Kari Sippola

TWO CASE STUDIES ON REAL TIME QUALITY COST MEASUREMENT IN SOFTWARE BUSINESS
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Abstract

Malmi et al. (2004) argue that the cost of quality (COQ) literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, batch after batch or customer after customer. Many modern businesses, such as the software business, are outright project based, or operate like a string of semi-independent projects characterized by unique resources, customized activity or work sequence order, and a predefined start and finish. COQ measuring and reporting are traditionally based on ex post calculations. In this study, an idea of real-time quality cost measurement will be developed and tested. The literature on real-time quality cost accounting is limited or even non-existent. The dissertation investigates whether it is possible to measure quality costs as a real-time basis in the software industry. The purpose is to develop a model for measuring quality costs on a real-time basis in software development. This is achieved by seeking answers to the research question how to measure quality costs on a real-time basis in the software industry. The research extends the current literature in three main respects. First, the study presents the idea of measuring quality costs in real-time basis. Second, a contribution is made by investigating how the characteristics of software business impact on the accounting of quality costs by presenting the nature and distinction of software business as well as its implications for software quality and applying quality cost measurement to the software business. Third, this study is expected to make a contribution by investigating how to use quality cost measurement as a management accounting tool in modern software business environment.

The constructive research approach (CRA) proposed by Kasanen et al. (1993) is used in a case company, A, that develops and produces packaged software used in embedded products. Since it is not typically possible to pass semi-strong or strong market tests within a medium-term time span, the construction is tested by using more detailed nuances within the weak market test category suggested by Labro and Tuomela (2003) in order to analyse the level of progress of the construct. The possibility of constructing a real-time cost of quality measurement system developed in Case A is also tested in another case company (Case B) to make the weak market test stronger, and the boundary conditions how to construct such a system in a totally different working environment are charted. The results indicate that such a system could be constructed irrespective of the cost accounting environment or the software used. The anticipated contribution arises from the fact that the construct is a novelty that leads to a new means of quality cost accounting in software business (cf. Lukka 2000).

Keywords: constructive research approach, cost accounting, cost of quality, embedded software, software business, software quality
Acknowledgements

It has been quite a long journey from my master’s thesis to completing this dissertation. This dissertation would not have been possible without the help and assistance of several people, who have supported, guided and encouraged me during this project. I begin from the beginning. My interest in quality issues began when I was doing the master’s thesis in 1994. Professor Petri Vehmanen was my supervisor in the master’s thesis project and he succeeded in kindling my interest in quality issues and quality costing. Thank you for this! When I started work as an assistant of accounting in the Department of Economics at the University of Oulu and began my licenciate thesis, keeping the same research area was still my main interest.

My interest in software issues was kindled during my postgraduate studies and on a course by Professor Samuli Saukkonen at the Department of Information Processing Science. After the course he offered me an opportunity to participate in the KÄYPRO (Development of an improvement approach for user interface development) Maturity Model for Software -project. The KÄYPRO as project was funded by the National Technology Agency of Finland (TEKES) in Infotech Oulu Software Process Improvement Research Action Laboratory (SPIRAL), in which the Department of Information Processing Science in the University of Oulu and Technical Research Centre of Finland (VTT Electronics Research Institute) in Oulu participate. By participating in this project, I learned about software and software quality characteristics, as well as the path that leads through the jungle of dozens of various software quality standards. I owe my special thanks to Professors Samuli Saukkonen and Kari Kuutti.

After this project it was quite easy to answer the question of focusing the licentiate thesis to one branch of business. The researcher’s interest was now directed to the high-tech and software business, also because this branch of business is well represented in the Oulu region. I also thank Professor Saukkonen for being the official examiner of my licentiate thesis “Quality cost measurement as a tool for top management in contemporary software business environment”. His pronouncement and the other given by my other examiner, Professor Robert Chenhall (Monash University), gave me the courage to continue the work after the Licentiate Thesis. I appreciate having professor Chenhall as my official examiner in my licentiate thesis.

I would like to thank the supervisor in my licentiate thesis, Professor Jukka Perttunen, for valuable comments and support during the maturation of that work.
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A case-study research could have never be done without the case-companies. I will always be grateful to financial manager, Petri H., M.Sc. at Case Company A for asking me to attend to the company’s accounting and quality development projects. Working at an embedded software company has been extremely
important for me as a management accounting person. I had the privilege to see how software is developed in practice, not only by reading the books and journal articles. I would also like to thank managing director Kauko S., acting manager of SW department Pekka V., testing manager Kai N., quality manager Mikko Y., manager of HW department Markku N., and all the other people at the company who were interviewed. I also thank the other staff of Company A for a friendly attitude to my work while I was doing research at their premises.

I would also like to thank Case Company B for the chance to do research work there. I would like to thank manager Kai N., sales manager Tarja P., group managers Sami S. and Lasse M., and all the other interviewees at the company and its sister company, and Sales Manager Sauli O. and key account manager Riku M. at the mother company of B. I would also like to thank the manager of subcontracting Heikki Salmi of Nokia Ltd.

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Oulu, November 2008

Kari Sippola
## Contents

**Abstract**  
5  
**Acknowledgements**  
9  
**List of Abbreviations**  
13  
**1 Introduction**  
15  
1.1 Background  
15  
1.2 Aim of the research and the anticipated contribution  
17  
1.3 The research process  
18  
1.4 Theoretical framework  
21  
1.4.1 Methodological orientation  
21  
1.4.2 The constructive research approach  
26  
1.4.3 Specific steps in constructing the real time cost of quality measurement model  
28  
1.5 Structure of the study  
34  
**2 Concept of quality, quality cost accounting and quality in the software business**  
37  
2.1 Concept of quality: contents and essential nature  
37  
2.1.1 Multiple definitions of quality  
39  
2.1.2 Total Quality Management as a way of thinking  
43  
2.2 A review of quality cost research  
44  
2.2.1 History of quality costing  
45  
2.2.2 Quality cost research in management accounting  
47  
2.2.3 Studies on quality costing in production economics and software engineering  
49  
2.3 Characteristics of software business and software quality  
53  
2.3.1 Software products and processes  
54  
2.3.2 Software product quality characteristics  
57  
2.3.3 Benefits of improved software usability  
61  
2.3.4 User Perceived Quality and Quality in Use  
64  
**3 Quality cost accounting in traditional and activity based costing environment**  
73  
3.1 Principle elements of the PAF-approach  
74  
3.1.1 Quality cost models – “traditional” and “new”  
79  
3.1.2 Approaches to quality improvement  
86  
3.2 Measuring quality costs with the Taguchi approach  
89
3.2.1 Example of estimating intangible quality costs ........................................ 92
3.3 Types of quality costs levels ...................................................................... 95
3.4 Drawbacks of the PAF-approach ............................................................... 99
  3.4.1 Difficulties in collecting and measuring quality costs .................... 102
3.5 Process cost approach (New customer and process focused poor quality cost model) ............................................................... 107
3.6 Quality cost measurement in Activity-Based Costing
  environment .......................................................................................... 113
  3.6.1 Cost assignment view of ABC ...................................................... 113
  3.6.2 Process view of ABC .................................................................. 118
3.7 Comparison between COQ approaches and ABC .................................... 120
  3.7.1 Integrated COQ-ABC framework .............................................. 123
3.8 COQ measurement and reporting under ABC-environment .................... 127
  3.8.1 Use of COQ information ............................................................. 130

4 Cost of software quality ............................................................................. 135
  4.1 Introduction to the cost of software quality ........................................... 135
  4.2 Benefits of using quality cost accounting in the SW-business ............... 138
  4.3 Elements of COSQ information .......................................................... 140
  4.4 Findings of the empirical COSQ-research done in software companies .......................................................... 144

5 Case A. Constructing a real time cost of quality measurement model ....... 153
  5.1 Case selection ..................................................................................... 153
  5.2 Description of the Case Company A ................................................... 154
    5.2.1 Starting point of the empirical project ....................................... 155
    5.2.2 Working methods during the fieldwork phase ............................ 156
    5.2.3 Description of the result of the preliminary phase .................... 160
    5.2.4 The change process .................................................................. 175
  5.3 The Description of the constructed quality cost measuring system RQC ............................................................................. 177
    5.3.1 Examining the scope of the solution’s applicability .................... 181

