostly describing the success through their personal factors.

At the same time, the greater interaction between the project manager and the customer supports the growth of customer confidence in the development team. This in turn may result in a greater level of customer involvement throughout the project, leading to customer satisfaction in the end of the project. Also, the project managers' lack of involvement or understanding of the customer requirements could possibly explain the little interest in the product satisfying the specified requirements on the part of the project manager.

It is worrisome that the project managers in this study show so little interest in satisfying the requirements set by the customers. Customer acceptance is necessary during both the initial planning of the project where the product requirements are set as well as the closing of the project in the implementation phase. An important truth of project implementation suggests that one can never talk to customers enough. (Pinto and Kharbanda, 1995, pp.11-86) Communication with the customer should be continuous throughout the evolvement of the project as much can change that alters the customer's perceptions of the product.

2. Which basic project management activities support the project success?

There is evidence from (Jiang et al., 2004) that the basic project management activities of CMMI are not significantly related to project success. We have evaluated the basic project management activities of CMMI Continuous Representation, ISO/IEC IS 15504, PMBoK and other sources of project management literature in 29 industry software projects. The study focused on the intensity of the implementation of these basic project management activities and their relationship to project success.

The only significant relationship between project management activities and project success comes from the project management literature. Directing and managing the people in the project team through motivating and supervising them, and coordinating the interaction between team members were described as the most important project management activities supporting the project success.

There were only few process model practices moderately related to project success. The project management related practices of project planning and estimation selected from process models were the only activities described as important for the project success. The project resource and stakeholder involvement planning, and estimation of project attributes are the prerequisites for good project planning and accurate project estimation, respectively.

These results confirm the findings in (Verner and Evanco, 2005; and Verner and Cerpa, 2005), both of which described the crucial factors of project success through managing the project team in terms of motivating the team members, coordinating the communication of team members and relating well to the team. Similarly to (Pinto and Kharbanda, 1995, pp.11-86) our results illustrate that the behavioural and organizational issues, as opposed to the technical issues, are the primary drivers of project success. (O'Suilleabhain et al., 2000) state that most process improvement experts neglect the reality that human factors, skills and social and teamwork competencies have significant influences on success. This is contrary to the belief of many process people who feel that processes can make the company independent of people. (O'Suilleabhain et al., 2000) Based on the results of this research, process models could also contain best practices about directing and managing people in the project teams.

3. What affects the intensity of implementing the basic project management activities?

There is confusing evidence in literature (Elemam and Birk, 2000; Goldenson and Herbsleb, 1995) on whether the type and size of the organization and of the project affect the relationship between higher process capability and project success. Our research studied the relationship between the type and size of the organization and of the project, and the intensity with which the basic project management activities have been implemented in the projects. We used separately the size of the company and of the software development department in our research. Also, the size of the project consists of various factors – the duration of the project, the size of the development team and the number of the end-users.

No significant relationship was found between the type of the company and of the project, and the intensity of implementing the basic project management activities. At the same time, the results indicate that it is more likely that a company developing new applications implements more of the basic project management activities than the companies maintaining or customizing the packaged software.

Although all types of projects require good project management, the activities defined as the basic project management activities in our study consist of model practices necessary for new product development. They might be too heavy on detail for the projects customizing packaged software or maintaining the software.

Another indicator of project type was studied in the context of implementing the basic project management activities in industry projects. The implementation of basic project management activities were unaffected by the development life cycle model used in the project. Where prototyping development was used in the project, the most time-consuming and demanding activities like measurement- and analysis-related practices were not implemented at all. Also, more demanding practices in requirements management – the tracking of change requests – were not implemented when prototyping or a spiral development model was followed.

We assumed that larger companies located in multiple sites would implement more model practices that allow for easier coordination and management of large projects over the various locations. Contrary to this assumption, our results indicate that the size of the company does not significantly affect the intensity with which the basic project management activities are implemented. At the same time, the larger software development departments implement more basic project management activities than the smaller software development departments. This confirms the findings in (Elemam and Birk, 2000) that showed how the size of the organization affects the relationship between the improvements in software requirements analysis and the productivity of software projects. Similarly to these results, our research indicates that the implementation of basic project management activities is more intense in large software development departments than in small ones.

At the same time, the smaller development teams had fewer conflicts in their teams during the projects, with a more successful product being developed as a result of the project than the larger development teams. This finding supports the sub-division of large projects into smaller projects which are more easily planned and managed by the smaller development teams.

The experience of project manager was also studied in our research where both experience in software development and project management were described. The experience of project manager was not significantly related to project success. Interestingly, a project manager experienced in project management was more likely to lead the project to success than one experienced in software development. This finding is also confirmed in (Verner and Evanco, 2005) suggesting that project managers should have a broad managerial background rather than expertise in any particular technical area.

Most of the basic project management activities studied in this research have been derived from the process models of CMMI Continuous and ISO/IEC IS 15504. It should therefore be obvious that the companies and projects that use software standards and process models are more likely to implement similar project management activities. On the other hand, the model practices should be generic enough for any company that wants to increase process and product quality, to apply them – regardless of the standards used in the project and company.

No significant relationship was found between the usage of standards and the implementation of basic project management activities. There is an indication, however, that companies and projects using process models also implement project management activities related to measurement and analysis, and risk management. Companies that use process models collect measurement data, and communicate and store the measurement results. The projects where standards are used have also established the data measurement analysis procedures and the scope of the project risk management, and defined the risk management strategies. Other than that, the intensity with which the basic project management activities are implemented is not affected by the usage of standards or process models in the company or project. These findings are also supported by the results described in (Verner and Evanco, 2005) where most projects identified risks at the beginning of the project, but only a few controlled the risks throughout the project.

Similarly to the results in (Verner and Evanco, 2005), the activities related to completing the project were not intensively implemented in the projects studied in our research. This suggests that the project managers view each project as a standalone entity and therefore do not perceive the project evaluation upon project completion as important. As long as the causes of failed projects are not analysed, understood and communicated, it is unlikely that the project performance can improve in subsequent projects.

5.3. Future research

This research aimed to discover the relevancy of basic project management activities to industry projects and to the success of these projects. The results show that the basic project management activities are not significantly related to project success. In this research we also studied the relationship between the implementation of basic project management activities and project success.

The model of basic project management activities was constructed in this research, elements derived from process models and various sources of project management literature. The model elements were grouped together using the differentiation of known and unknown factors. Similar grouping of known and unknown factors could be used in other studies where straightforward integration of model elements is not possible.

The model of basic project management activities constructed in this research was evaluated by triangulating the data. Triangulation of data increased the validity of results as the findings of data analysis were confirmed by three different methods. Triangulation allowed better analyses and visualisation of the results in data-intensive research. A similar approach could be used in other studies that involve high-volume data.

The findings of this research could be corroborated by broadening the scope of perspectives under study. Whereas in the current research, only the project manager's perspective was studied, studying also the perspectives of the customers, the developers and the managers on project success and implementation of project activities could give significant additional insight into the topic. Also, to see whether the findings of this study depend on the narrow focus of process improvement or are universal among project managers, additional studies could be conducted to learn more about the project managers' perception of project success.

As was stated a number of times in this research, the data gathering method used in the research did not allow for the generalizability of the results to the entire population. Additional studies should be carried out based on random sampling. In order to get responses to the survey through random sampling however, the survey questionnaire should be shortened, or else an in-depth case study approach could prove to be more suitable for such a research.

Further studies into the software quality related issues, especially the implementation of process model guidance in industry will be carried out in Estonia as a result of a project similar to the SataSPIN project in Finland. The aim of the project is to increase quality awareness in Estonian software industry. As a result of the project, Baltic Software Measurement Association should be re-established, which will continuously provide software quality related know-how to the local software companies.

REFERENCES

Author's publications

Lepasaar M. (2001), *Software Process Improvement in Small Software Organisations – thesis for the degree of Master of Science in Engineering*. Tallinn Technical University, Department of Computer Engineering, Tallinn. 85p.

Lepasaar M., Varkoi T., Jaakkola H. (2001), "Models and success factors of process change". *In the Proceedings of the Product Focused Software Process Improvement*. Kaiserslautern, Germany. Pp. 68-77.

Lepasaar M., Kalja A., Jaakkola H., Varkoi T. (2001a), "Comparing Software Process Improvement in Estonia and Finland". *Baltic IT&T Review: A Business Journal for the Information Society*, no. 3 (22). Pp. 69-74.

Lepasaar M., Mäkinen T., Varkoi T. (2002), "Structural Comparison of SPICE and Continuous CMMI". *In the Proceedings of SPICE 2002*. Venice, Italy. Pp. 223-234.

Lepasaar M. and Mäkinen T. (2002a), "Integrating Software Process Assessment Models using a Process Meta Model". *In the Proceedings of the IEMC 2002*, Volume I. Cambridge, UK. Pp. 224-229.

Lepasaar M. and Mäkinen T. (2002b), "ISO/IEC 15504 Requirements for Compatible Software Process Assessment Models". *In the Proceedings of the EuroSPI 2002*. Nuremberg, Germany. Pp. 189-197.

Lepmets M. (2005), "Factor analysis tables"
http://www.lepmets.com/FactorAnalysis.htm

Other publications

Ahvenjärvi S., Karimaa E., Lepasaar M. (2002), "Juran on Planning for Quality by Joseph M. Juran". Jaakkola H., Lepasaar M., Mäkinen T., Varkoi T. (eds.), *Origins of Quality Management,* No. A40/2002, Tampere University of Technology, Pori. Pp. 50-58.

Andersen N. E., Kensing F., Lundin J., Mathiassen L., Munk-Madsen A., Rasbech M., Sorgaard P. (1990), "Professional Systems Development – experience, ideas and action". *Business Information Technology Series*, Prentice Hall. Pp. 68-83.

Archibald R. D. (1992), *Managing High-Technology Programs and Projects*, 2nd edition, John Wiley & Sons, 1992. Pp. 178-339.

Arent J. (2000), "Transforming Software Organisations with the Capability Maturity Model". *In the Proceedings of the Product Focused Software Process Improvement at PROFES*. Oulu, Finland. Pp. 103-113.

Baskerville R. and Pries-Heje J. (1999), "Knowledge Capability and Maturity in Software Management". *DATA BASE for the advances of Information Systems*, Vol. 30, no. 2 (Spring). Pp.26-43.

Bate R., Shrum S. (1998), *CMM Integration (CMMI) Framework*, Software Engineering Institute.

Business TOP 500 (2000), "TOP 50 Information Technology companies". *In Äripäev,* http://www.aripaev.ee/123/Arvutifirmade_TOP50.htm, 15.10.2000 (In Estonian)

CMMI for Systems Engineering/Software Engineering, (2002), *Continuous Representation CMU/SEI-2002-TR-001, ESC-TR-2002-001,* Version 1.1, CMMI Product Development Team, Software Engineering Institute. 648p.

CMMI for Systems Engineering/Software Engineering, (2002a), *Staged Representation CMU/SEI-2002-TR-002, ESC-TR-2002-002,* Version 1.1, CMMI Product Development Team, Software Engineering Institute. 644p.

Coallier F. and Azuma M. (1998), "Introduction to Software Engineering Standards". El Emam K., Drouin J.-N., and Melo W. (eds.), *SPICE – The Theory and Practice of Software Process Improvement and Capability Determination*. IEEE Computer Society Press, CA. Pp. 1-19

Conger S. (1994), *The New Software Engineering*. Wadsworth Publishing Company. Belmont, California. 816p.

Cooper R. G. (1993), *Winning at New Products*. 2nd edition, Addison-Wesley, Massachusetts. 358p.

Correlation (2005), "Correlation coefficient calculation in theory" - http://www.bized.ac.uk/timeweb/crunching/crunch_relate_expl.htm, 12.05.2005.

Cunningham J. B. (1997), "Case study principles for different types of cases". *Quality & Quantity*, Kluwer Academic Publishers, Netherland. Pp. 401-423.

Dean B. V. (1985), "Project Management: Methods and Studies". *Studies in Management Science and Systems,* Vol.11, Elsevier Science Publishers. Pp.i-xi.

Eklund A., Holmström J., Leppänen V.-J. "Out of Crisis by W. Edwards Deming". Jaakkola H., Lepasaar M., Mäkinen T., Varkoi T. (eds.), *Origins of Quality Management*, No. A40/2002, Tampere University of Technology, Pori. Pp. 1-12.

El Emam K. and Birk A. (2000), "Validating the ISO/IEC 15504 Measure of Software Requirements Analysis Process Capability". *IEEE Transactions on Software Engineering*, Vol. 26, no. 6 (June). Pp. 541-566.

European Commission Innovation Scoreboard (2006), http://europa.eu.int/rapid/pressReleasesAction.do?reference=MEMO/06/5&format=HTML&aged=0&language=EN&guiLanguage=en, 12.01.2006.

European Software Institute, http://www.esi.es, 08.04.2005.

Factor analysis (2005), "factor analysis in theory" - http://www.statsoftinc.com/textbook/stfacan.html, 11.05.2005.

FiSMA (2007), "Finnish Software Metrics Association". http://www.fisma.fi, 20.02.2007.

Fowler F. J. (2002), *Survey research methods*. Sage Publications, California. 192p.

Goldenson D. R. and Herbsleb J. (1995), "After the Appraisal: A Systematic Survey of Process Improvement, Its Benefits, and Factors that Influence Success". *Technical Report CMU/SEI-95-TR-009*. Software Engineering Institute. 66p.

Gupta S. K. and Taube L. R. (1985), "A state of the art survey of research on project management". Dean B. V. (ed.), *Project Management: Methods and Studies, Studies in Management Science and Systems,* Vol. 11, Elsevier Science Publishers. Pp. 298-318.

Hansen B., Rose J., Tjornehoj G. (2004), "Prescription, description, reflection: the shape of the software process improvement field". *International Journal of Information Management*, Vol. 24. Pp. 457-472.

Herbsleb J., Carleton A., Rozum J., Siegel J., Zubrow D. (1994), *Benefits of CMM-Based Software Process Improvement: Initial Results - Technical Report CMU/SEI-94-TR-13 (August)*. Software Engineering Institute. 53p.

Huisman M. (2000), *PhD dissertation on the Deployment of Systems Development Methodologies: A South African Experience*. Potchefstroom University, Potchefstroom, South Africa. 242p.

Humphrey S. W. (1989), *Managing the Software Process*. SEI Series in Software Engineering, Software Engineering Institute. 487p.

Humphrey S. W. (2004), "The Process Bureaucracy". Software Engineering Institute, http://www.sei.cmu.edu/publications/articles/watts-humphrey/process-bureaucracy.html, 12.10.2004.

Hunter R. B. and Thayer R. H. (2001), "Software Process Improvement". *IEEE Computer Society*, CA. Pp. 1-5.

Iivari J. (1991), "A paradigmatic analysis of contemporary schools of IS development". *European Journal of Information Systems*, No 4. Pp. 249-272.

INSPIRE (2000), Estonian Information Technology Society, "INSPIRE programme" http://www.eits.ee/?nav=toimkonnad&text=inspire, 17.08.2000 (In Estonian)

ISO 9000 (2005), *ISO 9000:2005, Quality management systems – fundamentals and vocabulary*, 3rd edition, ISO/IEC TC 176/SC1, 30p.

ISO 9000-3 (2004), *Software Engineering – Guidelines for the Application of ISO 9001:2000 to Computer Software*, 1st edition, ISO/IEC JTC1/SC7, 54p.

ISO 9001 (2000), *International Standard ISO 9001:2000, Quality management systems – Requirements*, 3rd edition, ISO/IEC TC 176/SC2, 23p.

ISO/IEC 12207:1995 Amendment 1 (2002), *Information Technology – Software Life Cycle Processes,* 1st edition, ISO/IEC JTC1/SC7, 53p.

ISO/IEC 12207:1995 Amendment 2 (2004), *Information Technology – Software Life Cycle Processes,* 1st edition, ISO/IEC JTC1/SC7, 8p.

ISO/IEC 15288 (2002), *Systems Engineering – System Life Cycle Processes,* 1st edition, ISO/IEC JTC1/SC7, 62p.