6 Case B. Testing the possibility for constructing real time cost of quality measurement in another company ......................................................... 187
  6.1 Case selection and the objectives in Case B ......................................... 187
  6.2 Case B and its mother company ........................................................... 188
  6.3 Description of the data ........................................................................ 189
    6.3.1 Themes of the interviews ............................................................ 191
6.3.2 History and business concept of Case B......................................... 193
6.3.3 Summary of the themes and main development objectives
suggested by interviewees .......................................................... 194
6.3.4 The possibility of implementing real time cost of quality
accounting (RQC) in Case Company B........................................ 202
7 Conclusions  205
  7.1 Contributions......................................................................................... 205
  7.2 Evaluation of the study – reliability and validity .............................. 211
  7.3 Limitations of the research and avenues for future research.......... 216
References  219
Appendices  237
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Activity Based Costing</td>
</tr>
<tr>
<td>ABM</td>
<td>Activity Based Management</td>
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<tr>
<td>ASQ</td>
<td>American Society for Quality (since 1998)</td>
</tr>
<tr>
<td>ASQC</td>
<td>American Society for Quality Control (until 1998)</td>
</tr>
<tr>
<td>BDM</td>
<td>BDM International company</td>
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<tr>
<td>BPR</td>
<td>Business Process Re-engineering</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>CD</td>
<td>Committee Draft</td>
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<tr>
<td>CIM</td>
<td>Computer-integrated Manufacturing</td>
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<td>CMM</td>
<td>Capability Maturity Model for Software</td>
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<tr>
<td>COC</td>
<td>Cost of Conformance</td>
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<tr>
<td>CONC</td>
<td>Cost of Nonconformance</td>
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<td>COQ</td>
<td>Cost of Quality</td>
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<tr>
<td>COSQ</td>
<td>Cost of Software Quality</td>
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<tr>
<td>DIS</td>
<td>Draft International Standard</td>
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<tr>
<td>EOQ</td>
<td>The European Organization for Quality</td>
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<td>GQM</td>
<td>Goal Question Metric paradigm</td>
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<tr>
<td>GUI</td>
<td>Graphical user interface</td>
</tr>
<tr>
<td>IAQ</td>
<td>International Academy for Quality</td>
</tr>
<tr>
<td>IEC</td>
<td>The International Electrotechnical Commission</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>KÄYPRO</td>
<td>Käytettävyysuunnittelun prosessien arviointi ja kehittäminen (Development of an improvement approach for user interface development)</td>
</tr>
<tr>
<td>LSL</td>
<td>Lower Specification Limit</td>
</tr>
<tr>
<td>MET</td>
<td>Suomen Metalli-, Kone- ja Sähköteknisen Teollisuuden Keskusliitto (Federation of Finnish Metal, Engineering and Electrotechnical industries)</td>
</tr>
<tr>
<td>NPVCF</td>
<td>Net present value of the software quality revenues and costs or cash flows</td>
</tr>
<tr>
<td>NPVIC</td>
<td>Net present value of the initial investment and ongoing maintenance costs for the software quality initiative</td>
</tr>
<tr>
<td>OWT</td>
<td>Own Tool -software developed at Case Company B</td>
</tr>
<tr>
<td>PAF</td>
<td>Prevention – Appraisal – Failure -model</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed circuit board</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>PQC</td>
<td>Poor quality costs</td>
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<td>PSP</td>
<td>Personal software process</td>
</tr>
<tr>
<td>QC</td>
<td>Quality cost(s), quality costing</td>
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<tr>
<td>QFD</td>
<td>Quality function deployment</td>
</tr>
<tr>
<td>RQC</td>
<td>Real time quality costing</td>
</tr>
<tr>
<td>RES</td>
<td>Raytheon's Equipment Division</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>ROSQ</td>
<td>Return on Software Quality</td>
</tr>
<tr>
<td>SFS</td>
<td>Suomen standardisoimisliitto, The Finnish Union of Standardization</td>
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<tr>
<td>SPICE</td>
<td>Software Process Improvement and Capability dEtermination</td>
</tr>
<tr>
<td>SPIRAL</td>
<td>Software Process Improvement Research Action Laboratory</td>
</tr>
<tr>
<td>SQA</td>
<td>Software quality assurance</td>
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<tr>
<td>SQI</td>
<td>Software quality investment</td>
</tr>
<tr>
<td>SQM</td>
<td>Software quality maintenance</td>
</tr>
<tr>
<td>SQPI</td>
<td>The ratio of the present value of the difference between the software quality revenues and costs divided by the software quality investment</td>
</tr>
<tr>
<td>SQR</td>
<td>Software quality revenues</td>
</tr>
<tr>
<td>TCOQ</td>
<td>Total Cost of Quality</td>
</tr>
<tr>
<td>TEKES</td>
<td>Teknologian kehittämiskeskus (The National Technology Agency of Finland)</td>
</tr>
<tr>
<td>TQC</td>
<td>Total Quality Control</td>
</tr>
<tr>
<td>TQM</td>
<td>Total Quality Management</td>
</tr>
<tr>
<td>TSOSQ</td>
<td>Total Cost of Software Quality</td>
</tr>
<tr>
<td>UCD</td>
<td>User-centered design</td>
</tr>
<tr>
<td>UI</td>
<td>User interface</td>
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<tr>
<td>USL</td>
<td>Upper Specification Limit</td>
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<tr>
<td>WBS</td>
<td>The Work Breakdown Structure</td>
</tr>
<tr>
<td>VTT</td>
<td>Valtion Teknillinen Tutkimuslaitos (Technical Research Centre of Finland)</td>
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1 Introduction

1.1 Background

The explosive growth of the software industry in recent years has focused attention on the problems long associated with software development: uncontrollable costs, missed schedules, and unpredictable quality. To remain competitive, software firms must deliver high quality products on time and within budget. However, to bring their products to market more quickly, software managers may avoid quality improvement processes such as design reviews and code inspections, believing that these processes add only time to the development cycle. Certainly the economics of improving quality are not well understood in the software development world (Krishnan 1996). For example, a study on the adoption of the Software Engineering Institute’s Capability Maturity Model reports the following quote from a software manager: “I’d rather have it wrong than have it late. We can always fix it later” (Paulk et al. 1994).

Humphrey (1996) argues that when the quality of the parts of a software system is poor, the development process becomes fixated on finding and fixing defects. The magnitude of this fix process is often a surprise. As a result, the entire project becomes so preoccupied with defect repair that more important user concerns are ignored. When a project is struggling to fix defects in a system test, it is usually in schedule trouble as well.

Knowledge of the cost of quality deficiencies and insufficient features, the COQ (Cost of Quality) is a useful aid to identifying problem areas in business or organizational life. By studying the breakdown of these quality costs, one gains an opportunity to carry out effective improvement activities, dealing first of all with the problems which cause the highest costs. Once the company’s quality costs are determined, its employees and management realize the usually remarkably high costs incurred when the quality level is not the intended one. This realization can have positive effects on both motivation and improvement activities within the company (Sörqvist 1998).

The meaning of quality as improving the competitiveness of a company’s products and functions has become more apparent in the course of time. Because of this, the meaning of an effective quality control system has become more and more essential. One of the problems in improving and controlling quality, has,
however, been a lack of illustrative indicators, or parameters, with the aid of which it is possible to measure and follow quality and quality goals.

Information systems of companies have traditionally produced ample information concerning financial processes. The development of data systems has further improved the flow of internal information in firms. Also, the real processes of a company can now be more effectively brought under systematic control. This means that it is possible to set clear and measurable objectives, measure realization, report the differences between the objectives and realization, and perform corrective actions in accordance with the deviation.

The evaluation of a company’s quality situation can be made easier by using financial measurements. This is important because the terms used by quality professionals are unfamiliar to most of the people. The importance of quality can be explained to management by using quality costs. By using quality costs (Cost of Quality, COQ), management’s interest in quality improvement may hence be obtained. (Tervonen 1992: 2)

Crosby (1986: 40–41) states that the reason for management not being interested in quality has been the fact that quality practitioners have not been able to show the real size of quality costs and thus the meaning of quality as an important element of competition. Cost accounting based on earlier quality concepts has shown quality costs to be 2–4 per cent of turnover. According to Horngren-Foster-Datar (1994: 794), quality costs range from 15 per cent to 20 per cent of sales1 for many organizations. Modern, comprehensive cost accounting based on modern quality concepts has shown quality costs to be about 15–20 per cent of turnover in manufacturing companies and 35 per cent of operating costs in service companies (Campanella & Corcoran 1983: 17). In the electronics industry, quality transactions add up to some 25 to 40 per cent of manufacturing overhead (Cooper-Kaplan 1991: 348).

As can be seen, quality costs based on modern quality concepts seem very large. It is surprising if company management can make rational decisions based on knowledge that represents only the tip of the iceberg presented by older methods. If the source of information behind a decision is distorted, the decision has no chance to achieve the goals that were set. In addition, most COQ measurement systems in use do not trace quality costs to their sources (O’Guin

1 It is often difficult to state the exact percent of COQ because there are no universally accepted accounting techniques how to calculate quality costs. This causes a distortion of the COQ percents presented.
which prevents managers from identifying where the quality improvement opportunities lie.

1.2 Aim of the research and the anticipated contribution

The purpose of this study is to develop a model for measuring quality costs on a real time basis in software development. This is achieved by seeking answers to the following research questions:

1. How to measure quality costs on a real time basis in software industry?
2. How do the characteristics of software business impact on the accounting of quality costs?
3. How to use quality cost measurement as a management accounting tool in a modern software business environment?

Answers to the above questions are sought through the development of a theoretical framework and the analysis of the key concepts of the study. The thesis extends the current literature in three main respects.

First, the study presents the idea of measuring quality costs on a real time basis. Despite advances in quality management and systems, most managers still find it difficult to link quality development projects with expected economic returns (Ittner & Larcker 1996). Ittner (1999) considers the primary reason for this to be the lack of adequate methods for determining the financial consequences of poor quality. The literature on real time quality cost accounting is limited or even non-existent. In this thesis, the idea is demonstrated by developing a model for measuring the cost of quality on a real time basis in Case Company A (a constructive case study); and the boundary conditions for how to construct such a system in a totally different working environment are also charted in Case Company B. The constructive research approach (CRA) proposed by Kasanen et al. (1993) is used in a Case Company A that develops and produces packaged software used in embedded products. Since it is not typically possible to pass semi-strong or strong market tests within a medium-term time span, the construction is tested by using more detailed nuances within the weak market test category suggested by Labro and Tuomela (2003) in order to analyse the level of progress of the construct. As such, this dissertation also contributes to Labro and Tuomela’s (2003) study by using their weak market test testing method.

Second, a contribution is made by answering the research question how do the characteristics of software business impact on the accounting of quality costs
by presenting the nature and distinction of software business as well as its implications to software quality and applying quality cost measurement to software business. Malmi et al. (2004) argue that the COQ literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, batch after batch or customer after customer. Many modern businesses, however, are outright project based, or operate like a string of semi-independent projects characterized by unique resources, customized activity or work sequence order, and a predefined start and finish. In Case A of the thesis, the emphasis was mainly on the first type of contribution in Lukka’s (2000) classification – the construct itself is a novelty that it introduces an awareness of a completely new means to achieve certain ends. The anticipated contribution arises from the fact that the construct is a novelty that leads to a new means of quality cost accounting in the software business.

Third, this study is expected to make a contribution by answering the research question how to use quality cost measurement as a management accounting tool in modern software business environment. Malmi et al. (2004) follow the constructive approach suggested by Kasanen et al. (1993), considering the practice-relevant problem of managers having to justify investments in quality improvement (Ittner & Larcker 1996, Ittner 1999, cf. Kasanen et al. 1993). The construct developed by Malmi et al. – collaborative approach for managing project cost of poor quality – provides some indication of expected cost savings or expected reductions in resource consumption given that certain poor quality cost elements can be removed or the required proactive actions are successful (Malmi et al. 2004: 314). In this thesis, this point will be elaborated further by providing an indication of real time cost of quality information classified by software product versions, calendar time, quality cost categories, or by defect type. By using such information, the managers can gain a deeper understanding of (quality) cost behaviour in the software business. Regardless of the earlier research done considering quality costing, there is still limited evidence on how to use quality cost accounting as a management accounting tool.

1.3 The research process

The research process of the thesis can be divided into main stages. To be able to answer the above research questions, an extensive preparatory study was made of the approaches traditionally used to measure quality costs. Literature reviews
were conducted in areas including management accounting and industrial engineering, especially the TQM\(^2\) literature. The preparatory work was based on a literature review as well as on the researcher’s earlier experience in constructing quality cost measurement systems in case companies. The purpose of the preparatory study was to map the existing methods used for measuring quality costs and the experience gained through these methods. The researcher also wrote articles on quality cost measurement in various environments\(^3\).