ISO/IEC 15504-1 (2004), *ISO/IEC 15504-1 Information Technology – Process Assessment – Part 1: Concepts and vocabulary*, 1st edition, ISO/IEC JTC1/SC7, 19p.

ISO/IEC 15504-5 (2006), *ISO/IEC 15504-5 Information Technology – Process Assessment – Part 5: An Exemplar Process Assessment Model,* 1st edition, ISO/IEC JTC1/SC7, 162p.

ISO/IEC TR 15504-1 (1998), *ISO/IEC TR 15504-1 Information Technology – Software Process Assessment – Part 1: Concepts and introductory guide*, ISO/IEC JTC1/SC7, 20p.

Iversen J. H. (2000), *Data-driven Intervention in SPI Practice – thesis for the degree of PhD in Computer Science*. Aalborg University, Denmark. 166p.

Jiang J. J., Klein G., Hwang H., Huang J., Hung S. (2004), “An exploration of the relationship between software development process maturity and project performance”. *Information and Management*, Vol. 41. Pp. 279-288.

Jonassen Hass A. M., Johansen J., and Pries-Heje J. (1998). “Does ISO 9001 Increase Software Development Maturity?” *In the 24th EUROMICRO Conference*, Vol. 2. Vesteras, Sweden. Pp. 20860-20867.

Jones C. (1996), “The economics of software process improvement”. *Computer*, Vol. 29, Issue 1 (January). Pp. 95-97.

Juran (2006), “Quality Management”, *Juran Institute*, http://www.juran.com/lower.cfm?article_id=32, 23.10.2006.

Järvinen J. (2000), *Measurement based continuous assessment of software engineering processes – thesis for the degree of PhD*. Technical Research Centre of Finland, Espoo. 119p.

Järvinen P. (2001), *On Research Methods*. Juvenes Print, Tampere, Finland. 190p.

Kalja A. and Oruaas J. (1999), "An Overview of the SPI Activities in Estonia". *In Proceedings of the EuroSPI'99 conference*. Pori, Finland. Pp. 8.41-8.47

Kautz, K. (1998), "Software Process Improvement in Very Small Enterprises: Does It Pay Off?" *Software Process – Improvement and Practice*, no. 4. Pp. 209-226

Keen J. S. (1987), *Managing Systems Development*, 2nd edition, John Wiley & Sons. 398p.

Kerzner H. (2001), *Project Management – a systems approach to planning, scheduling and controlling*, 7th edition. John Wiley & Sons. 1181p.

Kezsbom D. S. and Edward K. A. (2001), *The New Dynamic Project Management: Winning through the Competitive Advantage*, 2nd edition, John Wiley & Sons. 600p.

Kinnula A. (2001), *Software Process Engineering Systems: Models and Industry Cases – thesis for the degree of PhD*. University of Oulu, Finland. 117p.

Klaamann V. (2005) "Eesti IKT sektor 2004", Eesti Infotehnoloogia Liit, 2005. http://www.itl.ee/docs/Sektoriuuring_2004_120106.doc, 02.11.2006 (in Estonian)

Klaamann V. (2006) "Eesti IKT sektor 2005", Infotehnoloogia Avalikus Halduses, Aastaraamat 2006, Riigi Infosüsteemide Osakond. http://www.riso.ee/et/pub/2006it/?mn=46&prnt=42, 10.11.2006 (In Estonian)

Kohonen T. (2000), *Self-Organizing Maps*. 3rd edition, Springer-Verlag, Berlin. 521p.

Komi-Sirviö S. (2004), *Development and Evaluation of Software Process Improvement Methods – thesis for the degree of PhD*. Univeristy of Oulu, Finland. 175p.

Koskela L. and Howell G. (2002), “The underlying theory of project management is obsolete”. *In Proceedings of the PMI Research Conference*. Seattle, USA. Pp. 293-302.

Lamberg I. (2004), “Finnish Software Business in Brief”, Software Business, http://www.swbusiness.fi/portal/cluster_information/what_is_software_business_/, 03.12.2004.

Leppälä K. (1995), *Inside a contract research laboratory: a study of concepts, methods and performance – thesis for the degree of PhD*. Technical Research Centre of Finland, Espoo. 274p.

Lientz B. P. and Rea K. P. (1995). *Project Management for the 21st Century*, 2nd edition. Academic Press. 395p.

Mäkinen T. (2004), *On the modeling of software process assessment – thesis for the degree of licentiate in information technology*. Tampere University of Technology, Pori. 84p.

Nardi P. M. (2003), *Doing survey research: a guide to quantitative methods*. Pearson Education, Boston. 250p.

O’Hara F. (2000), “European Experiences with Software Process Improvement”. *In the Proceedings of International Conference in Software Engineering.* Limerick, Ireland. Pp. 635-640.

O’Suilleabhain G., Jordan M., Messnarz R., Biro M., Street K. (2000), “The Perception of Quality Based on Different Cultural Factors and Value Systems”. *In proceedings of EuroSPI 2000*. Copenhagen, Denmark. Pp. 2-32 – 2-44.

Orlikowski W. J. (2002), “Knowing in practice: Enacting a collective capability in distributed organizing”. *Organization Science 13, No. 3*. Pp. 249-273.

Osmundson J. S. (2003), "Quality Management Metrics for Software Development". *Information and Management*, Vol. 40, no. 8. Pp. 799-812

Paija L. (2000), *ICT Cluster - The Engine of Knowledge-driven growth in Finland*. Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy. (In Finnish) 29p.

Paulk M. C. (1994), *A Comparison of ISO 9001 and the Capability Maturity Model for Software - Technical Report CMU/SEI-94-TR-12*. Software Engineering Institute. 78p.

Paulk M. C. (1998), "Foreword". Zahran S. (ed.), *Software Process Improvement – Practical Guidelines for Business Success*. Addison-Wesley. Pp. xv-xix

Paulk M. C. (1999), "Analyzing the Conceptual Relationship between ISO/IEC 15504 (Software Process Assessment) and the Capability Maturity Model for Software". *In the Proceedings of International Conference on Software Quality*. Cambridge, MA. http://www.telnet.com.tn/Doc/ISO_15504_Maturity_Model_for_Software.pdf 10.12.2000.

Paulk M. C. (2001), "Foreword". Hunter R. B. et al. (eds.), *Software Process Improvement.* IEEE Computer Society Press. Pp. xiii-xv.

Paulk M. C., Weber C., and Chrissis M. B. (1999), "The Capability Maturity Model for Software". *In Elements of Software Process Assessment and Improvement*. IEEE Computer Society Press. Pp. 3-15.

Pinto J. K. and Kharbanda O. P. (1995), *Successful Project Managers – Leading Your Team to Success.* Van Nostrand Reinhold, International Thomson Publishing, NY. 421p.

Porter M. (1985), *Competitive Advantage*. The Free Press. 557p.

Pressman R. S. (1992), *Software Engineering: A Practitioner's Approach.* McGraw-Hill, NY. 793 p.

"Projects in Controlled Environments" (2005), PRINCE2, http://www.prince2.org.uk/web/site/home/home.asp, 21.03.2005.

Project Management Body of Knowledge (2000), *A guide to Project Management Body of Knowledge*. Project Management Institute, Pennsylvania. 209p.

Rout T. P. (1998), "SPICE and the CMM: is the CMM compatible with ISO/IEC 15504?", http://www.sqi.gu.edu.au/~terryr/aquis98.pdf, 17.05.2001.

Rout T. and Tuffley A. (2002), "SPICE and CMMI: Conformance of the CMMI Models to ISO/IEC 15504". *In the Proceedings of SPICE 2002*. Venice, Italy. Pp. 235-244.

Royce W. (1998), *Software Project Management – A Unified Framework.* Addison-Wesley. 406p.

Smith N. J. and Thompson P. A. (1995), "Engineering Project Management Review". Smith N. J. (ed.), *Engineering Project Management*. Blackwell Science. Pp. 293-299.

Software Engineering Institute, http://www.sei.cmu.edu, 27.10.2005

SOM (2005), "Self-Organizing Maps in theory" - http://www.ucl.ac.uk/oncology/MicroCore/HTML_resource/SOM_Intro.htm, 10.12.2005.

SOM Toolbox (1999), Helsinki University of Technology, "The SOM Toolbox version 2". http://www.cis.hut.fi/projects/somtoolbox/, 08.12.2005.

Sommerville I. 2004. *Software Engineering*, 7th edition. Pearson Education. 759p.

SW-CMM. *Capability Maturity Model for Software*, Version 1.1. (1993), Paulk M. C., Curtis B., Chrissis M. B., Weber C. V. (eds.), Technical Report CMU/SEI-93-TR-024, Software Engineering Institute. 91p.

Turner J. R. (1993), *The handbook of project-based management*. McGraw-Hill, London. 540p.

Varkoi T. (2000), *Software Process Improvement Priorities in Small Enterprises – thesis for the degree of Licentiate of Technology*. Tampere University of Technology, Information Technology, Pori, Finland. 47p.

Verner J. M. and Evanco W. M. (2003), “An Investigation into Software Development Process Knowledge”. Aybüke A., Ross J., Claes W., Melika H (eds.), *Managing Software Engineering Knowledge*, Springer-Verlag, Germany. Pp. 29-43.

Verner J. M. and Evanco W. M. (2005), “In-house Software Development: What Project Management Practices Lead to Success.” *IEEE Software* (January/February). Pp. 86-93.

Verner J. M. and Cerpa N. (2005), “Australian Software Development: What Software Project Management Practices Lead to Success?” *In the Proceedings of the Australian Software Engineering Conference*, IEEE Computer Society. Pp. 70-77.

Ward R. P., Fayad M. E., Laitinen M. (2001), “Software Process Improvement in the Small”. In Communications of the ACM, Vol. 44, no. 4 (April). Pp. 105-107.

Wearne S. H. (1995), “Projects and Project Management”. Smith N. J. (ed.), *Engineering Project Management*. Blackwell Science. Pp. 3-12.

Yin R. K. (1989), *Case study research: design and methods*. Sage Publications, Beverly Hills Ca. 166p.

Ylikorpi M. (2005), ”Ohjelmistoala”. *Toimialaraporttissa* 17/2005, KTM:n ja TE-keskusten julkaisu, Edita Publishing OY. 50p. (In Finnish)

Zahran S. 1998. *Software Process Improvement – Practical Guidelines for Business Success.* Addison-Wesley, 443p.

APPENDICES

Appendix 1 provides detailed descriptions of the process models and international standards related to ISO/IEC IS 15504 and CMMI.

Appendix 2 lists the base and generic project management related practices selected from CMMI for the study.

Appendix 3 lists the base practices and generic practice indicators of project management related processes selected from ISO/IEC IS 15504 for the study.

Appendix 4 lists the project management processes described in the PMBoK.

Appendix 5 provides the comprehensive list of the basic project management activities selected for this study from CMMI, ISO/IEC IS 15504, the PMBoK and the project management literature.

Appendix 6 describes the survey questionnaire that was online for the respondents to answer.

Appendix 7 lists the correlation tables, which are referred to in the data analysis subsections of the thesis.

APPENDIX 1 – description of the process models and international standards related to ISO/IEC IS 15504 and CMMI

1. ISO 9000 family of standards

The ISO 9000 family of standards, listed below, has been developed to assist organisations, of all types and sizes, to implement and operate effective quality management systems: (ISO 9000, 2005)

5. ISO 9000 describes fundamentals of quality management systems and specifies terminology for quality management systems;
6. ISO 9001 specifies requirements for quality management systems for use where an organisation's capability to provide products that meet customer and applicable regulatory requirements needs to be demonstrated;
7. ISO 9004 provides guidance on quality management systems, including the processes for continual improvement that contribute to the satisfaction of an organisation's customers and other interested parties;
8. ISO 19011 provides guidance on managing and conducting environmental and quality audits.

The third edition of ISO 9001 (2000), called Quality Management Systems – Requirements, was published in 2000. It promotes the adoption of a process approach when developing, implementing and improving the effectiveness of a quality management system, to enhance customer satisfaction by meeting customer requirements. Process approach means the application of a system of processes within an organisation, together with their identification and interactions of these processes and their management.

The third edition of ISO 9001 (2000) supersedes the earlier editions of 9001, 9002 and 9003 that were published in 1994. ISO 9001 and ISO 9004 have been developed as a consistent pair of quality management system standards designed to complement each other.

ISO 9001 (2000) specifies requirements for a quality management system that can be used for internal application by organisations, or for certification, or for contractual purposes. It focuses on the effectiveness of the quality management system in meeting customer requirements.

ISO 9004:2000 is called Quality Management Systems – Guidelines for Performance Improvements. It gives guidance for the continual improvement of an organisation's overall performance and efficiency, as well as its effectiveness. ISO 9004 is recommended as a guide for organisations whose top management wishes to move beyond the requirements of ISO 9001, in pursuit of continual improvement of performance. ISO 9004 is not intended for certification or for contractual purposes. (ISO 9001, 2000)

The requirements of ISO 9001 are applied in software companies through the guidance of ISO 9000-3 (2004) named Software Engineering – Guidelines for the Application of ISO 9001 to Computer Software. ISO 9000-3 provides guidance of ISO 9001:2000 to the acquisition, supply, development, operation and maintenance of computer software. It identifies issues which should be addressed and is independent of the technology, life cycle models, development processes, sequence of activities, or organisational structure used by an organisation. Organisations with quality management systems for developing, operating or maintaining software based on ISO 9000-3 may choose to use processes from ISO/IEC 12207 Amendment 1 published in 2002 to support or complement the ISO 9001:2000 process model. ISO 9000-3 is not intended to be used as assessment criteria in quality management system registration/certification, the requirements are all in ISO 9001. (ISO 9000-3, 2004)

A study by (Jonassen Hass et al., 1998) suggests that the ISO 9001 certification also leads to improvement of software processes. It is not only the quality system and software quality management that is influenced by an ISO 9001 certification, but other software processes such as project management, testing and resource management are also influenced.

2. CMM for Software

In November 1986, the Software Engineering Institute (SEI), with assistance from the Mitre Corporation, began developing a process maturity framework that would help organizations improve their software processes. This effort was initiated in response to a request to provide the federal government with a method for assessing the maturity of its software contractors. In September 1987, the SEI released a brief description of the process maturity framework and a maturity questionnaire. The SEI intended the maturity questionnaire to provide a simple tool for identifying areas where an organization's software process needed improvement. Unfortunately, maturity questionnaire was too often regarded as "the model" rather than as a vehicle for exploring process maturity issues. (Paulk et al., 1999) After four years of experience with the software process maturity framework and the preliminary version of the maturity questionnaire, the SEI evolved the software process maturity framework into the Capability Maturity Model for Software (SEI, 1993).

The SW-CMM is based on knowledge acquired from software process assessments and extensive feedback form both industry and government. By elaborating the maturity framework, a model has emerged that provides organizations with more effective guidance for establishing process improvement programs. The initial release of the SW-CMM, Version 1.0, was reviewed and used by the software community during 1991 and 1992. (Paulk et al., 1999)

There are three key roles the SW-CMM plays. First, it helps to build an understanding of software process by describing the practices that contribute to a level of process maturity. The second role is to provide a consistent basis for conducting appraisals for software processes. The SW-CMM defines a scale for measuring process maturity, thus allowing an organization to accurately compare its process capability to that of another organization. The SW-CMM's third role is to serve as a blueprint for software process improvement; the SW-CMM can help an organization focus on areas it must address in order to advance to the next level of maturity. (Paulk et al., 1999)

The SW-CMM is organized on into five levels of organizational maturity, where each level represents an evolutionary stage of process capability. Figure A1-1 shows the five levels of the SW-CMM.