After this came the question of directing the study to one branch of business. The researcher’s interest was the high-tech and software business, mainly because this branch of business is a fruitful research area; typically COQ in manufacturing industry range from 5 to 25 percent of company sales, which contrasts significantly with the cost of software quality (COSQ), which appears to be roughly twice as much as the manufacturing COQ. This originates mainly from the nature of the software development process. Literally, software is developed, not constructed. Because of this intuitive way to develop (=manufacture) software products, there are always some ambiguity and inaccuracy in the management point of view of software development. To study COSQ, the researcher must have knowledge of software development process and software quality. In the second research stage a great amount of literature concerning software development, software business, and software quality was read, software quality courses were taken and seminar papers written on the topic area. The software development process can be defined as a set of activities, methods and practices that are used in the production and evolution of a software product. Improving the quality of the software products is realized in software development by improving the quality of the software development process. This thesis offers an extrapolation of the manufacturing and service industries’ cost of quality model for the business of software development. To understand the quality level in software development processes the researcher had to familiarize himself with the common maturity models used in the software business. The researcher’s knowledge of software development and software maturity was gained by participating in the KÄYPRO (Development of an improvement approach for user interface development)

\(^{2}\) The total quality management (TQM) doctrine is based on customer satisfaction, continuous improvement, quality assurance, standardization and fact-based management (Dean and Bowen, 1994)

Maturity Model for Software project. The knowledge gained of the Capability Maturity Model for software (CMM), SPICE (ISO 15504-standard) and Bootstrap maturity models, and the Goal Question Metric (GQM) method was also gained by participating in the project. The KÄYPRO project was a project funded by the National Technology Agency of Finland (TEKES) in Infotech Oulu Software Process Improvement Research Action Laboratory (SPIRAL³), in which the Department of Information Processing Science in the University of Oulu and Technical Research Centre of Finland (VTT Electronics research institute) in Oulu participate. By participating in this project, the researcher has also gained knowledge of software usability and other software quality characteristics, as well as clarification of the path that leads through the jungle of dozens of various software quality standards.

Based on the information obtained, the research process was concentrated on the empirical research, which was done on two case companies, A and B. The empirical part of the dissertation process was started in 2001 at Case Company A and in 2005 at Case Company B. In this study, two case companies were selected. The selection process of cases is discussed in the empirical part of the study (in Chapter 5.2.1) Multiple cases are employed to strengthen the market test for the construct developed in Case A. With regard to empirical work, this phase resembled other case study methodologies in which deep understanding of the issues researched is pursued through observing, interviewing, studying archival material, etc. (cf. Lukka 1999). Over 40 hours of interview data was collected and analyzed in Case Company A before and during the model construction process.

The construction developed in Case A was also tested using more detailed nuances within the weak market test category suggested by Labro and Tuomela (2003) in order to analyse the level of progress of the construct. The possibility of constructing a real time cost of quality measurement system developed in Case A was also tested in another case company, Case B, to make the market test stronger, and the boundary conditions how to construct such a system in a totally different working environment were also charted.

³ SPIRAL - Software Process Improvement Research Action Laboratory is a joint research group between the Department of Information Processing Science in the University of Oulu and the Software Engineering Group of VTT Electronics focusing on software process improvement. The objective of the SPIRAL research group is to develop and disseminate new software process improvement approaches that: 1) combine and enhance the strengths of process assessment, goal-oriented measurement, process modelling and risk management; 2) develop methods for focused product quality driven process improvement; are tailored specially to embedded software development; and 3) can be applied in practice.
1.4 Theoretical framework

1.4.1 Methodological orientation

The methodological orientation of the thesis is discussed first on a general level by positioning the study within different scientific approaches. This is followed by a presentation of the empirical research methods. The evaluation of the study is done at the end of the thesis. The assessment of the contribution, reliability and validity of the study are discussed at the end of the thesis. Limitations of the study and avenues for future research are also presented there.

Swieringa (1998: 43) points to the fact that most academic researchers are invisible to wider audiences than their own colleagues (cf. Lee 2003). Malmi and Granlund (2006) argue that several years ago two studies took as their task to explicitly analyse the issue of how to conduct practice relevant management accounting research and produce theoretical contribution (theorize) accordingly. Kasanen et al. (1993) argued for a constructive research approach in management accounting (see also Labro & Tuomela 2003) and Kaplan (1998) for innovation action research, both sharing a normative agenda and an aim to contribute directly to practice through scientific MA (management accounting) research. As Kasanen et al. (1993: 262) summarize it, “...management accounting is, in the end, a practical field where theory without pragmatic implications is empty”. According to Malmi & Granlund (2006), these two pieces seem to have had a very limited impact on research practice ever after. They also argue (p.5) that despite its practical purpose, explicit or implicit, management accounting research is often criticized for not having an impact on practice, let alone leading it. I argue that this study tries to fill this gap. Methodologically, this dissertation represents constructive research approach (CRA) (see e.g. Kasanen et al. 1993, for the constructive approach), which is discussed below in Chapter 1.4.2.

Malmi and Granlund (2006: 28–29) argue that an alternative approach to creating theories useful for practice is to solve practical problems with practitioners and synthesize the novel solutions into a more general form. Recently, based on their screening of how knowledge tends not to accumulate in the management accounting domain in a fruitful manner, Lukka and Granlund (2002) suggested increasing reliance on the constructive approach. The studies applying constructive research approach (e.g. Malmi et al. 2004, Tuomela 2005, Uusitalo 2007, see also Labro & Tuomela 2003) commit to strong interventionist actions in the case organizations, and the researchers actively participate in the innovation
process of new management control constructs. This reflects a strong contention with regard to positive accounting research. The action research tradition prominent especially in Sweden (e.g. Jönsson 1996) is not far from the constructive approach, through typically implying weaker intervention and having no particular innovative element (see Jönsson & Lukka 2007).

Doing case research has a fairly long history. Its roots are in the fields of cultural studies and other social studies, in which qualitative research methods have been used for a long time. The key word here is ethnography, which in the classic mapping refers to such research which is conducted in direct relationship with the targets of research, through participant observation (Hammersley & Atkinson 1995). The characteristic features of case research include that a small number of research objects are studied in their real-life, temporal, and spatial contexts. In case research, the researcher has direct and in-depth contact with the target(s) of the empirical examination over a considerable period of time, and is her/himself a major research instrument. The researcher typically collects empirical material in multiple ways, which are mutually supportive: observation, interview, and analysis of archival data (cf. Yin 1984, Scapens 1990, Otley & Berry 1994, Chua 1996, Berry & Otley 2004, Scapens 2004).

For this study, two case companies were selected. Selection of cases is an important aspect of building theory from case studies (Eisenhardt 1989: 536). At one extreme, some researchers focus on single organizations or sites; at the other extreme, some have much larger samples. Ahrens and Dent (1998: 3) emphasize that small sample studies typically have different objectives from large sample studies; and researchers with a technical focus aim to capture different aspects of the relationship between systems and organization from those with an organizational focus. Small samples typically permit closer engagement with the field than large samples. Rich descriptions of organizational practice build on such closer engagement. Eisenhardt (1989: 537) states that the cases may be chosen to replicate previous cases or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types. While the cases may be chosen randomly, random selection is neither necessary, nor even preferable.

Footnote: In this study I draw on Silverman’s (1993) usage of the term qualitative in relation to methodology, which, in the management accounting literature, has, with minor variations, also been referred to as naturalistic, holistic, interpretative, and phenomenological. It stands in contrast to a positivistic approach to research.
The common denominator of all modes of case research is that they tend to apply all the data collection methods first mobilised by ethnographers: observation, interviews, and analysis of archival material of the case. Ethnographic research tends to always imply immersion in the world due to the participant observation feature of the approach (Hammersley & Atkinson 1995). However, in ethnography, intervention is nevertheless typically kept to a minimum: intervention tends to be viewed as a threat to the scholarly value of the study rather than as a research weapon (Lukka 2005).

Regarding the researcher’s empirical intervention, there are two basic positions in (management) accounting academia. The dominant one is based on the idea that the research should, and can, be objective and value-free. Accordingly, the aim of the researcher is to describe and explain, as well as potentially to predict, the existing reality, and thereby to develop a prior theory of the field in question, but not to be involved with attempts to change the world (e.g. Friedman 1953, Watts & Zimmerman 1986). This position leads to an attempt to eliminate the researcher’s empirical intervention. The dominance of the non-interventionist position can be seen, for instance, in the fact that the standard literature on case or qualitative research discusses the researcher’s intervention only in passing, if at all (see e.g. Yin 1984, Silverman 1985 2000, Marshall & Rossman 1989, Stake 1995, Hammersley & Atkinson 1995). Non-interventionist case research tends to focus on formulating, understanding (making sense of), and explaining management accounting issues on a conceptual level. The development of these understandings and explanations may have different kinds of theory connections. (Jönsson & Lukka 2007: 375). In order to make a contribution to theory, the findings of non-interventionist case research needs to be translated – i.e. generalized – so that their meaningfulness in other contexts can be captured by the reader (Lukka & Kasanen 1995).

The alternative, often overlooked position in management accounting academia, the interventionist position, which is used in this research, allows for the researcher’s active participative co-operation with the actors in the field. Jönsson and Lukka (2007: 375) argue that the key advantage of interventionist research is the opportunity to collect more subtle and significant data than what can be accessed through more traditional research methods. They also argue (p. 376) that interventionist research approaches offer the researcher a lot of potential to gain emic (insider) understandings of what is going on in the case organization. According to Lukka (2005), the core belief here is that the researcher’s intervention may offer him/her an effective route to the inner structures and
processes of the research target, thereby making him/her able to connect prior theoretical understanding with practical knowledge, know-how, possibilities, and purposes. The researcher’s intervention is viewed as a fruitful, at the extreme even indispensable necessary, avenue for relevant new knowledge. In addition to adding to our theoretical understanding, interventionist research projects tend to have practical purposes, too – there is often a strong desire to change the world in the picture. The adopters of the interventionist approach do not accept the need for necessarily striving for objectivity and value-freeness in research, since – they argue – these qualities tend to be only myths in research, and furthermore, it is useful for the social sciences researchers to explicitly open up their values in their research projects. In addition, it has been argued that the pragmatic test of the usefulness of knowledge should be actually viewed as scientifically strong (e.g. Susman & Evered 1978, Kasanen et al. 1993). These arguments are considered especially relevant in applied fields, such as accounting (Mattessich 1995). The dissertation represents an example of an interventionist mode of case research.

An interventionist researcher has to conduct him/her study simultaneously with the flow of life in target organization. This allows his/her to bypass many of the potential threats to quality and contribution inherent in the *ex post facto* type of studies. For instance, there are no recollection problems and the issue examined is certainly relevant and topical. The fact that the researcher is thoroughly immersed in the practical flow of life also decreases the risk that s/he will be treated as a ‘tourist’ in the field, with whom one should communicate with simplified ‘child talk’ – an interventionist researcher tends to be taken seriously (Lukka 2005). “... she is viewed as a seriously taken participant in this process, and if so, she will be treated and talked to like ‘one of us’” (Jönssön & Lukka 2007: 376).

Keating (1995) distinguishes between the various roles that a management accounting case study can have regarding theory: theory discovery, theory refinement, and theory refutation (=theory testing). Theory refinement is further divided into two options: theory illustration and theory specification. Keating views these variations of case research as forming an iterative and circular process. By “theory discovery case study” Keating refers to research aiming at mapping “novel, dynamic”, and/or complex phenomena ignored or inadequately explained by existing theories” (p. 70). He defines “theory illustration case study” (a variation of theory refinement) as the pursuit to “establish the plausibility of a specific theoretical perspective by demonstrating its capacity to illuminate some previously unappreciated aspect of management accounting practice” (p. 70) and
“theory specification case study” (another variation of theory refinement) as the pursuit “to refine a sparse, unspecified theory in order to make it amenable to broad scale statistical test or critical case test” (p. 70). Finally, by “crucial test/counterpoint case study” (aiming at theory refutation/testing), Keating refers to research attempting “to falsify or otherwise refute a well-specified theory (p.70). (Lukka 2005).

In the formation for mapping case research in management accounting, I will apply Lukka’s (2005) taxonomy which is based on Keating (1995) in a slightly modified manner. While for Keating theory refinement is one of the main categories including the sub-categories of theory illustration and theory specification, Lukka (2005) ‘raises’ theory illustration to one of the main categories. On the other hand, Lukka uses theory refinement as a category including several types of elaborations of existing theory – as not only referring to theory specification as defined by Keating (which looks unnecessarily positivist tuned to Lukka) and not including theory illustration at all. In addition, Lukka uses the notion ‘theory testing case’ rather than the narrowly ‘theory refutation case’ privileged by Keating. Hence, the idea of the theory development cycle goes here from theory discovery via theory illustration and theory refinement to theory testing.

Based on the above contemplations, Lukka mobilises two analytical dimensions, in light of which he will examine existing and potential case research in management accounting. These dimensions are the nature of the researcher’s empirical intervention, including the categories of non-interventionist and interventionist case research, and the theory linkage of the study, including the options of theory discovery, theory illustration, theory refinement, and theory testing case research. On this basis, he forms the following six-item taxonomy: theory discovery case research, theory illustration case research, theory refinement case research, theory testing case research, action research, and constructive case research. The first four variations of case research in management accounting in this list predominantly seek to minimise the empirical intervention of the case researcher. In them, empirical intervention is generally regarded as a potential threat to the validity and reliability of the study (cf. McKinnon 1988, Lukka 2005). For the remaining two alternatives of case research the intervention of the researcher is transformed into a research weapon and it is therefore deliberately applied, not avoided (cf. Lukka 2005). Interventionist approaches, applied with skill and care, have significant potential for producing a new understanding of management accounting practices, not least
due their inherent quality of ascertaining the topicality and relevance of the issues examined (Lukka 2005). In the next section, CRA is discussed more detail.

1.4.2 The constructive research approach

Kasanen et al. (1993) presented the constructive research approach (CRA) in order to assist management accounting academics in taking a more active role in improving existing practices. The CRA could be defined as a research procedure for producing novel entities, such as models, diagrams, and plans, that solve emerging problems in running business organizations (Kasanen et al. 1993). The CRA relies on a pragmatic notion of truth, i.e. ‘what works is true’, and the intervening role of researcher(s) is characteristic of the research process (Lukka 1999). According to Lukka (2000 and 2002) the pursuit of innovations in both practical and theoretical terms and an intensive attempt to draw theoretic conclusions based on the empirical work are cornerstones of CRA. While action researchers tend to describe their preferred mode of intervention as ‘limited intervention’, this has become stretched further in the constructive research approach. According to Lukka (2005: 389) the style of intervention is therefore strong. The ideal outcome of the empirical work in CRA is a solution construction to the original problem, which has been shown to work in practice, in the original, and has both high practical and theoretical value.

Lukka (2000), distinguishes the CRA from the innovation action research, which was introduced quite recently by Kaplan (1998). Innovation action research is something that can be done after constructive research, or some other process, has produced new constructs. Innovation action research develop and refine a theory of a newly discovered management practice that is believed to be broadly applicable to a wide variety of organizations.

Aims to make innovations and to make a theoretical contribution are major factors differentiating between consulting and CRA. In the former, it is common for an existing technique to be applied to a different context with marginal alterations to previously developed model (Eden & Huxham 1996).

Labro and Tuomela (2003) recognize that several management accounting innovations have, in fact, been developed by consultants. They emphasize that the development of new constructs is not usually a consultant’s most important aim, but is a core issue in the CRA. According to Eden and Huxham (1996), consultants tend to make an incremental transfer from one specific context to another, without raising broader issues in a wider variety of contexts or raising
issues of linkage to broader statements made by others. They have neither time nor motivation to connect findings to theory since they do not feel obliged to publish their ideas (cf. Kaplan 1998). Additionally, Westbrook (1995) identifies five basic differences between consulting and action-type research. (Labro & Tuomela 2003).

First, the goal of consultants is not to develop new theory but to report an application. Second, consultants only report on success, and the paths and obstacles to success are rarely explored. Researchers also describe and analyse failed projects in order to learn from them (e.g. Malmi 1999, Olesen & Myers 1999, Kasurinen 2002). Third, consultants rarely describe sufficient context to permit the reader to assess the potential for generalization and make comparisons with other reported situations. Fourth, the consultant shares a single common goal with the company, the completion of an analysis and/or the implementation of change. The researcher will have this goal as part of a larger primary goal, which the company may not share, i.e. the discovery of new knowledge. Fifth, researchers should not charge any fees, at least not more than the costs incurred (see Labro & Tuomela 2003). Kaplan (1998) disagrees with the fifth point and argues that compensation builds commitment. Finally, Mouritsen et al. (2002) point out the researchers’ advantage over consultants and other tradesmen in knowledge: being critical. Researchers reflect on the conditions of the knowledge it produces and on the validity claims of its propositions rather than concentrating on the saleability of solutions and knowledge (Labro & Tuomela 2003).

Labro and Tuomela (2003: 418) point out that addressing both practical and theoretical progression is not very common in the prevailing management accounting research. On the other hand, most (management) accounting researchers have concentrated solely on identifying the potential for theoretical contribution. This is, of course, not their ‘fault’, but mirrors the requirements for publications in well-established journals. On the other hand, the seminal article on the CRA (Kasanen et al. 1993) somewhat excessively (and deliberately in order to evoke discussion) addressed the practical problem-solving perspective. Their conclusion is that the origins of a constructive study may lie either in practice or theory. In both cases, the essential issue is that after identifying the first need, be it practical or theoretical, this is complemented by ensuring that there is also a possibility for genuinely novel insights in the other dimension.
1.4.3 **Specific steps in constructing the real time cost of quality measurement model**

By identifying specific steps in the constructive research approach, it is easier to point out important issues related to particular parts of my research process. There are seven crucial steps in the CRA (Kasanen *et al.* 1993, Lukka 2000, 2002\(^6\)).

1. to find a practically relevant problem which also has research potential;
2. to examine the potential for long term research co-operation with the target organization;
3. to obtain a general and comprehensive understanding of the topic;
4. to innovate and construct a theoretically grounded solution idea;
5. to implement the solution and test whether it works in practice
6. to examine the scope of the solution’s applicability;
7. to show the theoretical connections and the research contribution of the solution

While it would be possible to discuss any research approach exclusively in terms of reliability and different dimensions of validity or purely in terms of theoretical linkages and empirical procedures, it is useful to take the research process as the starting point for analysis (see e.g. Labro & Tuomela 2003). In this way, we can address different methodological aspects, such as theoretical connections, while keeping a practical focus on doing constructive research (see Ahrens & Dent (1998) for a similar approach).

Labro and Tuomela (2003: 415) emphasize that these seven steps are a powerful means of bringing forward the key points in studies made using the constructive research approach. Steps 3, 4 and 5, for example, are related most of all to ensuring internal validity, while the sixth step explicitly brings forward the need to deal also with external validity. Most steps are partly overlapping with the previous and following phases of the research process. The third step – obtaining a profound understanding of the topic – continues throughout the entire research process. In addition, developing a theoretical understanding is likely to have started well before the actual constructive research process. Similarly, the seventh step, showing the theoretical contribution(s), covers the entire research process. This step means that theoretical linkages should be considered throughout the

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\(^6\) Originally, Kasanen *et al.* (1993) mentioned six steps in conducting constructive research. Lukka (2000) complemented these by adding a new step, examining the potential for long term co-operation, to this prescription.
research process in order to make the project meaningful to the research community, even though the exact theoretical contribution can be elaborated on only in the final part of the research process.

In the empirical part of the thesis, certain particularities of the study are discussed that I consider to be of prime relevance to the conduct of constructive case research. With regard to each step, I will outline methodological imperatives given in the literature, describe the conduct of the study, and finally draw certain conclusions. The seven step approach (Kasanen et al. 1993, Lukka 2000, 2002) will be used in presenting the working process and evaluating the construction developed at Case Company A. As follows, the specific steps in constructing the real time cost of quality measurement model, are briefly presented.

1. To find a practically relevant problem which also has research potential

At the core of any constructive research project lies a practical problem. The development challenge should be, as Labro and Tuomela (2003: 416) point out, directly relevant to managers or other decision-makers. On the other hand, the problem should possess theoretically significant potential to be solved (Kasanen et al. 1993): there should not be an obvious solution available in the literature (Lukka 2000). Labro and Tuomela (2003: 438) argue that at the core of CRA is the pursuit of novel innovations. Transferring an existing technique from one field of science to another can be considered novel if it requires adding completely new knowledge and features to the model. Applying an existing construct as such to another organization may be good consulting work or part of an innovation action research (Kaplan 1998) but it should not be considered to be constructive research. Labro and Tuomela (2003: 416) point out that while earlier articles about the CRA heavily emphasize practical relevance, they do not indicate how researchers can find companies with interesting problems.

The practical relevance of the problems identified was rather obvious in this case study since the request for the development work came from the manager responsible (cf. e.g. Labro & Tuomela 2003). Consequently, a comprehensive study of the company’s quality costs was needed for practical purposes. The researcher’s expectations and the financial managers’s views about prevailing problems in quality cost accounting were also supported by other managers of the company. As Labro and Tuomela (2003: 418) point out, much of the contribution of constructive research rests on the premise that both instant practical progress and direct theoretical contributions are sought. In point of fact, this is a major differentiating factor between the CRA and consulting (which puts emphasis on
practical contribution) or the majority of other research methods (which have emphasis on theoretical contributions which may have some, but need not necessarily have any, (in)direct practical consequences). Accordingly, it is important that constructive researchers ensure that both kinds of contributions are indeed available. If not, it is possible that the empirical work may be discontinued or that the results of the study may not be interesting enough to warrant publication.

2. To examine the potential for long term research co-operation with the target organization

The second step in constructive research is to examine the possibilities for longitudinal co-operation with the case organization(s). Labro and Tuomela (2003: 418) emphasize that gaining and maintaining the commitment of the case company is crucial in order for the research process to be successful (cf. e.g. Lukka 2000). A possible way of ensuring commitment is to charge for the researcher’s services (Puolamäki 2000). Kaplan (1998) argues that compensation builds commitment. However, there may be some danger that a commercial consultancy relationship, with its inherent problems, will develop (Westbrook 1995). In Case Company A, a fixed fee was payed to the project researcher for a certain period of time. By so doing, commitment was ensured both for the company and researcher. The compensation was not, however, a primary issue from the perspective of either the company studied or the researcher, and the course of events how to conduct the research process was not limited in any way during the research process.