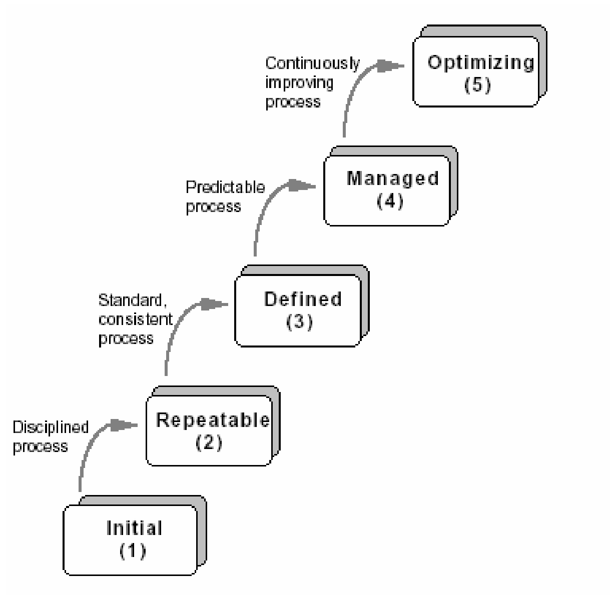


Figure A1-1. Five levels of Software Process Maturity (SEI, 1993)

Each level represents a stage of organizational maturity, described in terms of its "Key Process Area". A key process area is a group of related activities considered to be important for an organization functioning at the appropriate process maturity level. Each key process area is organized into five sections called common features. The common features specify the key practices that, when collectively addressed, accomplish the goals of the key process area. The internal structure of the maturity levels is shown in Figure A1-2.

Besides the Capability Maturity Model for Software, there are several other CMM models described at (SEI, 2005):

1. People Capability Maturity Model (P-CMM) that is designed to allow software organizations to integrate work-force improvement with software process improvement programs guided by SW-CMM.
2. Software Acquisition Capability Maturity Model (SA-CMM) is a model for benchmarking and improving the software acquisition process.

3. Systems Engineering Capability Maturity Model (SE-CMM) describes the essential elements of an organization's systems engineering process that must exist to ensure good systems engineering.
4. Integrated Product Development Capability Maturity Model (IPD-CMM) was developed to guide organizations in IPD design, appraisal and improvement.

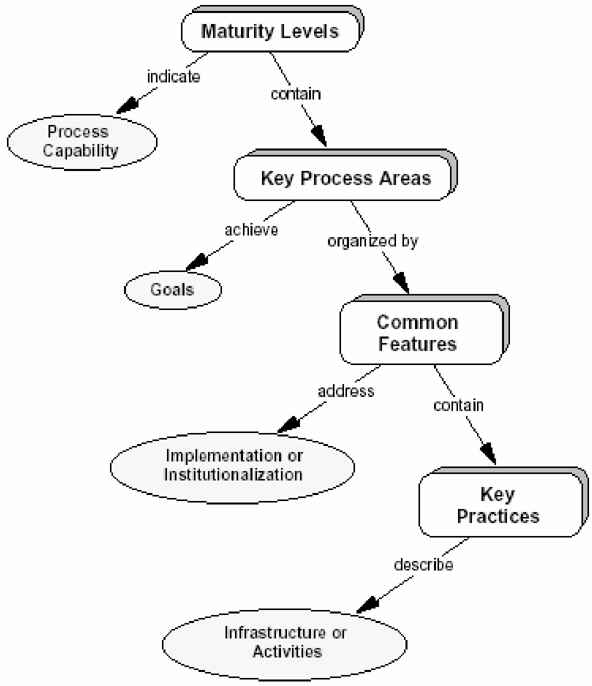


Figure A1-2. Structure of the Capability Maturity Model for Software (SEI, 1993)

In order to combine those models into one enterprise-wide process improvement model, the Capability Maturity Model Integration (SEI, 2002) was developed. It aims to improve organization's processes and its ability to manage the development, acquisition and maintenance of products and services. We describe the CMMI in greater detail later in this section.

The main criticism of CMM is that it has no formal theoretical basis and little empirical support, that it ignores people, reverses the institutionalisation of process for its own sake, and that it introduces an artificial goal (achieving a higher CMM level) in place of the goal of writing better software. The success stories written about the CMM projects define success largely as progress up the CMM levels, whilst consequent benefit to the company's ability to write useful software and to return a profit is left unexamined. It is clear that at least in one particular setting (large

American software companies writing software for defence contractors), CMM has been an extremely successful improvement tool. However, this may be due to extremely close financial relationship between research sponsors, researchers, software vendors and software buyers, as to the quality of the improvement tool. (Hansen et al., 2004)

3. ISO/IEC 15288

This International Standard of ISO/IEC 15288 (2002) is called Systems Engineering – Systems Life Cycle Processes. It provides a common process framework covering the life cycle of manmade systems. This life cycle spans the conception of ideas through to the retirement of a system. It provides the processes for acquiring and supplying system products and services that are configured from one or more of three primary classes of system elements: hardware, software and humans. In addition, this framework provides for the assessment and improvement of the life cycle processes.

The processes in ISO/IEC 15288 (2002) form a comprehensive set from which an organization can construct system life cycle models appropriate to its product and services. An organization, depending on its purpose, can select and apply an appropriate subset to fulfil that purpose.

The life cycle processes of ISO/IEC 15288 (2002) are described in four groups shown in Figure A1-3 below. In addition to the four groups, the tailoring process is also added. The purpose of the tailoring process is to create a life cycle, consisting of stages and processes that are adapted in order to satisfy particular circumstances or factors. (ISO/IEC 15288, 2002)

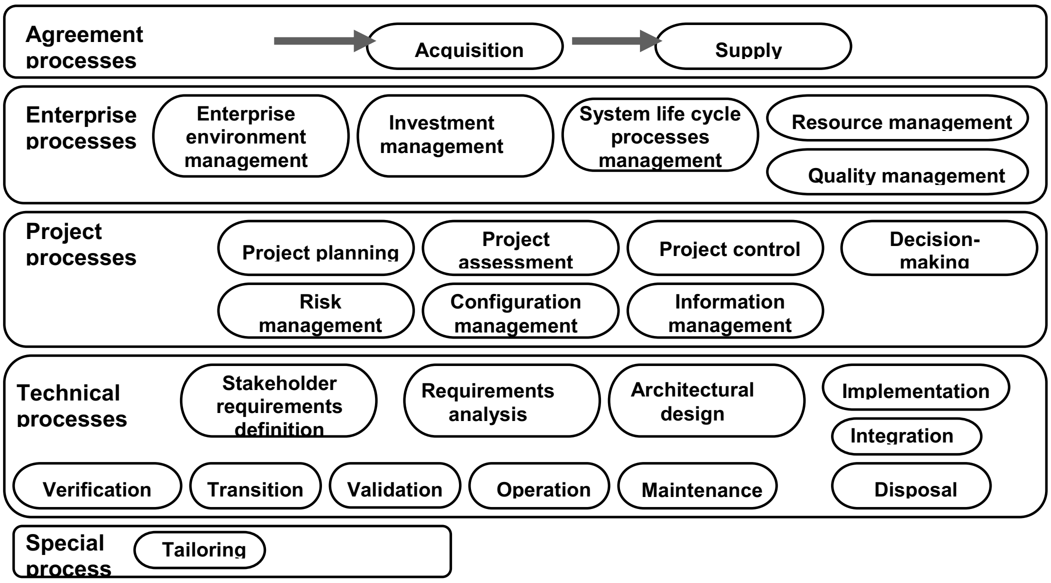


Figure A1-3. The system life cycle process of 15288 (2002)

ISO/IEC 15288 (2002) can be used in one or more of the following modes:

1. By an organization – to help establish an environment of desired processes. These processes can be supported by an infrastructure of methods, procedures, techniques, tools and trained personnel. The organization may then employ this environment to perform and manage its projects and progress systems through their life cycle stages.
2. By an acquirer and a supplier – to help develop an agreement concerning processes and activities. Via the agreement, the processes and activities in 15288 (2002) are selected, agreed to and performed.

4. ISO/IEC 12207

In June 1989, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) initiated the development of an International Standard ISO/IEC 12207 on Software Lifecycle Processes. The international standard was published in August 1995. (Zahran, 1998, pp. 364-365) It is the first international standard to provide a comprehensive set of life cycle processes, activities and tasks for software that is part of a larger system, stand alone software product, and software services. The standard provides common software process architecture for the acquisition, supply, development, operation and maintenance of software. The standard also provides the necessary supporting processes, activities and tasks, and organizational processes, activities and tasks for managing and improving the processes. (ISO/IEC 12207, 2004)

Experience in using ISO/IEC 12207 as the basis for organizations' software life cycle process and in two-party situations, has resulted in some lessons learned and has provided some valuable inputs to the update process. (ISO/IEC 12207, 2002) Amendment 1 was published in 2002 to establish a co-ordinated set of software process information that can be used for process definition and process assessment and improvement. Amendment 1 resolved the granularity issue related to the use of ISO/IEC 12207 for process assessment and provides the process purpose and outcomes to establish a Process Reference Model in accordance with the requirements of ISO/IEC TR 15504-2. A Process Reference Model provides definitions of processes in a life cycle described in terms of process purpose and outcomes, together with an architecture describing relationships between the processes. A Process Reference Model provides the mechanism whereby externally defined assessment models are related to the assessment framework defined by ISO/IEC TR 15504. (ISO/IEC 12207, 2004)

The use of Amendment 1 for process assessment revealed technical defects and editorial issues in certain processes of the Process Reference Model. These defects have impacted the development of the exemplar assessment model ISO/IEC IS 15504-5. ISO 12207 Amendment 2 (2004) resolves these deficiencies and provides to the users of the Process Reference Model and to the developers of assessment models an improved basis for their work.

The substantive part of ISO/IEC 12207:1995 sets out the activities and tasks required to implement the high level life cycle processes to achieve desirable capability for acquirers, suppliers, developers, maintainers and operators of systems containing software. Based on ISO 12207 Amendment 1 (2002) and Amendment 2 (2004) the three life cycle process categories of ISO/IEC 12207:1995, i.e., Organizational, Primary and Supporting described through the Purposes and Outcomes are described in Figure A1-4 below. Within each of the process categories are descriptions in terms of a purpose statement, which comprise unique functional objectives when instantiated in a particular environment. The purpose statement includes additional material identifying the outcomes of successful implementation. (ISO/IEC 12207, 2002)

The standard does not define how, or in what order, the elements of the purpose statements are to be achieved. The outcomes will be achieved in an organization through various detailed practices being carried out to produce work products. These performed practices, and the characteristics of the work products produced, are indicators that demonstrate whether the specific purpose is being achieved. (ISO/IEC 12207, 2002)

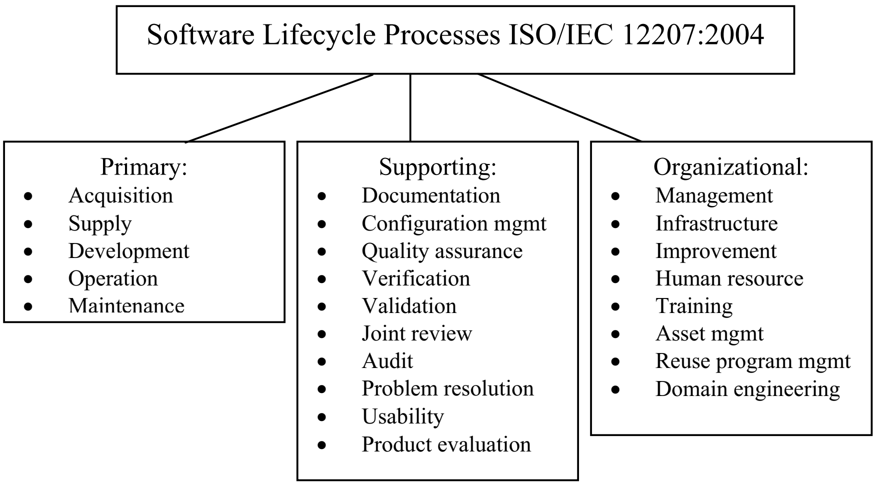


Figure A1-4. ISO/IEC 12207 (2004) Software Lifecycle Processes

The process model does not represent a particular process implementation approach nor does it prescribe a system/software life cycle model, methodology or technique. Instead the reference model is intended to be tailored by an organization based on its business needs and application domain. The organization's defined process is adopted by the organization's projects in the context of the customer requirements. The reference model's purpose and outcomes are indicators that demonstrate whether the organization's processes are being achieved. These indicators are useful to process assessors to determine the capability of the organization's implemented process and to provide source material to plan organizational process improvement. (ISO/IEC 12207, 2002)

APPENDIX 2 – list of base and generic project management related practices selected from CMMI Continuous

The following is the list of the basic project management activities derived from CMMI Continuous for this study.

Specific Project Management related Practices

Project Planning – the purpose is to establish and maintain plans that define project activities:

1. SP 1.1-1 Estimate the scope of the project
2. SP 1.2-1 Establish estimates of work products and task attributes
3. SP 1.3-1 Define project life cycle
4. SP 1.4-1 Determine estimates of effort and cost
5. SP 2.1-1 Establish project budget and schedule
6. SP 2.2-1 Identify project risks
7. SP 2.3-1 Plan for data management
8. SP 2.4-1 Plan for project resources
9. SP 2.5-1 Plan for needed knowledge and skills
10. SP 2.6-1 Plan stakeholder involvement
11. SP 2.7-1 Establish the project plan
12. SP 3.1-1 Review plans that affect the project
13. SP 3.2-1 Reconcile work and resource levels
14. SP 3.3-1 Obtain plan commitment

Project Monitoring and Control – the purpose is to provide an understanding of the project's progress so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan:

15. SP 1.1-1 Monitor project planning parameters
16. SP 1.2-1 Monitor commitments

17. SP 1.3-1 Monitor project risks
18. SP 1.4-1 Monitor data management
19. SP 1.5-1 Monitor stakeholder involvement
20. SP 1.6-1 Conduct progress reviews
21. SP 1.7-1 Conduct milestone reviews
22. SP 2.1-1 Analyse issues
23. SP 2.2-1 Take corrective action
24. SP 2.3-1 Manage corrective action

Requirements Management – the purpose is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products:

25. SP 1.1-1 Obtain an understanding on requirements
26. SP 1.2-1 Obtain commitment to requirements
27. SP 1.3-1 Manage requirements changes
28. SP 1.4-2 Maintain bi-directional traceability of requirements
29. SP 1.5-1 Identify inconsistencies between project work and requirements

Supplier Agreement Management – the purpose is to manage the acquisition of products from suppliers for which there exists a formal agreement:

30. SP 1.2-1 Select suppliers
31. SP 1.3-1 Establish supplier agreements
32. SP 2.3-1 Accept the acquired product

Measurement and Analysis – the purpose is to develop and sustain a measurement capability that is used to support management information needs:

33. SP 1.1-1 Establish Measurement Objectives
34. SP 1.2-1 Specify Measures
35. SP 1.3-1 Specify Data Collection and Storage Procedures
36. SP 1.4-1 Specify Analysis Procedures
37. SP 2.1-1 Collect Measurement Data

38. SP 2.2-1 Analyse Measurement Data
39. SP 2.3-1 Store Data and Results
40. SP 2.4-1 Communicate Results

Configuration Management – the purpose is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits:

41. SP 2.1-1 Track Change Requests
42. SP 1.1-1 Identify Configuration Items
43. SP 1.2-1 Establish a Configuration Management System
44. SP 1.3-1 Create or release baselines
45. SP 2.2-1 Control Configuration Items
46. SP 3.1-1 Establish Configuration Management records
47. SP 3.2-1 Perform Configuration Audits

Generic Project Management Practices

48. GP 1.1 Perform Base Practices;
49. GP 2.1 Establish an Organizational Policy;
50. GP 2.2 Plan the Process;
51. GP 2.3 Provide Resources;
52. GP 2.4 Assign Responsibility;
53. GP 2.5 Train People;
54. GP 2.6 Manage Configurations;
55. GP 2.7 Identify and Involve Relevant Stakeholders;
56. GP 2.8 Monitor and Control the Process;
57. GP 2.9 Objectively Evaluate Adherence;
58. GP 2.10 Review Status with Higher Level Management.