3. Obtaining a general and comprehensive understanding of the topic

Becoming familiar with both the practical and the theoretical underpinnings of the topic constitutes the third step in the CRA (Labro & Tuomela 2003). According to Lukka (2000: 117, see also Lukka & Tuomela 1998) this phase is very different from consulting assignments in terms of the more extensive theoretical and empirical groundwork. The researcher needs solid ex-ante knowledge of theory in order to make informed interventions (Dickens & Watkins 1999) during the research process. In addition, even though the innovation phase may be very heuristic (Kasanen et al. 1993), knowledge of the existing literature is needed in order to analyse the theoretical contribution of the study.

In this study, previous knowledge of the relevant literature had been accumulated before the empirical research phase began. The researcher’s
Licentiate thesis (Sippola 2000) offered an extrapolation of the management and service industries’ COQ Model for the business of software development. As this research (Sippola 2000) presented a theoretical framework for quality cost measurement in the software business, and reported results obtained from other companies, it was obtained that there is still an obvious avenue for future empirical research. This research partly lowered the doorstep for the researcher to gain access to Case Company A. Issues considering quality cost measurement had been familiar to the researcher since 1994, when his master’s thesis (Sippola 1994) was published. Knowledge of the literature was complemented by attending both academic and non-academic conferences, seminars and workshops. Congress papers (Sippola 2001, 2003, 2005, and 2007) were also written during the research process.

With regard to empirical work, this phase resembles other case study methodologies in which deep understanding of the issues researched is pursued through observing, interviewing, studying archival material, etc. (Lukka 1999). In Case A, the data collection process was meticulous, involving long periods in the field. The interviewees had time to get used to the presence of the researcher in both case companies. As McKinnon (1988) states, the longer the researcher spends in the studied context, the less vulnerable the study is to factors that jeopardize its reliability and validity. Some modernization is advisable, however. The notorious tale of the sociologist being finally rediscovered in a Borneo jungle wearing a hula-hula skirt and a ring in his nose warns us about the threat of Going Native. McKinnon (1988) states that researchers undertaking qualitative studies must maintain an appropriate distance from the studied context.

In the study, I also noticed the fact raised by Lukka (2005) that the interventionist researcher is thoroughly immersed in the practical flow of life; this also decreases the risk that s/he will be treated as a ‘tourist’ in the field.

4. Innovating and constructing a theoretically grounded solution idea

An intensive search for a (both practically and theoretically) innovative solution is the primary feature distinguishing constructive research from other types of action research and most consultancy work (Labro & Tuomela 2003). Consequently, Labro and Tuomela (2003) emphasize that the aim of developing a basic model picked up from a textbook would not meet the criteria of constructive research, even if this construct would be something new to the firm in question. Lukka (2000, 2002) argues that the innovation phase is a creative, and possibly even heuristic sequence of events during which co-operative teamwork between the
researcher(s) and company managers is crucial. The above mentioned points were also important in Case A.

5. Implementing the solution and testing whether it works in practice

Since constructive research relies on a pragmatic view of truth, the implementation phase is an elementary part of the research (Lukka 2000). Moreover, the phase of trying out the construct is critical, since even a failed implementation test may turn out to be theoretically interesting (Lukka & Tuomela 1998). It should be borne in mind that the implementation test has a twofold purpose: a successful implementation means both that the research process has been successful, at least with regard to the most critical factors, and that the construct has been technically feasible (Lukka 2000, 2002).

Shields (1995) argues that when a new management accounting construct is implemented and taken into use, it means that a management accounting change is taking place. In order to cope with the challenges of change, the researchers need to be alert not only to the technical issues but to the behavioural and organizational variables that are likely to play a paramount role in the pursuit of successful implementations. In addition to addressing and taking advantage of the basic advancing forces of change, i.e. motivators, catalysts and facilitators of change (Innes & Mitchell 1990), the role of leaders and the need for a momentum for change should be acknowledged (Cobb et al. 1995). Moreover, a profound analysis of potential barriers to change, i.e. confusers, frustrators and delayers of change, is useful when implementing a construct (Kasurinen 2002).

6. Examining the scope of the solution’s applicability

Labro and Tuomela (2003: 429) emphasize the point made by Lukka (2000), that the researcher(s) should become detached from the empirical data and consider the wider implications, i.e. external validity. The sixth step involves discussing those aspects of the construct that could be transferable to other organizations. In the case of failed implementation, it is possible to consider implementation problems that are also likely to emerge in other organizations.

In their seminal article, Kasanen et al. (1993) make a case for market-based validation of managerial constructs. The weak market test is passed when a manager is willing to apply the construct to his or her actual decision-making problem. Lukka (2000, 2002) has specified that the weak market test should really refer to the actual implementation of the construct, rather than the willingness to implement it. The semi-strong market test is passed if the construct is widely
adopted by companies. Passing the strong market test requires that the businesses applying the construct produce better results than those that are not using it. The third test seems very harsh, as even for widely accepted concepts or techniques such as ABC, just in time and total quality, researchers have found it very hard to measure the exact financial benefits resulting from the introduction from the construct, as these are confused with other business processes (e.g. Balakrishnan et al. 1996, Huson & Nanda 1995, Rust et al. 1995, Easton & Jarrell 1998, Reed et al. 1996, Kennedy 1997).

Lukka (2000) argues that in a constructive case study, it is practically impossible to go beyond the weak market test, where the main issue is whether or not the company has adopted the construct. Labro and Tuomela (2003: 438) add that the innovation action research approach (Kaplan 1998) could later be used to complement the constructive studies. Lukka and Kasanen (1995) emphasize that constructive case researchers can and should assess the transferability of their construct, at least to some extent. This is true even if the final applicability judgement (of the construct) resides with the reader, who is the only expert on his/her own circumstances. By providing a rich description of the research process and case context, constructive case researchers can provide important guidance in making the judgement on transferability. Lukka (2000) argue that external validity can and should be considered as early as the research design phase.

There is a wider applicability of the construct developed in case A, since in most software companies the software development process is a labour-intensive process, and the most of the quality costs come from finding and fixing defects. The applicability of the construct is also tested in Case B in the Chapter 6 of the thesis. The results show that the construction built in Case A could be constructed irrespective of the cost accounting environment or the software used.

7. Showing the theoretical connections and the research contribution

According to Lukka (2000), there are two primary ways of contributing to theory in constructive studies. First, it is possible that the construct itself is of such novelty that it introduces an awareness of a completely new means to achieve certain ends. This is the fundamental purpose of applied science (Mattessich 1995). Second, a constructive case study can serve the purpose of developing, illustrating, refining or testing a theory or theories (Keating 1995). Through the pragmatic implementation test, the underlying positive relationships are also tested. In this way, both successful and failed implementations may turn out to be
interesting and lead to the refinement, maybe even the discarding, of theories and proposals of new theories (Lukka 2000 2002).

Malmi et al. (2004) argue that the COQ literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, batch after batch or customer after customer. Many modern businesses, however, are outright project based, or operate like a string of semi-independent projects characterized by unique resources, customized activity or work sequence order, and a predefined start and finish. In Case A, the emphasis was mainly on the first type of contribution in Lukka’s (2000) classification. The construct is a novelty that leads to a new means of quality cost accounting in the software business. In addition to this, the identification of the quiddity of software business, e.g. the fact that software is developed, not constructed (Humphrey 1989), and software quality is also important, as quality cost measurement has so far only been modelled using ex-post calculation methods. This study also contributes to theory in the second way. An attempt is made to elaborate theory on linking software quality issues to quality cost measurement.

1.5 Structure of the study

The rest of the dissertation is organized as follows. The second chapter presents the concept of quality, summarizes the research done on quality cost accounting and explains the characteristics of software products and processes and various software quality models and standards for software quality. The chapter answers questions regarding the main characteristics of the software business compared to other businesses, the characteristics of software quality, and how the characteristics of the software business impact on the accounting of quality costs.

After this, the third chapter, cost of quality measurement in traditional cost accounting and in a activity based accounting environment, presents various approaches of measuring COQ, and the results of the research done on describing the role of the cost accounting environment in accounting of quality costs. The chapter presents a conceptual framework for measuring quality costs in various cost accounting environments.

The fourth chapter is a description of the cost of software quality measurement. The section presents the benefits of using COSQ and an example of a COSQ chart, and the empirical results gained from the research done in the
field. The chapter explains why the recognition of quality costs is a key issue in the software business.

After this, the idea of real time quality cost accounting is presented in Chapter Five and the construction developed in Case Company A is tested using the detailed nuances within the weak market test category suggested by Labro and Tuomela (2003) in order to analyse the level of progress of the construct. The chapter answers research questions on how to measure quality costs on a real time basis in the software industry and how to use quality cost measurement as a management accounting tool in a modern software business environment. The results of the empirical research done in Case Company A are presented there.

In the sixth chapter the possibility of constructing a real time cost of quality measurement system as developed in Case A is tested in another case company (Case B), and it is investigated if and how such a system could be built in a totally different working environment.

The seventh chapter presents the main findings of the thesis, and discusses the potential insights, and provides a basis for assessing the contribution of the study. Evaluation of the study and limitations of the research, as well as avenues for future research are also presented there.
2 Concept of quality, quality cost accounting and quality in the software business

2.1 Concept of quality: contents and essential nature

Despite the interest of managers, quality remains a term that is easily misunderstood. In everyday speech, its synonyms range from luxury and merit to excellence and value. Different companies also appear to mean different things when they use the word, as do different groups within the same firm. Without further refinement, continued ambiguity and confusion are inevitable. (Garvin 1988: 39)

A better understanding of the term is therefore essential if quality is to assume a strategic role. The academic literature on the subject provides a convenient starting point; moreover, it has seldom been reviewed extensively. The problem is one of coverage. Scholars in four disciplines – philosophy, economics, marketing, and operation management – have explored quality, but each group has viewed it from a different vantage point. Philosophy has focused on definitional issues; economics, on profit maximization and market equilibrium; marketing, on the determinants of buying behaviour and customer satisfaction; and operations management, on engineering practices and manufacturing control. The result has been a host of competing perspectives, each based on a different analytical framework and employing its own terminology. (Garvin 1988: 39)

If quality is to be managed, it must first be understood. Conventional wisdom is seldom sufficient. It frequently points in wrong directions or is otherwise incomplete. If managers hope to succeed, they must first move aggressively to improve their understanding of quality practices and performance. They need to acquire more detailed information about consumer’s views, competitor’s quality levels, and especially the sources of their own quality performance. Conscious experimentation may well be required to distinguish effective from ineffective practices. Such efforts are likely to be costly and time-consuming, but they are essential if real progress is to be achieved. (Garvin 1988: 221–222)

With a unanimous, clear definition of quality, the phenomenon of management could more easily be viewed. Quality would thus be conceptualized and described easily: ‘this is quality’. Unfortunately this is not how things are. A general definition can not be offered for quality simply because the unanimous definition of quality does not exist, and secondly because a unanimous definition
is very difficult – almost an impossible mission on the basis of present knowledge. A lot of difficulties are met in defining the quality concept because the concept is complex and indistinct. (Savolainen 1992: 6)

As follows, some definitions of quality preceded in the literature are presented: In the dictionary of the new Finnish language, the Association of Finnish Literature, (1978: 7) quality has been determined as follows: those features, which do something only because of what it is, or which essentially belong to something; those things that give something its essential nature, or which is essential for something.

Juran (1988: 2) defines quality as follows: Quality consists of those product features which meet the needs of customers and thereby provide product satisfaction. Quality consists of freedom from deficiencies. Crosby (1979: 17) has defined quality as: Quality is conformance to requirements. Juran’s quality definition is thus larger than Crosby’s. Feigenbaum (1983: 7) defines quality: The total composite product and service characteristics of marketing, engineering, manufacture, and maintenance through which the product and service in use will meet the expectations of the customer. Horngren et al. (1991: 912) define quality as: Quality of a product or service means its conformance with a prespecified (and often pro announced) standard.

SFS-ISO 8402 -quality standard (1988: 2) defines quality as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. In the ASQC’s (1977 and 1987) guides for reducing quality costs, it is said concerning the definition of quality, that in the majority of cases quality is meant to be conformance to drawings and plans. However, quality is understood in the broader sense of the word in these guides, and it means fitness for customer’s use (Tervonen 1992a: 10). In the survey among Finnish quality experts in 1992 the definition of quality includes both the qualities of functions. Customer satisfaction had the largest approval (Tervonen 1992b: 10). Schonberger states: “Quality is like art. Everybody stands for it and recognizes it when they see it, but everybody defines it in a different way” (Schonberger 1989: 157). As can be seen, quality as a concept is very complex and varied. To be able to measure quality, it must first be defined. If quality can not be measured, how can we separate good and poor quality? (Lillrank 1990: 39)

7 The original definition in Finnish: “Ne (ollainaiset tai tilapäiset) ominaisuudet, jotka tekevät jonkin siksi, mikä se on, tai jotka ollainaisesti kuuluvat johonkin; se, mikä antaa jollekin sen ollainaisen leiman tai on ominaisuus jollekin.”
2.1.1 Multiple definitions of quality

Five principal approaches to defining quality can be identified: manufacturing-based, product-base, value-based, transcendent, and user-based (Garvin 1988: 40). According to Lillrank (1990: 41) quality can be defined from six different approaches. All of these approaches have their own advocates in the company organization. These dimensions do not exclude each other. In practice, one of these definitions receives priority, and this is how it actually should be: the production manager must emphasize quality of production, and marketing must defend the customers point of view. It is good for the company to emphasize the definition which is the most suitable for the company’s products and market. Quality management is needed just because it is important to fix these different viewpoints together to get the best combination. (Lillrank 1990: 41)

From the management point of view, the different approaches to quality create both needs and chances for management, because the different approaches (or absence of different approaches) also causes problems. The ideas of quality from the different functions in the organisation often differ from each other. These different kinds of approaches can be used in trying to make solutions to different kinds of problems in the company. (Savolainen 1992: 12–13)

Manufacturing-Based quality

Virtually all manufacturing-based definitions identify quality as ‘conformance to requirements’. Once a design or a specification has been established, any deviation implies a reduction in quality. Excellence is equated with meeting specifications and with ‘making it right the first time’. (Garvin 1988: 44)

While the manufacturing-based approach recognizes the consumer’s interest in quality – a product or service that deviates from specifications is likely to be poorly made or unreliable, providing less satisfaction than one that is properly constructed or performed – its primary focus is internal. This is a serious weakness, for little attention is paid to the link, in the customers’ minds, between quality and product characteristics other than conformance. Rather, quality is defined in a manner that simplifies engineering and production control. On the design side, this has led to an emphasis on reliability engineering. On the manufacturing side, it has meant an emphasis on statistical quality control. Both techniques are designed to weed out deviations early. The former, by analyzing a product’s basic components, identifying possible failure modes, and then
proposing alternative designs that enhance reliability. The latter, by employing statistical techniques to discover when a production process is performing outside acceptable limits. (Garvin 1988: 45, Lillrank 1990: 42)

Each of these techniques is focused on the same end: cost reduction. According to the manufacturing-based approach, improvements in quality (which are equivalent to reductions in the number of deviations) lead to lower costs, for preventing defects is viewed as less expensive than repairing or reworking them. Firms are therefore assumed to be performing sub-optimally. (Garvin 1988: 45) The limitation on the manufacturing-based approach is that quality is dependent on the knowledge and ability of the product designers and process engineers, and the competence of the standards that they have developed. If the standard is defective, the product will be defective, although it is very well done according to the specifications. Crosby, as well as Deming, Juran and Feigenbaum, represents the manufacturing-based quality approach as well as the Japanese Taguchi. (Lillrank 1990: 42)

Product-Based quality

According to the second definition of quality, product-based, quality is seen as a precise and measurable variable. This means that quality is the sum of product characteristics. Quality is included in the standards and in the product concept. (Garvin 1988: 42, Lillrank 1990: 42–43). This approach lends a vertical or hierarchical dimension to quality, for goods can be ranked according to the amount of the desired attribute they possess. An unambiguous ranking, however, is possible only if the attributes in question are ranked in the same order by virtually all buyers. Product-based definitions of quality first appeared in economics literature, where they were quickly incorporated into theoretical models. In fact, the early economic research on quality focused almost exclusively on durability, simply because it was so easily translated to the above framework. Since durable goods provide a stream of services over time, increased durability implies a longer stream of services – in effect, more of the good. Quality differences could therefore be treated as differences in quantity, considerably simplifying the mathematics. (Garvin 1988: 42)

Because a product-based quality approach does not take customer satisfaction into consideration, it may cause dramatic effects to the company. Paul Lillrank gives an example of this: the Swiss watch industry was in trouble as it did not understand that customers did not respect the features of Swiss watches, but
customers preferred the cheap price, the large quantity of different models and the type of features. The basic idea of the product-based quality approach is that the customer buys the product. But it is more fit to say that the customer buys satisfaction for his or her needs. If alternative ways of satisfying needs appear, customers may also reject a fine product. (Lillrank 1990: 43)

Value-Based quality

The value-based approach defines quality in terms of costs and prices. Thus, a quality product is one that provides performance or conformance at an acceptable price or cost. By this reasoning, a $550 running shoe, no matter how well constructed, could not be a quality product, for it would find few buyers (Garvin 1988: 45). The value-based quality approach is important because it does not handle quality as an abstract matter, but fixes it to price and the purchasing power of customers. (Lillrank 1990: 43–44).

A survey of consumer perceptions of quality in twenty-eight product categories suggests that the value-based view is becoming more prevalent. The study’s overall conclusion was that ‘quality is increasingly apt to be discussed and perceived in relationship to price.’ (Garvin 1988: 46)

Competition-Based quality

According to the competition-based approach, quality is seen as relative for the customer and strategic for the company. The customer compares the price-quality level to competitors’ levels. The company for its part must pay attention to its competitors (Savolainen 1992: 12). The weakness of the competition-based definition is that the company may try to imitate and copy its competitors: if the competitor drops the price, one must follow; if the competitor brings new products to market, one must always try to keep up. The competition-based company easily gives up making initiatives. (Lillrank 1990: 44)

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**User-Based quality**

User-based definitions start from the premise that quality ‘lies in the eyes of the beholder.’ Individual consumers are assumed to have different wants or needs, and the goods that best satisfy their preferences are the ones they regard as having the highest quality. This is an idiosyncratic and personal view of quality, and one that is highly subjective (Garvin 1988: 43). According to the user-based approach, quality is the ability of the product to satisfy the needs and wants of the customer. A quality product satisfies the customers needs so much that they will buy the same brand name again and again (Lillrank 1990: 44). The user-based approach also has restrictions. The observation of the current needs of the customer will not lead the firm to radical innovations, because customers may not want such things that do not exist. (Lillrank 1990: 47)

In the marketing literature, the user-based approach has led to the notion of ‘ideal points’: precise combinations of product attributes that provide the greatest satisfaction to a specified customer. In the economics literature, it has led to the view that quality differences are captured by shifts in a product’s demand curve. And in the operations management literature, it has given rise to the concept of ‘fitness for use’. Each of these concepts, however, faces two problems. The first is practical: how to aggregate widely varying individual preferences so that they can lead to meaningful definitions of quality at the market level. The second is more fundamental: how to distinguish those product attributes that connote quality from those that simply maximise consumer satisfaction9 (Garvin 1988: 43).

**Environmental-Based quality**

In the environmental-based quality concept all the effects, which the product will cause to the environment and to society, will be considered (destroying non-renewable natural resources, recycling, healthiness) (Savolainen 1992: 12). The environmental-based quality concept measures quality on the grounds of clear standards and indicators. Thus the quality of the product will not only be defined by the needs and requests of the customer, but also the outside quarters. Quality is not in the product, it is the way the product will adapt to the ecosystem. (Lillrank 1990: 49)

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9 For more about this problem, see Garvin 1988: 43-44
In this research, quality is defined as User-Based: the goal of quality is to totally satisfy the needs and requirements of both external and internal customers, combined with faultless action in the all functions of the company.

2.1.2 Total Quality Management as a way of thinking

Many manufacturing organizations have adopted total quality management (TQM) to compete in markets characterized by improved quality and service attributes, often at highly competitive prices. The approach to ensuring that quality is provided in terms of both market results and the means to this end has elevated quality to a strategic competitive variable (Conti 1993). A challenge for management accounting has been to ensure that managerial performance measures are relevant to these developments in TQM. (Chenhall 1997).

A distinctive characteristic of international markets is the increased requirement from consumers for high quality products and services without concomitant increases in prices (Johnson & Thomas 1988, Hayes et al. 1988, De Meyer et al. 1989, Drucker 1990, Hall et al. 1991). With the growing awareness that quality of final products and services is a strategic competitive variable, companies have recognized also that the concept of high quality must be applied to production processes to generate quality products and minimize costs. (Chenhall 1997). TQM has evolved as a philosophy that emphasizes the need to provide customers with highly valued products and to do so by improvements in efficiency by way of eliminating waste, reducing lead times at all stages of the production process, reducing costs, developing people, and improving continuously (Crosby 1984, Hayes & Wheelwright 1984, Schonberger 1986, Gerwin 1987, Hall 1987, Maskell 1989, Harmon & Peterson 1990).

Oakland (1993: IX) argues that continuous cost reduction, productivity and quality improvement have proved essential for organisations to stay in operation. We cannot avoid seeing how quality has developed into the most important competitive weapon, and many organizations have realised that TQM is the way of managing for the future. TQM is far wider in its applications than assuring product or service quality – it is a way of managing business processes to ensure complete ‘customer’ satisfaction at every stage, internally and externally.