APPENDIX 3 – list of the base practices and generic practice indicators of project management related processes selected from ISO/IEC IS 15504 for the study

Project management and related practices of IS 15504

1. MAN.3.BP1: Define the scope of work
2. MAN.3.BP2: Define project life cycle
3. MAN.3.BP3 Evaluate feasibility of the project
4. MAN.3.BP4: Determine and maintain estimates for project attributes
5. MAN.3.BP5: Define project activities and tasks.
6. MAN.3.BP6: Define needs for experience, knowledge and skills.
7. MAN.3.BP7: Define project schedule.
8. MAN.3.BP8: Identify and monitor project interfaces.
9. MAN.3.BP9: Allocate responsibilities.
10. MAN.3.BP10: Establish project plan.
11. MAN.3.BP11: Implement the project plan.
12. MAN.3.BP12: Monitor project attributes.
13. MAN.3.BP13: Review progress of the project.
14. MAN.3.BP14: Act to correct deviations.

15. ACQ.3.BP1: Negotiate the contract / agreement with the supplier
16. ACQ.3.BP2: Approve contract. The contract is approved by relevant stakeholders
17. ACQ.3.BP3: Award contract. The contract is awarded to the successful proposer/tenderer

18. SPL.1.BP1 Establish communication interface with customer
19. SPL.1.BP2 Perform customer enquiry screening
20. SPL.1.BP3 Establish customer proposal evaluation criteria
21. SPL.1.BP4 Evaluate customer request for proposal
22. SPL.1.BP7 Prepare supplier proposal response
23. SPL.1.BP8 Establish confirmation of agreement

24. CFG.4.BP2 Record the request for change
25. CFG.4.BP3 Record the status of change requests
26. CFG.4.BP5 Assess the impact of the change
27. CFG.4.BP6 Identify the verification and validation activities to be performed for implemented changes
28. CFG.4.BP7 Approve changes before implementation
29. CFG.4.BP8 Schedule the change
30. CFG.4.BP9 Review the implemented change

31. ENG.1.BP1 Obtain customer requirements and requests
32. ENG.1.BP3 Agree on requirements
33. ENG.1.BP4 Establish customer requirements baseline

34. CFG.3.BP4 Investigate and diagnose the cause of the problem
35. CFG.3.BP5 Assess the impact of the problem
36. CFG.3BP6 Execute urgent resolution action, where necessary

37. MAN.5.BP1: Establish risk management scope
38. MAN.5.BP2: Define risk management strategies
39. MAN.5.BP3: Identify risks
40. MAN.5.BP4: Analyze risks
41. MAN.5.BP5: Define and perform risk treatment actions.
42. MAN.5.BP6: Monitor risks
43. MAN.5.BP7: Take corrective action

44. QUA.1.BP4 Identify and record problems and non-conformances
45. QUA.4.BP3 Conduct joint management and technical reviews

Generic practice indicators:

46. GPI 1.1.1 Achieve the process outcomes through the performance of base practices
47. GPI 2.1.1 Identify the objectives for the performance of the process

48. GPI 2.1.2 Plan the performance of the process to fulfill the identified objectives
49. GPI 2.1.3 Monitor and control the performance of the process
50. GPI 2.1.4 Allocate and use resources to perform the process according to plan
51. GPI 2.1.5 Manage the interfaces between involved parties

52. GPI 2.2.1 Define the requirements for the work products
53. GPI 2.2.2 Define the requirements for documentation and control of the work products
54. GPI 2.2.3 Identify, document and control the work products
55. GPI 2.2.4 Review and adjust work products to meet the defined requirements

APPENDIX 4 – list of the project management processes described in the PMBoK

This appendix describes the processes of the PMBoK. The processes are first listed into 9 knowledge areas and then into 5 process groups based on the PMBoK (PMI, 2000).

Project management processes grouped into 9 project management knowledge areas based on the PMBoK.

Project Integration Management:

1. Project Plan Management
2. Project Plan Execution
3. Integrated Change Control

Project Scope Management:

1. Initiation
2. Scope Planning
3. Scope Definition
4. Scope Verification
5. Scope Change Control

Project Time Management:

1. Activity Definition
2. Activity Sequencing
3. Activity Duration Estimating
4. Schedule Development
5. Schedule Control

Project Cost Management:

1. Resource Planning
2. Cost Estimating
3. Cost Budgeting

4. Cost Control

Project Quality Management:

1. Quality Planning
2. Quality Assurance
3. Quality Control

Project Human Resource Management:

1. Organizational Planning
2. Staff Acquisition
3. Team Development

Project Communications Management:

1. Communications Planning
2. Information Distributing
3. Performance Reporting
4. Administrative Closure

Project Risk Management:

1. Risk Management Planning
2. Risk Identification
3. Qualitative Risk Analysis
4. Quantitative Risk Analysis
5. Risk Response Planning
6. Risk Monitoring and Control

Project Procurement Management:

1. Procurement Planning
2. Solicitation Planning
3. Solicitation
4. Source Selection
5. Contract Administration
6. Contract Closeout

Project management processes grouped into 5 project management process groups based on the PMBoK.

Initiating processes:

1. Initiation – part of project scope management

Planning processes:

1. Scope Planning
2. Scope Definition
3. Activity Definition
4. Activity Sequencing
5. Activity Duration Estimating
6. Schedule Development
7. Risk Management Planning
8. Resource Planning
9. Cost Estimating
10. Cost Budgeting
11. Project Plan Development
12. Quality Planning
13. Organizational Planning
14. Staff Acquisition
15. Communications Planning
16. Risk Identification
17. Qualitative Risk Analysis
18. Quantitative Risk Analysis
19. Risk Response Planning
20. Procurement Planning
21. Solicitation Planning

Executing processes:

1. Project Plan Execution
2. Quality Assurance
3. Team Development

4. Information Distribution
5. Solicitation
6. Source Selection
7. Contract Administration

Controlling processes:

1. Integrated Change Control
2. Scope Verification
3. Scope Change Control
4. Schedule Control
5. Cost Control
6. Quality Control
7. Performance Reporting
8. Risk Monitoring and Control

Closing processes:

1. Contract Closeout
2. Administrative Closure

APPENDIX 5 – comprehensive list of the basic project management activities selected for this study from CMMI, ISO/IEC IS 15504, the PMBoK and project management literature

Table A5-1. Basic project management activities from CMMI and ISO/IEC IS 15504

IS 15504	CMMI
Project Management	Project Planning, Monitoring & Control
MAN.3.BP1: Define the scope of work	SP 1.1-1 Estimate the scope of the project
MAN.3.BP2: Define project life cycle	SP 1.3-1 Define project life cycle
MAN.3.BP3 Evaluate feasibility of the project	
MAN.3.BP4: Determine and maintain estimates for project attributes	SP 1.2-1 Establish estimates of work products and task attributes
	SP 1.4-1 Determine estimates of effort and cost
MAN.3.BP7: Define project schedule	SP 2.1-1 Establish project budget and schedule
MAN.3.BP5: Define project activities and tasks	
MAN.3.BP6: Define needs for experience, knowledge and skills	SP 2.5-1 Plan for needed knowledge and skills
	SP 2.4-1 Plan for project resources
	SP 2.3-1 Plan for data management
MAN.3.BP8: Identify and monitor project interfaces	
MAN.3.BP9: Allocate responsibilities	SP 2.6-1 Plan stakeholder involvement
MAN.3.BP10: Establish project plan	SP 2.7-1 Establish the project plan
MAN.3.BP11: Implement the project plan	
	SP 3.1-1 Review plans that affect the project
	SP 3.2-1 Reconcile work and resource levels
	SP 3.3-1 Obtain plan commitment
MAN.3.BP12: Monitor project attributes	SP 1.1-1 Monitor project planning parameters
	SP 1.2-1 Monitor commitments
	SP 1.3-1 Monitor project risks
	SP 1.4-1 Monitor data management
	SP 1.5-1 Monitor stakeholder involvement
MAN.3.BP13: Review progress of the project	SP 1.6-1 Conduct progress reviews
	SP 1.7-1 Conduct milestone reviews
	SP 2.1-1 Analyse issues
MAN.3.BP14: Act to correct deviations	SP 2.2-1 Take corrective action

	SP 2.3-1 Manage corrective action

Change Request Management IS 15504	Configuration Management CMMI
CFG.4.BP2 Record the request for change	
CFG.4.BP3 Record the status of change requests	SP 2.1-1 Track Change Requests
CFG.4.BP5 Assess the impact of the change	
CFG.4.BP6 Identify the verification and validation activities to be performed for implemented changes	
CFG.4.BP7 Approve changes before implementation	
CFG.4.BP8 Schedule the change	
CFG.4.BP9 Review the implemented change	
	SP 1.1-1 Identify Configuration Items
	SP 1.2-1 Establish a configuration management system
	SP 1.3-1 Create or release baselines
	SP 2.2-1 Control Configuration Items
	SP 3.1-1 Establish Configuration Management records
	SP 3.2-1 Perform Configuration Audits

Requirements Elicitation IS 15504	Requirements Management CMMI
ENG.1.BP1 Obtain customer requirements and requests	
	SP 1.1-1 Obtain an understanding on requirements
ENG.1.BP3 Agree on requirements	
	SP 1.2-1 Obtain commitment to requirements
ENG.1.BP4 Establish customer requirements baseline	
	SP 1.3-1 Manage requirements changes
	SP 1.4-2 Maintain bi-directional traceability of requirements
	SP 1.5-1 Identify inconsistencies between project work and requirements

Contract Agreement IS 15504	Supplier Agreement Management CMMI
	SP 1.2-1 Select suppliers

ACQ.3.BP1: Negotiate the contract / agreement with the supplier	SP 1.3-1 Establish supplier agreements
ACQ.3.BP2: Approve contract. The contract is approved by relevant stakeholders	
ACQ.3.BP3: Award contract. The contract is awarded to the successful proposer /tenderer	
	SP 2.3-1 Accept the acquired product

Supplier Tendering IS 15504	
SPL.1.BP1 Establish communication interface with customer	
SPL.1.BP2 Perform customer enquiry screening	
SPL.1.BP3 Establish customer proposal evaluation criteria	
SPL.1.BP4 Evaluate customer request for proposal	
SPL.1.BP7 Prepare supplier proposal response	
SPL.1.BP8 Establish confirmation of agreement	

Problem resolution management IS 15504	
CFG.3.BP4 Investigate and diagnose the cause of the problem	
CFG.3.BP5 Assess the impact of the problem	
CFG.3BP6 Execute urgent resolution action, where necessary	

Risk Management IS 15504	
MAN.5.BP1: Establish risk management scope	
MAN.5.BP2: Define risk management strategies	
MAN.5.BP3: Identify risks	SP 2.2-1 Identify project risks (project planning)
MAN.5.BP4: Analyze risks	
MAN.5.BP5: Define and perform risk treatment actions	
MAN.5.BP6: Monitor risks	
MAN.5.BP7: Take corrective action	

Quality Assurance IS 15504	
QUA.1.BP4 Identify and record problems and non-conformances	

QUA.4.BP3 Conduct joint management and technical reviews	

	Measurement and Analysis CMMI
	SP 1.1-1 Establish Measurement Objectives
	SP 1.2-1 Specify Measures
	SP 1.3-1 Specify Data Collection and Storage Procedures
	SP 1.4-1 Specify Analysis Procedures
	SP 2.1-1 Collect Measurement Data
	SP 2.2-1 Analyse Measurement Data
	SP 2.3-1 Store Data and Results
	SP 2.4-1 Communicate Results

Generic Practice Indicators IS 15504	Generic Practices CMMI
GPI 1.1.1 Achieve the process outcomes	GP 1.1 Perform Base Practices
GPI 2.1.1 Identify the objectives for the performance of the process	
	GP 2.1 Establish an Organizational Policy
GPI 2.1.2 Plan the performance of the process to fulfill the identified objectives	GP 2.2 Plan the Process
	GP 2.4 Assign Responsibility
GPI 2.1.3 Monitor and control the performance of the process	GP 2.8 Monitor and Control the Process
GPI 2.1.4 Allocate and use resources to perform the process according to plan	GP 2.3 Provide Resources
GPI 2.1.5 Manage the interfaces between involved parties	
	GP 2.5 Train People for Performing the Process
	GP 2.6 Manage Configurations
	GP 2.7 Identify and Involve Relevant Stakeholders
	GP 2.9 Objectively Evaluate Adherence
	GP 2.10 Review Status with Higher Level Management
GPI 2.2.1 Define the requirements for the work products	
GPI 2.2.2 Define the requirements for documentation and control of the work products	
GPI 2.2.3 Identify, document and control the	

work products	
GPI 2.2.4 Review and adjust work products to meet the defined requirements	

Project finalizing activities from the PMBoK:	
Information to formalize project completion is gathered and disseminated	
The project is evaluated after closing	
The lessons learned are compiled for future projects	

Project Directing activities from the project management literature:	
Directions are given to the project team	
Supervise the project team	
Motivate the people in the project team	
Coordinate the interactions between the people in the project team	
Explain the reasons behind the decision-making to the project team	
Resolve the conflicts within the project team	

APPENDIX 6– Survey Questionnaire

The survey questionnaire can be divided largely into three sections – background questions (about the company, the project manager and the project), the project success factors, and the project management practices applied in the project.

Background questions

A – Company background information

A1 - What is the core business area of your organization?

Administrative services

Finance/banking/insurance

Software house/software consulting

Manufacturing

Education

Other, please specify

A2 - Is your company situated in various locations/sites either nationally or internationally?

Yes

No

A3 - What is the total number of people employed in your organization (all locations)?

A4 - What is the total number of people employed in software/systems development (at all locations)?

Please indicate what percentage of your IS department's effort are devoted to the following activities?

A5 - Development of new applications

A6 - Systems maintenance and support

A7 - Customization of packaged software products

A8 - What standards/models have been used in the IS development?

ISO 9000 family

ISO 12207

ISO/IEC 15288

ISO/IEC IS 15504

CMMI

Other, please specify

B - Project manager's background information

Please indicate what percentage of your working time is devoted to the following activities in the development projects?

B1 - Project management

B2 - Systems/software analysis

B3 - Systems/software design

B4 - Programming

B5 - Testing

B6 - User training

B7 - Other, please specify

B8 - What is your personal experience in developing systems/software?

Less than 1 year

1-2 years

3-5 years

5-10 years

More than 10 years

B9 - What is your personal experience in project management?

Less than 1 year

1-2 years

3-5 years

5-10 years

More than 10 years

C - Project background information

Please consider one recent successfully completed development project that you managed while answering questions from this point forward:

<u>C1 - Please describe the type of the recent successfully completed development project you managed?</u>

Development of a new system

Enhancement of an existing system

Redesign of an existing system

<u>Please describe the development project you managed?</u>

C2 - Number of staff of the development team (developers and customer's project manager/representative

C3 - Number of end-users/clients of the software product

C4 - Duration of the development project in months

<u>C5 - Please describe the target users of the development project you managed?</u>

In-house clients (same organization)

External clients (different organization)

<u>Did the project you managed follow any life cycle model? You may mark more than one item.</u>

C6 - Phased process – successive phases, i.e. following phase starts at the completion of the prior one

C7 - Prototyping

C8 - Spiral models – successive spirals of analysis, design, prototype implementation, prototype use, evaluation

C9 - Evolutionary development – the system is consciously planned to be delivered incrementally (by subsystems, feature sets, etc.)

C10 - Concurrent development – analysis, design and implementation take place virtually concurrently

C11 - Other life cycle model used, please specify

C12 - What standards/models were used in the development project?

ISO 9000 family

ISO 12207

ISO/IEC 15288

ISO/IEC IS 15504

CMMI

Other, please specify

D - Project success factors

To what extent do you agree with the following statements about the development project you managed?

Totally disagree Totally agree

D1. The project was completed on schedule	1	2	3	4	5
D2. The project was completed within the budget	1	2	3	4	5
D3. The project was accepted by the customers/users	1	2	3	4	5
D4. The project achieved its goals	1	2	3	4	5
D5. The speed of developing the product was high	1	2	3	4	5
D6. The developed product satisfied all the stated requirements	1	2	3	4	5
D7. Overall, the project represented excellent work	1	2	3	4	5
D8. Overall, the developed product was a success	1	2	3	4	5
D9. Overall, the project was a success	1	2	3	4	5

Additional comments:

Project management practices applied in the recent successfully completed development project that you managed

To what extent do you agree with the following statements about the project planning of the development project you managed?

E - Project Planning

Totally disagree Totally agree

E1. The scope of project work was defined	1	2	3	4	5
E2. Project life cycle was defined	1	2	3	4	5
E3. Feasibility of the project was evaluated	1	2	3	4	5
E4. Project activities and tasks were defined	1	2	3	4	5
E5. Needs for experience, knowledge and skills were defined	1	2	3	4	5
E6. Project resources were planned	1	2	3	4	5
E7. Data management (documentation) was planned for	1	2	3	4	5
E8. Project interfaces were identified and monitored	1	2	3	4	5
E9. Stakeholder involvement was planned	1	2	3	4	5
E10. Responsibilities were allocated	1	2	3	4	5
E11. Project plan was established	1	2	3	4	5
E12. Project plan was implemented	1	2	3	4	5
E13. Plans that affect the project were reviewed	1	2	3	4	5
E14. Work and resource levels were reconciled	1	2	3	4	5
E15. Commitment to the plan was obtained	1	2	3	4	5
E16. Overall, the project was well planned	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

F - Project estimation

Totally disagree Totally agree

F1. Project attributes (business goals, size, complexity of the project, etc.) were estimated	1	2	3	4	5
F2. Project quality goals were estimated	1	2	3	4	5
F3. Project effort was estimated	1	2	3	4	5
F4. Project budget was estimated	1	2	3	4	5
F5. Project schedule was defined	1	2	3	4	5
F6. Overall, project was well estimated	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

<u>G - Project Monitoring and Control</u>

Totally disagree Totally agree

G1.Project commitments were monitored:	1	2	3	4	5
G2.Project risks were monitored	1	2	3	4	5
G3.Data management (documentation) was monitored	1	2	3	4	5
G4.Stakeholder involvement was monitored	1	2	3	4	5
G5.Project interfaces were monitored	1	2	3	4	5
G6.Project progress was reviewed	1	2	3	4	5
G7.Milestone reviews were conducted	1	2	3	4	5
G8.Issues in the project were analysed	1	2	3	4	5
G9.Deviations from plans were corrected and managed	1	2	3	4	5
G10. Overall, project was well monitored and controlled	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

<u>H - Requirements Management</u>

Totally disagree Totally agree

H1.Customer requirements and requests were obtained	1	2	3	4	5
H2.An understanding on requirements was obtained	1	2	3	4	5
H3.Requirements were agreed on	1	2	3	4	5
H4.Commitment to requirements was obtained	1	2	3	4	5
H5.Customer requirements baseline was established	1	2	3	4	5
H6.Requirements changes were managed	1	2	3	4	5
H7.Bi-directional traceability of requirements was maintained (requirements are traceable from customer requests to code and also backwards)	1	2	3	4	5

H8. Inconsistencies between project work and customer requirements was identified	1	2	3	4	5
H9. Overall, the requirements were well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

I - Supplier Tendering

	Totally disagree				Totally agree
I1. Communication interface with customer was established	1	2	3	4	5
I2. Customer enquiry screening was performed	1	2	3	4	5
I3. Customer proposal evaluation criteria was established	1	2	3	4	5
I4. Customer request for proposal was evaluated	1	2	3	4	5
I5. Supplier proposal response was prepared	1	2	3	4	5
I6. Confirmation of agreement was established	1	2	3	4	5
I7. Overall, supplier tendering was well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

J - Change Request and Configuration Management

	Totally disagree				Totally agree
J1. The customer request for change was recorded	1	2	3	4	5
J2. Status of change requests was tracked	1	2	3	4	5
J3. The impact of the change was assessed	1	2	3	4	5
J4. Prior to implementing changes, the verification and validation activities were identified	1	2	3	4	5
J5. Changes before implementation were approved	1	2	3	4	5
J6. Changes were scheduled	1	2	3	4	5
J7. Implemented changes were reviewed	1	2	3	4	5

J8. The configuration items, components, and related work products to be placed under configuration management were identified	1	2	3	4	5
J9. Configuration management and change management system for controlling the work products was established	1	2	3	4	5
J10. The baseline for internal use and for the customer were created and released	1	2	3	4	5
J11. Configuration items were controlled	1	2	3	4	5
J12. Records describing the configuration items were established and maintained	1	2	3	4	5
J13. Configuration audits were performed to maintain integrity of the configuration baselines	1	2	3	4	5
J14. Overall, change requests were well managed	1	2	3	4	5
J15. Overall, configurations were well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

<u>K - Supplier Agreement Management/ Contract Agreement</u>

Product or product component acquired from the supplier were delivered to the project customer? Yes / No (please proceed to the next question)

Totally disagree Totally agree

K1. Suppliers were selected	1	2	3	4	5
K2. Supplier agreement/contract was negotiated with the supplier	1	2	3	4	5
K3. Supplier contract was approved by relevant stakeholders	1	2	3	4	5
K4. Contract was awarded to the successful tenderer	1	2	3	4	5
K5. Acquired product was accepted	1	2	3	4	5
K6. Overall, supplier agreement was well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

L - Risk Management

Totally disagree Totally agree

L1. The risk management scope was established	1	2	3	4	5
L2. The risk management strategies were defined	1	2	3	4	5
L3. The risks were identified	1	2	3	4	5
L4. The risks were analysed	1	2	3	4	5
L5. The risk treatment actions were defined and performed	1	2	3	4	5
L6. The risks were monitored	1	2	3	4	5
L7. Corrective action was taken, when needed	1	2	3	4	5
L8. Overall, project risks were well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

M - Problem Resolution Management

Were there any problems/issues that were dealt with during the project? Yes / No (please proceed to the next question)

Totally disagree Totally agree

M1. The cause of a problem was investigated and diagnosed	1	2	3	4	5
M2. Impact of the problem was assessed	1	2	3	4	5
M3. Urgent resolution action was executed when necessary	1	2	3	4	5
M4. Overall, problem resolution was well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

N - Quality Assurance

	Totally disagree				Totally agree
N1. The problems and non-conformances of the developed product were identified and recorded	1	2	3	4	5
N2. Joint management and technical reviews were conducted	1	2	3	4	5
N3. Overall, product quality was well assured	1	2	3	4	5
N4. Overall, process quality was well assured	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

O - Measurement and Analysis

	Totally disagree				Totally agree
O1. Project measurement objectives were established	1	2	3	4	5
O2. The project measures that address the measurement objectives were specified	1	2	3	4	5
O3. The measurement data collection and storage procedures were specified	1	2	3	4	5
O4. The analysis procedures of measurement data were specified	1	2	3	4	5
O5. The measurement data was collected	1	2	3	4	5
O6. The measurement data was analysed	1	2	3	4	5
O7. The measurement data and results were stored	1	2	3	4	5
O8. The measurement results were communicated	1	2	3	4	5
O9. Overall, the project data was well measured and analysed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

P - Project directing

Totally disagree Totally agree

P1. Project staff committed to the directions given to them	1	2	3	4	5
P2. Project staff responded well to supervision	1	2	3	4	5
P3. People in the project were motivated	1	2	3	4	5
P4. Project staff interaction was well coordinated	1	2	3	4	5
P5. Reasons behind the decision-making were understood by the project staff	1	2	3	4	5
P6. Conflicts within the project team did not emerge	1	2	3	4	5
P7. Overall, the project was carried out in a positive teamwork environment	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

Q - Process performance management

Totally disagree Totally agree

Q1. Project management base practices were performed and the process outcomes achieved	1	2	3	4	5
Q2. Objectives for the performance of the project management process were identified	1	2	3	4	5
Q3. An organizational policy was established	1	2	3	4	5
Q4. The project management process was planned to fulfil the identified objectives	1	2	3	4	5
Q5. Responsibility for the project management process was assigned	1	2	3	4	5
Q6. The performance of the project management process was monitored and control	1	2	3	4	5
Q7. Resources to perform the project management process were allocated and used	1	2	3	4	5
Q8. Interfaces between involved parties were managed	1	2	3	4	5
Q9. People were trained for performing the project management process	1	2	3	4	5

Q10. Configurations were managed	1	2	3	4	5
Q11. Relevant stakeholders of project management were identified and involved	1	2	3	4	5
Q12. Adherence was objectively evaluated	1	2	3	4	5
Q13. Status of project management activities was reviewed with the higher-level management	1	2	3	4	5
Q14. Overall, process performance was well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

<u>R - Management of process outcomes/work products</u>

Totally disagree Totally agree

R1. The requirements for the project management work products were defined	1	2	3	4	5
R2. The requirements for project management documentation and control of the work products were defined	1	2	3	4	5
R3. The work products were identified, documented and controlled	1	2	3	4	5
R4. The work products were reviewed and adjusted to meet the defined requirements	1	2	3	4	5
R5. Overall, the process work products were well managed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

<u>S - Project completion</u>

Totally disagree Totally agree

S1. Information to formalise the project completion was	1	2	3	4	5

gathered and disseminated					
S2. The project was evaluated after closing	1	2	3	4	5
S3. The lessons learned were compiled for the future projects	1	2	3	4	5
S4. Overall, the project was well completed	1	2	3	4	5

Additional practices:

…………………………………………………………..	1	2	3	4	5
…………………………………………………………..	1	2	3	4	5

APPENDIX 7 – Correlation Tables

Table A7-1. Correlation between the type of a project and model practices

Correlation between type of project (C1) and model practices (E-S)

	variable	**C1**
model practices:		**correlation coefficient**
scope defined	E1	-0.08
lifecycle defined	E2	0.04
feasibility evaluated	E3	-0.18
tasks defined	E4	-0.24
needs for experience defined	E5	-0.15
project resources planned	E6	-0.05
data management planned	E7	-0.08
project interfaces identified	E8	0.18
stakeholder involvement planned	E9	-0.25
responsibilities allocated	E10	-0.29
project plan was implemented	E11	0.09
plans that affect project were reviewed	E12	-0.07
work and resource levels reconciled	E13	-0.17
commitments to plan obtained	E14	-0.55
the project was well planned	E15	-0.08
effort was estimated	F3	-0.10
budget was estimated	F4	-0.28
schedule was estimated	F5	0.05
the project was accurately estimated	F6	-0.26
project commitments were monitored	G1	-0.09
project risks were monitored	G2	-0.33
data management were monitored	G3	-0.15
stakeholder involvement was monitored	G4	-0.10
project interfaces were monitored	G5	0.02
project progress was reviewed	G6	-0.34
milestone reviews were conducted	G7	-0.09
issues in project were analysed	G8	-0.37
deviations from plans corrected and managed	G9	-0.33
the project was well monitored and controlled	G10	-0.28
customer requirements were obtained	H1	-0.27
understanding on requirements was obtained	H2	-0.24
requirements were agreed on	H3	-0.07
commitments to requirements were obtained	H4	-0.28
customer requirement baseline established	H5	-0.16
requirement changes were managed	H6	-0.08
bi-directional traceability established	H7	-0.08
inconsistencies bw project work and req identified	H8	-0.03

the requirements were well managed	H9	-0.15
communication interface was established	I1	-0.17
customer inquiry screening performed	I2	-0.02
customer proposal evaluation criteria established	I3	0.08
customer request for proposal was evaluated	I4	0.12
supplier proposal response was prepared	I5	0.03
confirmation of agreement established	I6	-0.02
the supplier tendering was well managed	I7	0.00
Customer request for change recorded	J1	0.20
model practices:	**variable**	**C1**
status of change requests tracked	J2	0.18
impact of change assessed	J3	0.07
change verification and validation id-d	J4	0.13
changes approved before implementation	J5	0.14
changes were scheduled	J6	0.00
implemented changes reviewed	J7	0.04
items to be placed under CM identified	J8	0.09
CM and change mgmt systems established	J9	0.08
baselines were created	J10	0.18
changes to conf items were controlled	J11	0.18
records describing conf items established	J12	0.16
configuration audits performed	J13	0.04
the change requests were well managed	J14	0.03
the configurations were well managed	J15	-0.08
Applicable	K1	-0.15
suppliers were selected	K2	-0.19
supplier agreement negotiated with supplier	K3	-0.27
supplier contract approved by relevant stakeholders	K4	-0.30
contract awarded to successful tenderer	K5	-0.21
acquired product was accepted	K6	-0.24
the supplier agreement was well managed	K7	-0.21
risk mgmt scope established	L1	-0.18
risk mgmt strategies defined	L2	-0.24
risks identified	L3	0.09
risks analysed	L4	-0.02
risk treatment actions defined and performed	L5	-0.16
risks monitored	L6	-0.30
corrective actions taken when needed	L7	-0.04
the project's risks were well managed	L8	-0.13
Applicable	M1	-0.09
cause of problem investigated	M2	-0.25
impact of problem assessed	M3	-0.27
resolution action executed	M4	-0.26
the problem resolution was well managed	M5	-0.31

problems of developed product identified	N1	-0.31
joint mgmt and technical reviews conducted	N2	-0.11
product quality was well assured	N3	-0.28
process quality was well assured	N4	-0.31
project measurement objectives established	O1	0.00
project's measures specified	O2	0.15
measurement data collection procedures specified	O3	0.22
analysis procedures specified	O4	0.11
measurement data collected	O5	0.24
measurement data analysed	O6	0.13
measurement data and results were stored	O7	0.29
measurement results communicated	O8	0.00
the project data was well measured and analysed	O9	0.19
project's staff committed to directions	P1	-0.21
project's staff responded well to supervision	P2	-0.08
people in the project were motivated	P3	-0.31
project's staff interaction was well coordinated	P4	-0.35
reasons of decision-making understood by staff	P5	-0.36
conflicts in project team didn't emerge	P6	-0.28
model practices:	**variable**	**C1**
the project was carried out in positive environment	P7	-0.36
base practices were performed	Q1	-0.14
objectives for performance identified	Q2	0.13
organisational policy established	Q3	0.13
process planned to fulfil identified objectives	Q4	0.17
responsibility for the process assigned	Q5	-0.27
performance of process monitored and controlled	Q6	-0.16
resources to perform process allocated and used	Q7	-0.36
interfaces between involved parties were managed	Q8	-0.18
people trained to perform process	Q9	-0.23
relevant stakeholders identified and involved	Q10	-0.22
adherence evaluated	Q11	0.14
status of process activities reviewed w mgmt	Q12	-0.12
the process performance was well managed	Q13	-0.06
requirements for WPs defined	R1	-0.04
requirements for documentation of WPs defined	R2	-0.04
WPs identified, documented and controlled	R3	-0.01
WPs reviewed and adjusted to meet defined req-s	R4	-0.16
the process work products were well managed	R5	-0.07
information to formalise project end gathered	S1	-0.01
project evaluated after closing	S2	-0.04
lessons learned were compiled for future projects	S3	-0.10
the project was well completed	S4	-0.01

Table A7-2. Correlation coefficient between the type of a company (A5, A6, A7) and model practices (E-S)