In the literature of quality management a number of characterizations of TQM can be found (Savolainen 1992: 25). Many of the ‘gurus’ appear to present different theories of quality management. In reality they are all talking the same ‘language’ but they use different dialects, the basic principles of defining quality
and taking it into account throughout all the activities of the ‘business’ are common. (Oakland 1993: X)

According to Savolainen (1992: 25) TQM is based on the User-Based approach of quality is a wide idea of quality. TQM can be seen as a way of thinking, as well as politics, manner of proceedings, and a number of tools, which can be implemented to control quality. TQM is a way of approach that concentrates on total commitment of the organization. The aspiration is to improve the efficiency and flexibility of the whole business. The matter in question is about the change of attitudes and skills so that the organizational culture will be changed to prevent errors and do things right the first time. Oakland (1993: 22–23) argues that the organization that believes that traditional quality control techniques, and the way they have always been used, will resolve their quality problems is wrong. TQM is far more than shifting the responsibility of detection of problems from the customer to the producer. It requires a comprehensive approach that must first be recognized and then implemented if the rewards are to be realized. TQM is an approach to improving the competitiveness, effectiveness and flexibility of a whole organization. It is essentially a way of planning, organizing and understanding each activity, and depends on each individual at each level. The impact of TQM on an organization is to ensure that the management adopts a strategic overview of quality. The approach must focus on developing a problem-prevention mentality.

TQM can be defined as a certain attitude, a way of thinking, that must first to be understood and then implemented. Different techniques are necessary, and tools are needed for implementing a TQM-way-of-thinking, but those tools are not the first place presuppositions (Savolainen 1992: 33–34). According to Munro-Faure (1992: XII–XIV) it is only possible to develop a TQM environment with the absolute commitment of management and all employees. The organisation needs to be flexible and adaptable, continuously seeking to improve. There are a number of key elements that help management to produce a TQM environment: a strong framework to retain order and control, the continuous striving for improvement and the adaptability to change to ensure the organisation responds to customer requirements.

2.2 A review of quality cost research

Research considering quality costing has been published in management accounting literature but also a substantial amount of research has been published
in the field of production economics (industrial economics) and also in software engineering (information processing science). Because of this, the literature review in chapter 2.2 is organized as follows. First, a short description of the history of quality cost accounting is made in chapter 2.2.1. Second, studies over quality costing in the field of management accounting literature are reviewed in chapter 2.2.2. Third, the body of literature dealing with quality costing in other fields, mainly in production economics and software engineering, is reviewed in chapter 2.2.3.

### 2.2.1 History of quality costing

One of the first publications on financial effects of quality, Economic Control of Quality of Manufactured Product, was written by Shewhart in 1931 (Tervonen 1992: 9). One of the earliest writings pertaining to the general concept of quality costs can be found in Dr. J. M. Juran’s Quality Control Handbook, Chapter I, ‘The Economics of Quality’. Most other papers and articles of that time dealt with more narrow economic applications. Among the earliest articles on quality costs systems as we know them today are W. J. Messer’s article of 1957, ‘The Quality Manager and Quality Costs’, Harold Freeman’s paper of 1960, ‘How to Put Quality Costs to Use’ and the Chapter 5 in Dr. A.V. Feigenbaum’s classic book, ‘Total Quality Control’ (Campanella 1990: 1–2). The most significant stage of development was the introduction of the (now traditional) four quality costs categories. Feigenbaum is one of the firsts who performed this categorization. (Tervonen 1992: 9)

In December 1963, the U.S. Department of Defence issued MIL-Q.9858 Quality Program Requirements, and made ‘Costs Related to Quality’ a requirement for many government contractors and subcontractors (for review, Campanella 1990: 2). This document helped the contractors and subcontractors to focus attention on the importance of quality cost measurements, but provided only a general approach to their implementation and use. It did, however, serve to elevate interest in the subject of quality costs.

The American Society for Quality Control (ASQC) Quality Cost Committee was formed in 1961 to dramatize the magnitude and importance of product...
quality to the well-being of manufacturing business through measurements of the
cost of quality (Campanella 1990: 2). In 1967 the ASQC published ‘Quality Costs –
What and How’ in which quality costs are defined only by category and by
reference to Feigenbaum. This booklet was revised in 1970 and 1974, and it may
still be the most definitive work on the subject, even if it does not include all the
cost elements that might be identified as being quality related in a total approach
to management of product and service quality. The fact that the emphasis is on
measuring and reducing (or optimizing) the major quality cost categories and
elements, rather than on the currently more popular quality cost improvement
projects approach, does not invalidate or detract from the value of the strategy or
advice in any way (Dale & Plunkett 1991: 8–9). Other ASQC publications that
deal best with practical aspects on how to do quality costing are ‘Guide for
Reducing Quality Costs and ‘Guide for Managing Supplier Quality Costs’ (Dale
& Plunkett 1991: 9).

The British Standards Institution’s publication – BS 6143 ‘Guide to the
Determination and Use of Quality Related Costs’ (1981 issue) – is in many
respects an abridged version of ‘Quality Costs – What and How’; and is according to
Dale and Plunkett (1991: 10) but a poor imitation.

The earliest Finnish writings pertaining to quality costs are also from the
1970s, such as Veräjänkorva (1974 and 1977) and Liesmäki (1974). The Finnish
Union of Standardization has published a handbook concerning quality costs (SFS
1977). As far as other business organizations are concerned, ‘Suomen Metalli-
Kone- ja Sähköteknisen Teollisuuden Keskusliitto’ (MET), Federation of Finnish
Metal, Engineering and Electrotechnical industries, has most significantly tried to
raise the appreciation of quality. (Tervonen 1992: 10)

In Finland, Tervonen has performed research in the area of quality costing.
He has done literature research on the quality costs concepts and categories in
1991 as well as an interview study on the quality costs practice in Finnish
industrial companies. His Licentiate’s dissertation deals with poor-quality costs.
MET has dealt with this matter in some of its publications (e.g. Virtanen 1986 and
Lipponen 1988). The latter was also a Master’s thesis in business economics. In
TEKES’s publications there has also been research on quality costs (e.g. Sippola
1998). There have also been articles on the subject in the special journal of
Laatuviesti (e.g. Sippola 1997).
2.2.2 Quality cost research in management accounting

Some business economists have conducted research work on quality costs. Doctoral theses have been written on the subject (Tyson 1987, Morse 1987, Ittner 1992). For example, in his doctoral thesis, Ittner investigated the behavior of quality cost expenditures in 48 manufacturing units belonging to 20 of the 23 participating firms. His tests, using both pooled data and plant-specific time series data, indicated that many of the manufacturing units in the sample achieved significant reductions in their reported non-conformance costs while simultaneously reducing reported conformance expenditures. The findings are consistent with the philosophy of continuous improvement.

Most managers still find it difficult to link quality development projects with expected economic returns. Ittner, (1999) considers the primary reason for this to be the lack of adequate methods for determining the financial consequences of poor quality. Previous literature on real time quality cost accounting is limited or even non-existent. In this thesis, the idea is demonstrated by developing a model for measuring the cost of quality on a real time basis in case company.

Quality cost research has mainly been a case-study research as it has, for example, applied quality cost techniques in a case company. Some research has also been conducted in different branch of business. An example of this research is the empirical study of the validity of quality costs in the paper and pulp industry by Pomenon, Carr, and Wendell (1994). Their research attempts to shed light on cost-to-quality relationships by examining the behavior of quality cost data reported by 47 paper and pulp mills belonging to 26 companies. Statistical tests using 1913 pooled monthly observations support the hypothesis according to which increased prevention and appraisal expenditures lead to reduced external failure cost. These relationships are moderated by the organization’s quality level, with increased conformance expenditures producing larger returns for lower quality mills than for higher quality mills (Pomenon et al. 1994: 214). The level of prevention and appraisal expenditures appears to have no immediate impact on internal failure costs, regardless of mill’s quality level. In fact, increased prevention and appraisal expenditures are positively correlated with internal failure costs in subsequent months. This pattern of simultaneous increases in internal failure costs and reductions in external failure costs is consistent with the hypothesis according to which companies in the early stages of the quality improvement process initially focus on reducing external failure. This leads to higher internal failure costs as inspection activities are increased to prevent
defective product from being shipped to the customer, thereby increasing the number of units scrapped or reworked internally. (Pomenon et al. 1994: 214)

The elemental literature of management accounting contains a little about quality costs. The topic of quality, as well as measurement of quality and quality costs, has been recently touched upon in the management accounting literature (Horngren et al. 1994, Morse 1991, Tervonen 1991, Atkinson et al. 1997). Given the central prominence that discussions of quality play in the economy today, it seems puzzling that cost of quality analysis is absent from accounting curricula and accounting journals (Shank & Govindarajan 1993: 25) In the last few years, there has, however, been quite a lot of QC-research in the area of management accounting, as can be seen from the list of articles presented above.

A recent article published is by Malmi et al. (2004). Their study follows the constructive approach suggested by Kasanen et al. (1993), considering the practice-relevant problem of managers having to justify investments in quality improvement (Ittner & Larcker 1996, Ittner 1999, cf. Kasanen et al. 1993). The construct by Malmi et al. – a collaborative approach for managing project cost of poor quality – developed provides some indication of expected cost savings or expected reductions in resource consumption given that certain poor quality cost elements can be removed or the required proactive actions are successful (Malmi et al. 2004: 314). Malmi et al. (2004) argue that the COQ literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, after batch or customer after customer. Many modern businesses, however, are outright project based, or operate like a string of semi-independent projects characterized by unique resources, customized activity or work sequence order, and a predefined start and finish.

There are also some other journal articles considering quality costing in management accounting (and in other accounting curricula). Albright & Roth (1992) and (1994) show how the Taguchi quality loss function can be used to estimate unrecorded quality costs. Brinkman (1994) discusses about quality cost reporting in a case company. The results of Carr & Pomenon (1994) reveal an emphasis on reducing external failure costs at the expense of conformance and internal failure costs. In addition, there is a time lag before conformance costs influence nonconformance costs. Carr & Tyson (1992) discuss how much prevention and appraisal costs should a company incur in order to improve quality. Diallo et al. (1995) discuss quality cost behaviour in the “new manufacturing environment”, Edmonds (1989) illustrate quality cost accounting
techniques developed in a case company, Gee (1994) discuss the effects of quality costs on a monopoly market, Godfrey et al. (1988) state that the a flaw in quality control systems is their focus on reducing individual, not total quality costs in production. Nandakumar et al. (1993) built a model to measure and account for the cost of quality. The model shows that it may not be optimal for quality improvement efforts to target products that have the highest defective levels, largest direct costs or consume the maximum capital resources. Ostrenga (1991) discuss the return on investment through the cost of quality, Pasewark et al. (1988) study the impact of socially motivated quality cost control policies on cost behavior, Poston (1996) describes the development and evolution of a comprehensive quality cost reporting system at the case company. Ravitz (1991) argue that cost of quality systems are bound to increase in importance because COQ-related activities consume as much as 25 percent or more of the resources used in companies. Reitsberger et al. (1990) study quality cost trade-off philosophies between Japan and Silicon Valley. Shank & Govindarajan (1994) discuss quality cost measurement from a strategic cost management perspective, and Simpson and Muthler (1987) discuss quality costs as facilitating the quality initiatives.