Correlation between type of company (A5-A7) and model practices (E-S)

model practices:	**variable**	A5	A6	A7
scope defined	E1	-0.24	0.04	0.09
lifecycle defined	E2	-0.17	-0.22	0.27
feasibility evaluated	E3	0.07	-0.38	0.25
tasks defined	E4	0.06	-0.26	0.08
needs for experience defined	E5	0.15	-0.49	0.13
project resources planned	E6	-0.12	-0.04	0.05
data management planned	E7	0.04	-0.17	-0.08
project interfaces identified	E8	-0.01	-0.18	0.11
stakeholder involvement planned	E9	0.16	-0.37	0.07
responsibilities allocated	E10	0.26	-0.25	-0.03
project plan was implemented	E11	-0.07	-0.06	-0.02
plans that affect project were reviewed	E12	0.07	-0.03	0.10
work and resource levels reconciled	E13	0.22	-0.42	0.15
commitments to plan obtained	E14	0.19	-0.41	0.01
the project was well planned	E15	0.26	-0.29	0.09
project attribute's were estimated	F1	-0.01	-0.12	0.15
effort was estimated	F3	0.34	-0.40	-0.10
budget was estimated	F4	0.38	-0.24	-0.19
schedule was estimated	F5	-0.02	-0.13	-0.08
the project was accurately estimated	F6	0.03	-0.32	0.23
project commitments were monitored	G1	0.02	-0.18	0.07
project risks were monitored	G2	0.16	-0.41	0.21
data management were monitored	G3	0.01	-0.37	0.19
stakeholder involvement was monitored	G4	0.08	-0.33	0.27
project interfaces were monitored	G5	-0.04	-0.11	0.17
project progress was reviewed	G6	0.36	-0.48	0.05
milestone reviews were conducted	G7	0.12	-0.31	0.20
issues in project were analysed	G8	0.27	-0.55	0.12
deviations from plans corrected and managed	G9	0.24	-0.39	0.13
the project was well monitored and controlled	G10	0.30	-0.44	0.16
customer requirements were obtained	H1	0.46	-0.43	-0.01
understanding on requirements was obtained	H2	0.38	-0.26	0.04
requirements were agreed on	H3	0.18	-0.04	0.15
commitments to requirements were obtained	H4	0.16	-0.26	0.14
customer requirement baseline established	H5	0.13	-0.47	0.30
requirement changes were managed	H6	0.33	-0.35	0.14
bi-directional traceability established	H7	0.14	-0.23	0.29
inconsistencies bw project work and req identified	H8	0.31	-0.32	0.03
the requirements were well managed	H9	0.24	-0.21	0.09
communication interface was established	I1	0.43	-0.29	0.00

customer inquiry screening performed	I2	0.09	-0.05	0.25
customer proposal evaluation criteria established	I3	0.05	-0.02	0.19
customer request for proposal was evaluated	I4	0.22	-0.10	0.14
supplier proposal response was prepared	I5	0.19	-0.12	0.17
confirmation of agreement established	I6	0.24	-0.09	0.13
the supplier tendering was well managed	I7	0.28	-0.19	0.14
Customer request for change recorded	J1	0.16	0.10	0.15
status of change requests tracked	J2	0.05	-0.02	0.22
impact of change assessed	J3	0.13	0.01	0.24
model practices:	**variable**	A5	A6	A7
change verification and validation id-d	J4	-0.01	-0.04	0.32
changes approved before implementation	J5	0.15	0.03	0.12
changes were scheduled	J6	0.18	0.08	0.11
implemented changes reviewed	J7	0.20	-0.10	0.26
items to be placed under CM identified	J8	0.14	0.03	-0.03
CM and change mgmt systems established	J9	0.03	0.07	0.05
baselines were created	J10	-0.15	0.10	0.15
changes to conf items were controlled	J11	0.13	-0.10	0.11
records describing conf items established	J12	0.02	-0.10	0.32
configuration audits performed	J13	-0.12	-0.01	0.39
the change requests were well managed	J14	0.19	-0.17	0.04
the configurations were well managed	J15	0.13	-0.20	0.05
Applicable	K1	-0.06	0.13	0.16
suppliers were selected	K2	-0.09	0.13	0.20
supplier agreement negotiated with supplier	K3	0.06	-0.07	0.17
supplier contract approved by relevant stakeholders	K4	0.02	-0.03	0.20
contract awarded to successful tenderer	K5	-0.06	0.04	0.20
acquired product was accepted	K6	0.00	0.00	0.19
the supplier agreement was well managed	K7	-0.03	0.04	0.20
risk mgmt scope established	L1	0.08	-0.18	0.28
risk mgmt strategies defined	L2	0.08	-0.05	0.20
risks identified	L3	0.08	-0.08	0.20
risks analysed	L4	0.26	-0.26	0.19
risk treatment actions defined and performed	L5	0.12	-0.22	0.33
risks monitored	L6	0.21	-0.30	0.30
corrective actions taken when needed	L7	0.12	-0.20	0.24
the project's risks were well managed	L8	0.19	-0.30	0.24
Applicable	M1	0.20	0.17	-0.10
cause of problem investigated	M2	0.30	0.04	-0.08
impact of problem assessed	M3	0.30	0.03	-0.07
resolution action executed	M4	0.28	0.00	-0.02
the problem resolution was well managed	M5	0.31	-0.03	-0.02
problems of developed product identified	N1	0.23	-0.30	0.12
joint mgmt and technical reviews conducted	N2	0.10	-0.17	0.24

product quality was well assured	N3	0.21	-0.41	0.19
process quality was well assured	N4	0.18	-0.26	0.26
project measurement objectives established	O1	0.24	-0.26	0.08
project's measures specified	O2	0.10	-0.07	0.12
measurement data collection procedures specified	O3	0.04	-0.04	0.22
analysis procedures specified	O4	-0.03	0.00	0.20
measurement data collected	O5	0.08	-0.07	0.09
measurement data analysed	O6	0.23	-0.33	0.16
measurement data and results were stored	O7	0.07	-0.16	0.15
measurement results communicated	O8	0.30	-0.41	0.17
the project data was well measured and analysed	O9	0.16	-0.21	0.17
project's staff committed to directions	P1	0.19	-0.03	-0.28
project's staff responded well to supervision	P2	0.06	-0.09	-0.07
people in the project were motivated	P3	0.44	-0.53	-0.16
project's staff interaction was well coordinated	P4	0.33	-0.39	-0.04
reasons of decision-making understood by staff	P5	0.31	-0.48	0.07
conflicts in project team didn't emerge	P6	-0.03	-0.16	0.00
the project was carried out in positive environment	P7	0.23	-0.25	-0.09
base practices were performed	Q1	-0.22	-0.10	0.21
model practices:	**variable**	A5	A6	A7
objectives for performance identified	Q2	-0.11	0.03	0.22
organisational policy established	Q3	-0.16	0.08	0.26
process planned to fulfil identified objectives	Q4	-0.19	0.17	0.23
responsibility for the process assigned	Q5	0.24	-0.20	-0.03
performance of process monitored and controlled	Q6	0.31	-0.42	0.29
resources to perform process allocated and used	Q7	0.18	-0.36	0.18
interfaces between involved parties were managed	Q8	0.15	-0.29	0.26
people trained to perform process	Q9	0.17	-0.02	0.08
relevant stakeholders identified and involved	Q10	0.27	-0.39	0.08
adherence evaluated	Q11	0.12	-0.03	0.22
status of process activities reviewed w mgmt	Q12	0.17	-0.34	0.17
the process performance was well managed	Q13	0.25	-0.27	0.20
requirements for WPs defined	R1	0.24	-0.26	0.19
requirements for documentation of WPs defined	R2	0.17	-0.16	0.18
WPs identified, documented and controlled	R3	0.11	-0.27	0.01
WPs reviewed and adjusted to meet defined req-s	R4	0.23	-0.51	0.06
the process work products were well managed	R5	0.11	-0.28	0.06
information to formalise project end gathered	S1	0.22	-0.30	0.20
project evaluated after closing	S2	0.13	-0.13	0.24
lessons learned were compiled for future projects	S3	0.19	-0.31	0.30
the project was well completed	S4	0.23	-0.22	0.25

Table A7-3. Correlation coefficients between the size of the project/company and model practices

Correlation between the size of the company and project with the process model practices

model practices:	**variable**	A3	A4	C2	C3	C4
scope defined	E1	-0.04	-0.21	-0.16	-0.16	-0.12
lifecycle defined	E2	-0.20	-0.25	-0.08	-0.06	-0.17
feasibility evaluated	E3	-0.09	-0.01	-0.14	0.13	-0.32
tasks defined	E4	0.07	0.16	-0.17	-0.35	-0.25
needs for experience defined	E5	-0.02	-0.01	-0.27	-0.04	-0.24
project resources planned	E6	-0.13	0.13	-0.22	-0.25	-0.49
data management planned	E7	-0.04	0.32	0.12	-0.15	-0.44
project interfaces identified	E8	0.28	0.21	-0.17	0.04	-0.47
stakeholder involvement planned	E9	-0.32	0.09	-0.08	0.05	-0.11
responsibilities allocated	E10	0.08	0.29	0.05	-0.09	-0.40
project plan was implemented	E11	0.19	0.28	0.15	-0.16	-0.27
plans that affect project were reviewed	E12	0.07	0.06	0.09	-0.02	-0.34
work and resource levels reconciled	E13	0.06	0.04	-0.06	0.16	-0.23
commitments to plan obtained	E14	-0.02	0.17	-0.10	-0.48	-0.36
the project was well planned	E15	-0.20	0.20	-0.01	0.02	-0.02
project attribute's were estimated	F1	-0.26	-0.01	0.03	0.19	-0.07
effort was estimated	F3	-0.05	0.14	-0.02	0.11	-0.04
budget was estimated	F4	0.23	0.27	0.33	0.17	0.03
schedule was estimated	F5	0.33	0.45	-0.07	-0.03	-0.70
the project was accurately estimated	F6	-0.28	-0.10	-0.18	-0.05	-0.11
project commitments were monitored	G1	0.16	0.17	-0.09	-0.15	-0.56
project risks were monitored	G2	0.00	0.05	0.02	0.07	-0.37
data management were monitored	G3	0.12	0.06	-0.11	0.02	-0.45
stakeholder involvement was monitored	G4	-0.06	0.23	0.02	0.07	-0.19
project interfaces were monitored	G5	0.17	0.27	-0.06	0.18	-0.44
project progress was reviewed	G6	0.09	0.25	-0.06	0.25	-0.25
milestone reviews were conducted	G7	0.04	0.17	0.16	0.09	-0.23
issues in project were analysed	G8	-0.09	0.04	-0.23	0.07	-0.27
deviations from plans corrected and managed	G9	0.06	0.24	0.10	-0.02	-0.28
the project was well monitored and controlled	G10	0.00	0.28	-0.04	0.06	-0.33
customer requirements were obtained	H1	0.04	-0.08	-0.25	0.22	-0.16
understanding on requirements was obtained	H2	-0.15	-0.09	-0.16	0.25	-0.02
requirements were agreed on	H3	0.06	0.05	-0.07	0.10	-0.17
commitments to requirements were obtained	H4	-0.04	0.06	-0.10	-0.24	-0.33
customer requirement baseline established	H5	-0.11	-0.01	-0.01	0.12	-0.24
requirement changes were managed	H6	0.32	0.34	0.00	0.21	-0.21
bi-directional traceability established	H7	0.20	0.16	0.06	0.02	0.11
inconsistencies bw project work and req identified	H8	-0.14	0.14	-0.03	0.35	0.19
the requirements were well managed	H9	-0.12	0.15	0.04	-0.03	0.00

communication interface was established	I1	0.13	-0.07	-0.16	0.26	-0.16
customer inquiry screening performed	I2	0.07	-0.18	-0.14	-0.10	-0.14
customer proposal evaluation criteria established	I3	0.39	0.32	-0.06	0.03	-0.15
customer request for proposal was evaluated	I4	0.26	0.19	0.05	0.12	-0.30
supplier proposal response was prepared	I5	0.22	0.07	-0.04	-0.06	-0.16
confirmation of agreement established	I6	0.31	0.14	-0.01	0.28	-0.26
the supplier tendering was well managed	I7	0.16	0.01	-0.11	0.08	-0.18
Customer request for change recorded	J1	0.34	0.34	0.30	0.45	0.25
status of change requests tracked	J2	0.45	0.44	0.26	0.15	-0.11
model practices:	**variable**	A3	A4	C2	C3	C4
impact of change assessed	J3	0.23	0.25	0.16	0.37	0.05
change verification and validation id-d	J4	0.14	0.28	0.13	0.31	0.07
changes approved before implementation	J5	0.24	0.44	0.14	0.33	0.02
changes were scheduled	J6	0.19	0.33	0.16	0.30	-0.02
implemented changes reviewed	J7	0.14	0.09	0.25	0.34	0.15
items to be placed under CM identified	J8	0.20	0.27	-0.25	0.12	-0.22
CM and change mgmt systems established	J9	0.10	0.26	-0.15	-0.13	-0.21
baselines were created	J10	0.03	0.12	-0.28	-0.22	-0.11
changes to conf items were controlled	J11	0.25	0.34	-0.04	0.27	0.01
records describing conf items established	J12	0.15	0.07	0.03	0.23	0.02
configuration audits performed	J13	0.04	-0.04	0.02	0.10	0.08
the change requests were well managed	J14	0.19	0.37	-0.13	-0.06	-0.15
the configurations were well managed	J15	-0.02	0.12	-0.35	-0.16	-0.25
Applicable	K1	0.30	0.03	0.47	0.17	0.10
suppliers were selected	K2	0.29	-0.05	0.50	0.18	0.07
supplier agreement negotiated with supplier	K3	0.20	-0.18	0.36	0.26	0.12
supplier contract approved by relevant stakeholders	K4	0.23	-0.13	0.38	0.26	0.04
contract awarded to successful tenderer	K5	0.22	-0.19	0.27	0.20	0.08
acquired product was accepted	K6	0.25	-0.13	0.40	0.25	0.08
the supplier agreement was well managed	K7	0.24	-0.13	0.39	0.21	0.09
risk mgmt scope established	L1	0.28	0.19	0.17	-0.12	-0.07
risk mgmt strategies defined	L2	0.44	0.33	0.30	0.01	-0.14
risks identified	L3	0.42	0.28	0.15	0.17	-0.23
risks analysed	L4	0.35	0.23	0.16	0.20	-0.17
risk treatment actions defined and performed	L5	0.23	0.23	0.16	0.10	-0.20
risks monitored	L6	0.26	0.09	0.20	0.18	-0.14
corrective actions taken when needed	L7	0.15	0.14	0.07	-0.03	-0.32
the project's risks were well managed	L8	0.13	0.19	0.05	0.10	-0.24
Applicable	M1	0.43	0.07	0.38	0.28	0.16
cause of problem investigated	M2	0.34	0.07	0.32	0.24	-0.05
impact of problem assessed	M3	0.38	0.07	0.30	0.23	-0.05
resolution action executed	M4	0.26	0.06	0.31	0.16	-0.05

the problem resolution was well managed	M5	0.28	0.00	0.26	0.20	-0.03
problems of developed product identified	N1	-0.12	0.12	-0.10	0.13	-0.16
joint mgmt and technical reviews conducted	N2	-0.03	-0.09	-0.07	0.07	-0.12
product quality was well assured	N3	-0.13	0.03	-0.24	0.00	-0.22
process quality was well assured	N4	-0.03	0.14	-0.07	-0.07	-0.02
project measurement objectives established	O1	0.06	-0.03	-0.12	-0.02	-0.09
project's measures specified	O2	0.11	-0.03	-0.01	-0.09	-0.13
measurement data collection procedures specified	O3	0.00	0.11	0.09	0.04	-0.08
analysis procedures specified	O4	0.22	0.16	0.15	-0.17	0.03
measurement data collected	O5	-0.01	0.26	0.04	-0.07	-0.08
measurement data analysed	O6	-0.15	0.12	-0.02	-0.02	-0.09
measurement data and results were stored	O7	-0.12	0.16	-0.06	-0.02	-0.05
measurement results communicated	O8	-0.14	-0.01	-0.09	-0.08	0.01
the project data was well measured and analysed	O9	0.00	0.13	0.01	0.00	0.02
project's staff committed to directions	P1	-0.16	0.08	-0.03	-0.06	-0.22
project's staff responded well to supervision	P2	-0.20	0.16	-0.21	-0.13	-0.24
people in the project were motivated	P3	-0.38	0.10	-0.24	-0.08	-0.05
project's staff interaction was well coordinated	P4	-0.33	0.09	0.00	-0.03	-0.04
reasons of decision-making understood by staff	P5	-0.44	-0.36	-0.23	0.21	0.11
model practices:	**variable**	A3	A4	C2	C3	C4
conflicts in project team didn't emerge	P6	-0.33	-0.27	-0.49	0.03	-0.20
the project was carried out in positive environment	P7	-0.24	0.08	-0.19	0.07	-0.16
base practices were performed	Q1	0.11	0.18	-0.07	-0.13	-0.31
objectives for performance identified	Q2	0.31	0.32	0.12	0.08	-0.29
organisational policy established	Q3	0.21	0.36	-0.03	-0.20	-0.23
process planned to fulfil identified objectives	Q4	0.17	0.39	0.05	0.02	-0.23
responsibility for the process assigned	Q5	0.20	0.35	0.24	0.20	-0.06
performance of process monitored and controlled	Q6	0.17	0.17	0.05	0.10	-0.12
resources to perform process allocated and used	Q7	-0.05	0.02	0.01	-0.01	-0.12
interfaces between involved parties were managed	Q8	0.15	0.06	0.02	0.11	-0.29
people trained to perform process	Q9	0.27	0.17	0.05	0.08	-0.12
relevant stakeholders identified and involved	Q10	-0.09	0.30	0.22	0.08	0.00
adherence evaluated	Q11	0.26	0.34	0.25	0.26	-0.04
status of process activities reviewed w mgmt	Q12	0.04	0.05	0.19	-0.01	-0.14
the process performance was well managed	Q13	0.13	0.32	0.14	0.19	-0.14
requirements for WPs defined	R1	0.25	0.32	0.09	-0.09	-0.20
requirements for documentation of WPs	R2	0.24	0.41	0.19	0.03	-0.16

defined						
WPs identified, documented and controlled	R3	0.01	0.26	-0.04	-0.37	-0.43
WPs reviewed and adjusted to meet defined req-s	R4	-0.09	-0.12	-0.21	-0.25	-0.38
the process work products were well managed	R5	-0.04	0.25	0.00	-0.26	-0.33
information to formalise project end gathered	S1	0.10	0.17	-0.17	0.13	-0.23
project evaluated after closing	S2	0.24	0.37	0.21	0.01	-0.16
lessons learned were compiled for future projects	S3	0.24	0.20	-0.07	0.09	-0.15
the project was well completed	S4	0.13	0.21	0.00	0.17	0.02

Table A7-4. Correlations between project success and model practices

Correlation between project success (D9) and model practices (E-S)

Model practices:	**variable**	D9
scope defined	E1	0.21
lifecycle defined	E2	0.43
feasibility evaluated	E3	0.58
tasks defined	E4	0.18
needs for experience defined	E5	0.36
project resources planned	E6	0.50
data management planned	E7	0.46
project interfaces identified	E8	0.09
stakeholder involvement planned	E9	0.71
responsibilities allocated	E10	0.49
project plan was implemented	E11	0.37
plans that affect project were reviewed	E12	0.22
work and resource levels reconciled	E13	0.29
commitments to plan obtained	E14	0.42
the project was well planned	E15	0.61
project attribute's were estimated	F1	0.41
effort was estimated	F3	0.59
budget was estimated	F4	0.27
schedule was estimated	F5	0.19
the project was accurately estimated	F6	0.62
project commitments were monitored	G1	0.26
project risks were monitored	G2	0.65
data management were monitored	G3	0.48
stakeholder involvement was monitored	G4	0.57
project interfaces were monitored	G5	0.21
project progress was reviewed	G6	0.36
milestone reviews were conducted	G7	0.43
issues in project were analysed	G8	0.56
deviations from plans corrected and managed	G9	0.55
the project was well monitored and controlled	G10	0.55
customer requirements were obtained	H1	0.31
understanding on requirements was obtained	H2	0.43
requirements were agreed on	H3	0.25
commitments to requirements were obtained	H4	0.42
customer requirement baseline established	H5	0.50
requirement changes were managed	H6	0.32
bi-directional traceability established	H7	0.26
inconsistencies bw project work and req identified	H8	0.32
the requirements were well managed	H9	0.48
communication interface was established	I1	0.03
customer inquiry screening performed	I2	0.07

customer proposal evaluation criteria established	I3	-0.20
customer request for proposal was evaluated	I4	0.02
supplier proposal response was prepared	I5	0.03
confirmation of agreement established	I6	0.11
the supplier tendering was well managed	I7	0.09
Customer request for change recorded	J1	-0.08
status of change requests tracked	J2	0.04
impact of change assessed	J3	0.06
change verification and validation id-d	J4	0.13
Model practices:	**variable**	D9
changes approved before implementation	J5	0.13
changes were scheduled	J6	0.24
implemented changes reviewed	J7	0.25
items to be placed under CM identified	J8	0.24
CM and change mgmt systems established	J9	0.20
baselines were created	J10	0.18
changes to conf items were controlled	J11	0.13
records describing conf items established	J12	0.07
configuration audits performed	J13	0.09
the change requests were well managed	J14	0.40
the configurations were well managed	J15	0.38
Applicable	K1	0.10
suppliers were selected	K2	0.06
supplier agreement negotiated with supplier	K3	0.14
supplier contract approved by relevant stakeholders	K4	0.13
contract awarded to successful tenderer	K5	0.04
acquired product was accepted	K6	0.11
the supplier agreement was well managed	K7	0.09
risk mgmt scope established	L1	0.32
risk mgmt strategies defined	L2	0.18
risks identified	L3	0.35
risks analysed	L4	0.47
risk treatment actions defined and performed	L5	0.43
risks monitored	L6	0.42
corrective actions taken when needed	L7	0.43
the project's risks were well managed	L8	0.61
Applicable	M1	-0.24
cause of problem investigated	M2	0.00
impact of problem assessed	M3	-0.02
resolution action executed	M4	0.07
the problem resolution was well managed	M5	0.04
problems of developed product identified	N1	0.51
joint mgmt and technical reviews conducted	N2	0.41
product quality was well assured	N3	0.63

process quality was well assured	N4	0.49
project measurement objectives established	O1	0.50
project's measures specified	O2	0.31
measurement data collection procedures specified	O3	0.35
analysis procedures specified	O4	0.32
measurement data collected	O5	0.31
measurement data analysed	O6	0.46
measurement data and results were stored	O7	0.30
measurement results communicated	O8	0.51
the project data was well measured and analysed	O9	0.43
project's staff committed to directions	P1	0.54
project's staff responded well to supervision	P2	0.42
people in the project were motivated	P3	0.75
project's staff interaction was well coordinated	P4	0.78
reasons of decision-making understood by staff	P5	0.68
conflicts in project team didn't emerge	P6	0.34
the project was carried out in positive environment	P7	0.69
base practices were performed	Q1	0.49
objectives for performance identified	Q2	0.28
Model practices:	**variable**	D9
organisational policy established	Q3	0.09
process planned to fulfil identified objectives	Q4	0.14
responsibility for the process assigned	Q5	0.27
performance of process monitored and controlled	Q6	0.37
resources to perform process allocated and used	Q7	0.35
interfaces between involved parties were managed	Q8	0.30
people trained to perform process	Q9	0.08
relevant stakeholders identified and involved	Q10	0.49
adherence evaluated	Q11	0.23
status of process activities reviewed w mgmt	Q12	0.45
the process performance was well managed	Q13	0.45
requirements for WPs defined	R1	0.31
requirements for documentation of WPs defined	R2	0.23
WPs identified, documented and controlled	R3	0.30
WPs reviewed and adjusted to meet defined req-s	R4	0.45
the process work products were well managed	R5	0.57
information to formalise project end gathered	S1	0.54
project evaluated after closing	S2	0.44
lessons learned were compiled for future projects	S3	0.35
the project was well completed	S4	0.47

Table A7-5. Correlations between A8 and C12, and model practices E-S

Model practice	Variable	A8	C12
scope defined	E1	-0.17	0.03
lifecycle defined	E2	-0.07	0.25
feasibility evaluated	E3	-0.01	0.26
tasks defined	E4	0.39	0.36
needs for experience defined	E5	0.32	0.24
project resources planned	E6	0.36	0.31
data management planned	E7	0.05	0.14
project interfaces identified	E8	0.17	0.20
stakeholder involvement planned	E9	0.17	0.12
responsibilities allocated	E10	0.06	0.13
project plan was implemented	E11	0.15	0.32
plans that affect project were reviewed	E12	0.28	0.41
work and resource levels reconciled	E13	0.24	0.30
commitments to plan obtained	E14	0.34	0.28
the project was well planned	E15	0.17	0.25
project attribute's were estimated	F1	0.04	-0.03
effort was estimated	F3	0.16	0.19
budget was estimated	F4	0.01	0.20
schedule was estimated	F5	-0.05	-0.07
the project was accurately estimated	F6	0.21	0.21
project commitments were monitored	G1	0.25	0.11
project risks were monitored	G2	0.11	0.41
data management were monitored	G3	-0.05	0.25
stakeholder involvement was monitored	G4	0.35	0.35
project interfaces were monitored	G5	0.27	0.13
project progress was reviewed	G6	0.32	0.19
milestone reviews were conducted	G7	0.31	0.35
issues in project were analysed	G8	0.40	0.25
deviations from plans corrected and managed	G9	0.02	0.49
the project was well monitored and controlled	G10	0.28	0.43
customer requirements were obtained	H1	0.03	0.11
understanding on requirements was obtained	H2	0.06	-0.06
requirements were agreed on	H3	0.23	0.06
commitments to requirements were obtained	H4	0.33	0.30
customer requirement baseline established	H5	0.11	0.29
requirement changes were managed	H6	0.06	0.31
bi-directional traceability established	H7	0.31	0.56
inconsistencies bw project work and req identified	H8	0.06	0.16

the requirements were well managed	H9	0.18	0.31
communication interface was established	I1	0.20	-0.01
customer inquiry screening performed	I2	0.52	0.29
customer proposal evaluation criteria established	I3	0.18	0.17
customer request for proposal was evaluated	I4	0.34	0.21
supplier proposal response was prepared	I5	0.39	0.21
confirmation of agreement established	I6	0.21	0.08
the supplier tendering was well managed	I7	0.34	0.12
Customer request for change recorded	J1	0.03	0.19
status of change requests tracked	J2	0.02	0.36
impact of change assessed	J3	0.11	0.19
change verification and validation id-d	J4	-0.16	0.02
changes approved before implementation	J5	-0.10	0.00
Model practice	**Variable**	**A8**	**C12**
changes were scheduled	J6	-0.01	0.06
implemented changes reviewed	J7	0.05	0.32
items to be placed under CM identified	J8	0.23	0.03
CM and change mgmt systems established	J9	0.40	0.12
baselines were created	J10	0.27	0.06
changes to conf items were controlled	J11	0.06	0.15
records describing conf items established	J12	0.19	0.24
configuration audits performed	J13	0.20	0.37
the change requests were well managed	J14	0.12	0.27
the configurations were well managed	J15	0.28	0.18
Applicable	K1	0.18	0.37
suppliers were selected	K2	0.14	0.29
supplier agreement negotiated with supplier	K3	0.12	0.20
supplier contract approved by relevant stakeholders	K4	0.11	0.18
contract awarded to successful tenderer	K5	0.14	0.17
acquired product was accepted	K6	0.12	0.18
the supplier agreement was well managed	K7	0.16	0.25
risk mgmt scope established	L1	0.46	0.57
risk mgmt strategies defined	L2	0.21	0.50
risks identified	L3	0.24	0.45
risks analysed	L4	0.22	0.43
risk treatment actions defined and performed	L5	0.24	0.48
risks monitored	L6	0.12	0.48
corrective actions taken when needed	L7	0.13	0.39
the project's risks were well managed	L8	0.10	0.45
Applicable	M1	-0.03	0.02

cause of problem investigated	M2	0.05	0.10
impact of problem assessed	M3	0.06	0.10
resolution action executed	M4	0.17	0.18
the problem resolution was well managed	M5	0.11	0.12
problems of developed product identified	N1	0.07	-0.03
joint mgmt and technical reviews conducted	N2	0.32	0.38
product quality was well assured	N3	0.22	0.17
process quality was well assured	N4	0.15	0.35
project measurement objectives established	O1	0.29	0.35
project's measures specified	O2	0.38	0.43
measurement data collection procedures specified	O3	0.41	0.37
analysis procedures specified	O4	0.35	0.54
measurement data collected	O5	0.62	0.34
measurement data analysed	O6	0.46	0.38
measurement data and results were stored	O7	0.53	0.23
measurement results communicated	O8	0.57	0.36
the project data was well measured and analysed	O9	0.38	0.47
project's staff committed to directions	P1	-0.04	0.03
project's staff responded well to supervision	P2	0.23	0.11
people in the project were motivated	P3	0.27	0.21
project's staff interaction was well coordinated	P4	0.25	0.36
reasons of decision-making understood by staff	P5	-0.16	0.17
conflicts in project team didn't emerge	P6	0.00	-0.14
the project was carried out in positive environment	P7	0.09	0.08
base practices were performed	Q1	0.06	0.43
objectives for performance identified	Q2	0.11	0.38
organisational policy established	Q3	0.27	0.12
Model practice	**Variable**	**A8**	**C12**
process planned to fulfil identified objectives	Q4	0.08	0.12
responsibility for the process assigned	Q5	0.28	0.22
performance of process monitored and controlled	Q6	0.29	0.46
resources to perform process allocated and used	Q7	0.27	0.46
interfaces between involved parties were managed	Q8	0.30	0.42
people trained to perform process	Q9	0.20	0.07
relevant stakeholders identified and involved	Q10	0.25	0.29
adherence evaluated	Q11	0.22	0.36
status of process activities reviewed w mgmt	Q12	0.25	0.39
the process performance was well managed	Q13	0.24	0.42
requirements for WPs defined	R1	0.51	0.41
requirements for documentation of WPs defined	R2	0.49	0.29

WPs identified, documented and controlled	R3	0.32	0.19
WPs reviewed and adjusted to meet defined req-s	R4	0.18	0.12
the process work products were well managed	R5	0.35	0.25
information to formalise project end gathered	S1	0.26	0.41
project evaluated after closing	S2	0.44	0.47
lessons learned were compiled for future projects	S3	0.30	0.41
the project was well completed	S4	0.33	0.41

Table A7-6. Correlation coefficients between life cycle models (C6-C10) and model practices (E-S)

model practice	variable	C6	C7	C8	C9	C10	C11
scope defined	E1	0.26	0.13	0.08	0.17	-0.05	-0.41
lifecycle defined	E2	0.17	-0.16	0.04	-0.03	0.09	-0.20
feasibility evaluated	E3	-0.13	0.01	0.22	-0.01	0.18	0.11
tasks defined	E4	0.18	0.10	0.20	0.07	0.19	-0.18
needs for experience defined	E5	0.13	0.11	0.32	0.09	0.19	0.01
project resources planned	E6	-0.13	-0.13	0.18	0.16	0.27	0.18
data management planned	E7	-0.02	0.04	0.27	0.15	0.04	-0.03
project interfaces identified	E8	-0.10	0.08	0.10	0.09	0.02	0.10
stakeholder involvement planned	E9	0.22	0.07	0.29	0.31	0.27	-0.14
responsibilities allocated	E10	0.16	0.08	-0.08	0.03	0.08	-0.35
project plan was implemented	E11	0.17	-0.20	0.01	0.03	-0.05	-0.09
plans that affect project were reviewed	E12	-0.01	0.23	0.09	-0.14	0.51	-0.19
work and resource levels reconciled	E13	-0.07	0.07	0.10	-0.09	0.52	0.01
commitments to plan obtained	E14	0.16	0.08	0.15	0.17	0.08	-0.39
the project was well planned	E15	0.37	-0.20	0.22	-0.20	-0.12	-0.20
project attribute's were estimated	F1	0.31	0.21	0.24	-0.14	0.04	-0.10
effort was estimated	F3	0.14	0.05	0.26	0.31	0.14	-0.20
budget was estimated	F4	0.07	0.17	0.02	-0.04	0.09	-0.31
schedule was estimated	F5	-0.16	0.11	-0.12	0.17	0.00	0.18
the project was accurately estimated	F6	0.31	0.14	0.34	-0.24	-0.09	-0.18
project commitments were monitored	G1	0.05	0.21	0.14	0.14	0.29	0.03
project risks were monitored	G2	-0.05	0.04	0.18	0.07	0.31	-0.17
data management were monitored	G3	-0.04	0.15	0.22	0.01	0.08	-0.15
stakeholder involvement was monitored	G4	0.17	0.00	0.36	-0.12	0.06	0.05
project interfaces were monitored	G5	0.17	0.09	0.05	-0.02	-0.05	0.25
project progress was reviewed	G6	-0.03	0.20	0.24	0.02	0.28	0.14
milestone reviews were conducted	G7	-0.10	0.15	0.28	0.00	0.15	0.05
issues in project were analysed	G8	-0.18	0.13	0.25	0.14	0.38	0.25
deviations from plans corrected and managed	G9	-0.12	-0.14	0.20	-0.14	0.31	-0.15
the project was well monitored and controlled	G10	-0.09	0.12	0.37	-0.07	0.34	-0.03
customer requirements were obtained	H1	0.23	0.18	-0.05	-0.19	0.36	-0.17
understanding on requirements was obtained	H2	0.32	0.15	-0.01	-0.12	0.36	-0.15
requirements were agreed on	H3	0.30	0.01	-0.25	-0.24	0.47	-0.04
commitments to requirements were obtained	H4	0.20	0.22	0.16	0.08	0.31	-0.32
customer requirement baseline established	H5	0.06	0.13	0.19	0.16	0.45	-0.25

requirement changes were managed	H6	0.00	-0.27	-0.24	0.08	0.27	-0.12
bi-directional traceability established	H7	0.18	-0.20	0.10	-0.16	0.08	-0.36
inconsistencies bw project work and req identified	H8	0.16	-0.06	0.18	-0.07	-0.06	0.00
the requirements were well managed	H9	0.26	-0.18	0.12	-0.17	0.09	-0.24
communication interface was established	I1	0.06	0.14	-0.02	-0.25	0.30	0.05
customer inquiry screening performed	I2	0.09	0.10	0.11	-0.36	0.27	0.03
customer proposal evaluation criteria established	I3	0.02	-0.05	-0.04	-0.27	-0.05	0.05
customer request for proposal was evaluated	I4	0.01	-0.21	-0.17	-0.29	0.23	0.26
supplier proposal response was prepared	I5	0.10	0.16	0.07	-0.14	0.04	-0.01
confirmation of agreement established	I6	0.14	0.17	-0.09	-0.19	0.17	-0.02
the supplier tendering was well managed	I7	0.17	0.13	0.01	-0.14	0.13	0.01
Customer request for change recorded	J1	0.16	-0.33	-0.26	-0.20	0.11	-0.01

model practice	**variable**	***C6***	***C7***	***C8***	***C9***	***C10***	***C11***
status of change requests tracked	J2	-0.22	-0.42	-0.37	0.16	0.26	-0.04
impact of change assessed	J3	0.31	-0.11	-0.24	-0.06	0.31	-0.08
change verification and validation id-d	J4	0.27	-0.19	-0.20	-0.12	0.18	-0.03
changes approved before implementation	J5	0.15	-0.18	-0.17	-0.10	-0.11	0.01
changes were scheduled	J6	0.14	-0.29	-0.24	-0.16	0.08	0.06
implemented changes reviewed	J7	0.33	-0.09	-0.07	-0.15	0.27	-0.31
items to be placed under CM identified	J8	0.11	-0.09	-0.11	0.06	0.10	0.06
CM and change mgmt systems established	J9	0.09	-0.13	-0.10	0.02	0.26	0.15
baselines were created	J10	0.20	-0.15	0.01	-0.17	-0.15	0.16
changes to conf items were controlled	J11	0.20	-0.15	0.03	-0.05	-0.04	-0.05
records describing conf items established	J12	0.30	-0.09	0.07	-0.29	0.03	-0.01
configuration audits performed	J13	0.20	-0.14	0.11	-0.33	0.19	-0.04
the change requests were well managed	J14	-0.04	-0.14	0.00	0.21	-0.06	-0.11
the configurations were well managed	J15	0.21	-0.04	0.12	-0.05	0.04	-0.10
Applicable	K1	-0.17	0.04	-0.13	0.15	0.19	-0.13
suppliers were selected	K2	-0.08	0.12	-0.12	0.22	0.16	-0.17
supplier agreement negotiated with supplier	K3	-0.07	0.19	-0.07	0.15	0.15	-0.07
supplier contract approved by relevant stakeholders	K4	-0.05	0.22	-0.11	0.15	0.15	-0.06
contract awarded to successful tenderer	K5	-0.04	0.25	-0.07	0.16	0.13	-0.12
acquired product was accepted	K6	-0.07	0.21	-0.11	0.17	0.13	-0.07
the supplier agreement was well managed	K7	-0.09	0.19	-0.06	0.19	0.11	-0.11
risk mgmt scope established	L1	0.41	-0.10	0.01	-0.09	-0.04	-0.37
risk mgmt strategies defined	L2	0.12	-0.13	-0.13	-0.07	-0.13	-0.29
risks identified	L3	-0.01	-0.16	-0.12	0.14	0.20	-0.04

risks analysed	L4	-0.03	-0.06	-0.06	0.19	0.22	-0.13
risk treatment actions defined and performed	L5	0.09	-0.04	0.07	0.01	0.23	-0.21
risks monitored	L6	0.11	0.00	0.00	-0.11	0.23	-0.31
corrective actions taken when needed	L7	0.12	-0.13	-0.07	0.01	0.27	-0.22
the project's risks were well managed	L8	0.06	-0.19	-0.04	-0.03	0.25	-0.26
Applicable	M1	0.07	0.03	-0.24	-0.18	0.03	-0.01
cause of problem investigated	M2	0.12	0.09	-0.19	-0.22	0.17	-0.09
impact of problem assessed	M3	0.11	0.16	-0.18	-0.15	0.12	-0.13
resolution action executed	M4	0.15	0.08	-0.15	-0.22	0.23	-0.05
the problem resolution was well managed	M5	0.20	0.16	-0.14	-0.26	0.16	-0.14
problems of developed product identified	N1	0.27	-0.07	0.00	-0.01	0.01	0.00
joint mgmt and technical reviews conducted	N2	0.06	0.14	0.23	-0.34	0.14	-0.02
product quality was well assured	N3	0.17	-0.07	0.13	-0.06	0.01	0.04
process quality was well assured	N4	0.14	-0.23	0.11	-0.30	0.03	-0.14
project measurement objectives established	O1	0.10	-0.21	-0.03	-0.27	0.11	-0.03
project's measures specified	O2	0.23	-0.03	-0.02	-0.25	0.24	-0.17
measurement data collection procedures specified	O3	0.21	-0.11	0.07	-0.05	0.26	-0.07
analysis procedures specified	O4	0.23	-0.10	0.06	-0.03	-0.05	-0.37
measurement data collected	O5	0.28	-0.33	0.02	-0.01	0.16	0.19
measurement data analysed	O6	0.32	-0.36	0.08	-0.24	0.13	0.08
measurement data and results were stored	O7	0.33	-0.26	0.10	-0.01	0.16	0.18
measurement results communicated	O8	0.35	-0.13	0.14	-0.19	0.17	-0.01
the project data was well measured and analysed	O9	0.33	-0.25	0.12	-0.23	0.13	-0.22
project's staff committed to directions	P1	-0.01	0.02	0.12	0.03	0.14	-0.04
project's staff responded well to supervision	P2	-0.01	0.01	0.39	0.05	0.01	0.02
people in the project were motivated	P3	0.05	-0.27	0.27	0.03	-0.10	0.16

model practice	**variable**	***C6***	***C7***	***C8***	***C9***	***C10***	***C11***
project's staff interaction was well coordinated	P4	0.00	-0.16	0.22	0.08	0.16	-0.11
reasons of decision-making understood by staff	P5	0.08	-0.07	0.25	-0.12	0.10	-0.21
conflicts in project team didn't emerge	P6	0.08	-0.08	0.00	-0.15	-0.08	0.22
the project was carried out in positive environment	P7	0.13	-0.16	-0.08	0.15	0.07	0.07
base practices were performed	Q1	0.00	-0.08	0.22	0.23	0.00	-0.33
objectives for performance identified	Q2	0.01	-0.16	0.01	-0.12	0.25	-0.09
organisational policy established	Q3	0.26	-0.12	-0.03	-0.01	-0.12	-0.11

process planned to fulfil identified objectives	Q4	0.13	-0.21	-0.08	-0.22	-0.02	0.09
responsibility for the process assigned	Q5	0.06	0.13	0.17	0.18	0.25	-0.17
performance of process monitored and controlled	Q6	0.24	0.00	0.17	-0.17	0.19	-0.33
resources to perform process allocated and used	Q7	0.22	0.00	0.15	0.02	0.13	-0.45
interfaces between involved parties were managed	Q8	0.15	-0.02	-0.03	0.00	0.27	-0.23
people trained to perform process	Q9	0.09	0.29	0.16	-0.15	-0.07	-0.19
relevant stakeholders identified and involved	Q10	0.14	-0.06	0.33	-0.02	0.06	-0.06
adherence evaluated	Q11	0.02	-0.04	0.07	-0.18	0.16	-0.03
status of process activities reviewed w mgmt	Q12	0.03	0.11	0.33	0.09	0.00	-0.22
the process performance was well managed	Q13	0.11	-0.23	0.03	-0.23	0.14	-0.14
requirements for WPs defined	R1	0.14	-0.09	-0.01	0.10	0.22	-0.09
requirements for documentation of WPs defined	R2	0.26	-0.09	-0.01	-0.02	0.09	-0.01
WPs identified, documented and controlled	R3	0.05	-0.04	0.20	0.09	0.11	0.01
WPs reviewed and adjusted to meet defined req-s	R4	0.01	0.25	0.29	0.11	0.19	-0.16
the process work products were well managed	R5	0.05	-0.04	0.24	0.17	0.17	-0.05
information to formalise project end gathered	S1	0.05	-0.17	0.06	-0.15	0.13	-0.02
project evaluated after closing	S2	0.07	-0.21	-0.01	-0.07	0.21	-0.01
lessons learned were compiled for future projects	S3	0.05	-0.04	0.03	-0.16	-0.04	-0.13
the project was well completed	S4	0.12	-0.18	-0.01	-0.21	0.16	-0.01

Table A7-7. Correlation coefficients between model practices and their summarizing variables

Model practice	**Variable**	
Project Planning		***E15***
scope defined	E1	0.30
lifecycle defined	E2	0.39
feasibility evaluated	E3	0.33
tasks defined	E4	0.27
needs for experience defined	E5	0.22
project resources planned	E6	0.29
data management planned	E7	0.36
project interfaces identified	E8	0.24
stakeholder involvement planned	E9	0.48
responsibilities allocated	E10	0.51
project plan was implemented	E11	0.43
plans that affect project were reviewed	E12	0.28
work and resource levels reconciled	E13	0.12
commitments to plan obtained	E14	0.40
the project was well planned	E15	1.00
Project Estimation		***F6***
project attribute's were estimated	F1	0.69
effort was estimated	F3	0.43
budget was estimated	F4	0.31
schedule was estimated	F5	0.27
the project was accurately estimated	F6	1.00
Project Monitoring and Control		***G10***
project commitments were monitored	G1	0.62
project risks were monitored	G2	0.72
data management were monitored	G3	0.64
stakeholder involvement was monitored	G4	0.81
project interfaces were monitored	G5	0.55
project progress was reviewed	G6	0.65
milestone reviews were conducted	G7	0.71
issues in project were analysed	G8	0.60
deviations from plans corrected and managed	G9	0.78
the project was well monitored and controlled	G10	1.00
Requirements Management		***H9***
customer requirements were obtained	H1	0.36
understanding on requirements was obtained	H2	0.68
requirements were agreed on	H3	0.61

commitments to requirements were obtained	H4		0.70
customer requirement baseline established	H5		0.50
requirement changes were managed	H6		0.50
bi-directional traceability established	H7		0.66
inconsistencies bw project work and req identified	H8		0.50
the requirements were well managed	H9		1.00
Supplier Tendering			***I7***
communication interface was established	I1		0.83
customer inquiry screening performed	I2		0.73
customer proposal evaluation criteria established	I3		0.55
customer request for proposal was evaluated	I4		0.73
supplier proposal response was prepared	I5		0.93
confirmation of agreement established	I6		0.83
the supplier tendering was well managed	I7		1.00
Model practice	**Variable**		
Change Request & Config Management			
		J14	***J15***
Customer request for change recorded	J1	0.37	0.13
status of change requests tracked	J2	0.60	0.39
impact of change assessed	J3	0.46	0.21
change verification and validation id-d	J4	0.51	0.51
changes approved before implementation	J5	0.74	0.46
changes were scheduled	J6	0.60	0.47
implemented changes reviewed	J7	0.45	0.40
items to be placed under CM identified	J8	0.63	0.77
CM and change mgmt systems established	J9	0.55	0.74
baselines were created	J10	0.52	0.75
changes to conf items were controlled	J11	0.62	0.67
records describing conf items established	J12	0.44	0.60
configuration audits performed	J13	0.22	0.49
the change requests were well managed	J14	1.00	0.61
the configurations were well managed	J15		1.00
Supplier Agreement		***K7***	
Applicable	K1		0.93
suppliers were selected	K2		0.98
supplier agreement negotiated with supplier	K3		0.96
supplier contract approved by relevant stakeholders	K4		0.97
contract awarded to successful tenderer	K5		0.96
acquired product was accepted	K6		0.98
the supplier agreement was well managed	K7		1.00

Risk Management			***L8***
risk mgmt scope established	L1		0.54
risk mgmt strategies defined	L2		0.44
risks identified	L3		0.74
risks analysed	L4		0.83
risk treatment actions defined and performed	L5		0.81
risks monitored	L6		0.71
corrective actions taken when needed	L7		0.90
the project's risks were well managed	L8		1.00
Problem Resolution Management			***M5***
Applicable	M1		0.89
cause of problem investigated	M2		0.97
impact of problem assessed	M3		0.98
resolution action executed	M4		0.97
the problem resolution was well managed	M5		1.00
Quality Assurance		***N3***	***N4***
problems of developed product identified	N1	0.88	0.57
joint mgmt and technical reviews conducted	N2	0.60	0.51
product quality was well assured	N3	1.00	0.71
process quality was well assured	N4		1.00
Measurement & Analysis			***O9***
project measurement objectives established	O1		0.74
project's measures specified	O2		0.85
measurement data collection procedures specified	O3		0.80
analysis procedures specified	O4		0.76
measurement data collected	O5		0.74
measurement data analysed	O6		0.87
measurement data and results were stored	O7		0.75
Model practice	**Variable**		
measurement results communicated	O8		0.85
the project data was well measured and analysed	O9		1.00
Project Directing			***P7***
project's staff committed to directions	P1		0.53
project's staff responded well to supervision	P2		0.50
people in the project were motivated	P3		0.72
project's staff interaction was well coordinated	P4		0.63
reasons of decision-making understood by staff	P5		0.39
conflicts in project team didn't emerge	P6		0.51
the project was carried out in positive environment	P7		1.00
Process Performance Management			***Q13***

base practices were performed	Q1	0.41
objectives for performance identified	Q2	0.71
organisational policy established	Q3	0.49
process planned to fulfil identified objectives	Q4	0.61
responsibility for the process assigned	Q5	0.42
performance of process monitored and controlled	Q6	0.79
resources to perform process allocated and used	Q7	0.41
interfaces between involved parties were managed	Q8	0.62
people trained to perform process	Q9	0.44
relevant stakeholders identified and involved	Q10	0.56
adherence evaluated	Q11	0.73
status of process activities reviewed w mgmt	Q12	0.47
the process performance was well managed	Q13	1.00
Process Outcome (Work Product) Management		***R5***
requirements for WPs defined	R1	0.69
requirements for documentation of WPs defined	R2	0.57
WPs identified, documented and controlled	R3	0.87
WPs reviewed and adjusted to meet defined req-s	R4	0.77
the process work products were well managed	R5	1.00
Project Completion		***S4***
information to formalise project end gathered	S1	0.87
project evaluated after closing	S2	0.81
lessons learned were compiled for future projects	S3	0.76
the project was well completed	S4	1.00

Tampereen teknillinen yliopisto
PL 527
33101 Tampere

Tampere University of Technology
P.O. Box 527
FIN-33101 Tampere, Finland