2.2.3 Studies on quality costing in production economics and software engineering

Scientific treaties concerning quality costs have been especially popular in the USA and in the UK. Technical universities have been the center of research work concerning quality costs and the quality of products and different operations. Quality costs have been emphasized in Ph.D-studies in the departments of industrial economics (Morgan 1964, Gryna 1988, Carlson 1990, Chen 1989, Bajpai 1990, Holland 1990, Moraddess 1986, Viger-Chantal 1995). The only doctoral thesis considering cost and quality management I noticed in software product management has been written by Krishnan in 1996.

There have been plenty of journal articles considering quality costing. The content of the research done is shortly presented as follows (articles in alphabetical order). Abdul-Rahman et al. (1996) describe the use of a quality cost matrix to capture the cost of non-conformance during a construction project. Beheiry (1991) describes the role of activity based costing in quality cost accounting, Bohan and Horney (1991) pinpoint the cost of quality in a service company, Bottorf (1997) states how to avoid the roadblocks and reap the benefits
of COQ, Bland et al. (1998) examine quality costing as an administrative process, Burgess (1996) examine the behaviour of quality costs through the system dynamics method more rigorously, and Carr (1992) explains how a case company in service business adapted cost of quality concepts. Chen and Tang (1992) present a pictorial approach to measuring COQ, which is patterned after that used in a computer-based information system design. Chong (1996) constructed models to describe cost behavior and financial outcomes of companies under different competitive markets. Crosby (1983) argue that COQ is a communications tool and it should be used to motivate changes where necessary. Denton and Kowalski (1988) study how measuring non-conformance costs reduced manufacturer’s cost of quality. Foster’s (1996) study was undertaken to examine the relationship between conformance and quality-related costs in a case company. Goulden and Rawlins (1995) introduce a quality costing system using the process model, within a division of a case company. The system was introduced to identify and prioritize improvement areas within the context of a continuous improvement program. A critical review of a former quality costing system within the division based on the prevention, appraisal, and failure model is included in their study. Gray (1995) argue that if a company devoted to quality improvement is finding itself frustrated or inarticulate about what its real results are, designing and implementing a quality cost system might be the answer. Israel (1991) state that quality cost systems are intended to help achieve quality goals, Ittner and Larcker (1996) measure the impact of quality initiatives on firm financial performance, Johnson (1995) conducted a project to identify existing measures of the cost of quality (COQ) that could be used by a client’s engineering unit. A number of measures of the COQ were identified, some of which were transferable to the client organization’s setting. Johnson and Kleiner (1993) argue that the conventional wisdom of the business community in the USA has been that in order to improve the quality of a product the cost of manufacturing will go up. The study shows that by reducing the amount of variability in a process will improve quality, increase productivity, and lower costs. Keogh et al. (1996) illustrates that problems still exists with quality costs even when well educated, determined staff are involved in ensuring quality assurance throughout the system in an enlightened organization. Kumar and Brittain (1995) state that it is important that the cost of quality is used as a management tool, and as an indicator of the economic health of the organization. It is revealed that there is some evidence in the literature, supported by the results of a survey, that organizations are skeptical about the real strength of this tool which was proposed, in the present format, by
Joseph Juran in the 1950s. The importance and strength of this tool are highlighted, and the relative position of the manufacturing sector in the UK is established through a detailed survey. Laszlo (1997) investigate the role of quality cost in TQM. He states that a cost-based approach to select the quality improvement projects that are appropriate to the organization is a key part of the strategy for overall business success – to do the right things right. Maycock & Shaw (1994) made a pilot quality costing study to a health care organization, and Moen (1998) constructed a new quality cost model used as a top management tool. Plunkett and Dale (1987) made a literature review on quality related costs, and criticized ‘economic quality cost models’ (1988). Porter and Rayner (1992) made a survey of small firms in the North of England which showed that only a minority of firms systematically monitor quality costs and that quality costs are frequently underestimated. Pursglove and Dale (1996) examine the development and setting of a quality costing system in a case organization. In the established system, three major difficulties were encountered: the lack of information which could be utilized for quality costing purposes, an unrefined accounting system and a lack of data on non-conforming product. Robison (1997) integrates COQ elements in the team problem solving process. He suggests a ten-step approach to find, prioritize, and solve problems based on the cost of poor quality. Schneiderman (1986) state that as defect levels fall, failure costs decline while appraisal plus prevention costs rise. This trade-off suggests that an optimum quality level exists and that efforts to further improve quality about this level will increase total cost and decrease financial performance. Thus, proponents of this view argue that striving for zero defects (ZD) through a program of continuous improvement is not in a company’s best economic interest. Sullivan and Owens (1983) report a survey designed to obtain information about the way quality cost systems are organized and about top management attitudes toward the systems. Forty-five responses from readers in the US, Canada, and overseas were obtained. Results showed that companies use their quality cost systems for a variety of purposes. Companies appear to have been looking to the future when they started collecting quality costs: some firms used quality costs for quality improvement, while others introduced them as the basis for action. Respondents indicated that quality cost reports receive wide circulation outside the quality department at the companies represented in the sample. Quality cost reports seem to be making their way to top management. About 25% of the firms responding indicated that their quality systems were new. This may imply that quality cost systems are being developed rapidly at that time. Thorne (1990) discuss the basic concepts of

A significant amount of research concerning quality issues has come from the Quality Management Centre UMIST, Manchester. In particular, there has been a great deal of work on quality costs, published by both Dale and Plunkett, the most important of which is probably their 1991 work entitled *Quality Costing*. Examples from the research studies of particular industries suggest that quality cost can range from 5 to 25 per cent of the annual company sales turnover (Dale & Plunkett 1991). A pilot study of quality costs at Sun Microsystems, based in Linlithgow, Scotland, illustrates that problems still exist with quality costs, even if well educated, determined staff are involved in ensuring quality assurance throughout the system in an enlightened organization. (Keogh *et al.* 1996: 29).

There have been continuous conference discourses concerning quality costs in the annual ASQC conferences. Some discourses have also taken place in the annual conferences of the European Organization for Quality (EOQ), as well as in different technology conferences. (Tervonen 1992: 11–12)

Quality costs have also been dealt with in general surveys of the field published in the USA (Crosby 1979, Feigenbaum 1983, Harrington 1987, Gryna 1988), and in UK (Munro-Faure 1992, Dale & Plunkett 1991). The ASQC has published several guides concerning quality costing (for instance Campanella 1990).

The major part of both the speakers in quality conferences and the writers in journals considering quality cost issues have been either consultants or persons working for quality departments of companies. Academic presenters and writers have been a minority. This research area is thus largely based on practical views.

In their review of literature, Plunkett and Dale (1987: 40–41) have not found any French or Italian articles on quality related costs in English. One article; Kume 1985, was found from Japanese sources. (Tervonen 1992: 12)

Primarily, there has been research on the area of software quality only in recent years. Examples of the research (regarding journals articles and conference discourses) are Brodman (1998) who state that cost of quality analysis used in a case company is a viable mechanism for measuring the overall effect of software improvement. By using it to monitor and reduce software COQ, productivity and

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12 There are problems in measuring COQ because no universal accounting techniques are developed to measure these costs. The problems of measuring COQ are further discussed in chapter 3.4.
predictability can be increased. Dion (1993) used the COQ model as a means of interpreting the results of quality initiatives undertaken at a case company’s division. Hersch (1993) discuss the return on process improvement. Houston (1998) state that cost of quality is the easiest and most cost-effective way for the CMM\textsuperscript{13} level\textsuperscript{14} 1 or 2 organization to begin seeing the results of software process improvement. Houston & Keats (1996) have studied the results of the research done on the topic of cost of software quality. They found that while the costs of software quality assurance and process improvement have been a topic of concern for over 20 years (Alberts 1976) and the COQ categories have often been used broadly in discussions of software quality (Daugherty 1988), very limited data has been available in the open literature for discussing the cost of software quality (COSQ). Houston & Keats (1997a) identified the cost categories associated with the cost of quality and discussed the relationship between the costs of achieving quality and costs due to lack of quality. They went on to examine the elements of the emerging field of the cost of software quality (COSQ) and the potential benefits of employing it, as well as COSQ’s use in software process improvement. In their (1997b) article, Houston and Keats discuss how the optimum cost of quality is shown as absolute costs against a quality measure and how simulation can be used to predict COSQ for software process improvement (SPI). Humphrey (1997) discusses the current state of software quality and suggests that software industry must follow the same quality principles as other technological industries. Knox (1993) argues that since investments in software quality are not meant to realize quick, dramatic returns, the defect prevention processes probably offer the most immediate visible evidence that the overall cost of quality has been reduced.

### 2.3 Characteristics of software business and software quality

In this chapter, the nature and distinction of software business as well as its implications to software quality are illustrated. The chapter explains the nature of

\textsuperscript{13} Capability Maturity Model developed at Software Engineering Institute at Carnegie Mellon University in Pittsburgh. The CMM was originally described in the book Managing the Software Process (Addison Wesley Professional, Massachusetts, 1989). The CMM was conceived by Watts Humphrey, who based it on the earlier work of Phil Crosby. Active development of the model by the SEI (US Dept. of Defense Software Engineering Institute) began in 1986.

\textsuperscript{14} Maturity levels: It is a layered framework providing a progression to the discipline needed to engage in continuous improvement. An organization develops the ability to assess the impact of a new practice, technology, or tool on their activity. Hence it is not a matter of adopting these, rather it is a matter of determining how innovative efforts influence existing practices.
software products and processes, software product quality characteristics and economics of software quality. In the chapter, various quality standards for software quality are also presented. The relationships between different types of quality and quality in the software lifecycle are also described.

### 2.3.1 Software products and processes

Krasner (1999: 500) describes some problems considering software quality as follows: software is one of the most important and yet one of the most economically challenging technologies of the current era. As a purely intellectual product, it is among the most labor-intensive, complex, and error-prone technologies in human history. Even though many successful software products and systems exist in the world today, an overall lack of attention to quality has led to many problematic systems that do not work right, as well as to many software products that are late, over budget, or canceled.

Software projects have always been a challenge to manage. According to Humphrey (1989), this originates from the nature of software development. Literally, software is developed, not constructed. Because of this intuitive way to develop software products, there are always some ambiguity and inaccuracy in the management point of view of software development. The software product is defined as a term that refers to a program and all the associated information and materials needed to support its installation, operation, repair and enhancement. The ISO definition for a software product is as follows: A software product is a complete set of computer programs, procedures and associated documentation and data designated for delivery to a user. (ISO9000-3 1991)

Software is a special kind of product compared to other products, because software has no physical existence, there is lack of knowledge of client needs at the start, the client needs changes in time, there is a rapid rate of change in hardware and software, and customers have high expectations, particularly with respect to adaptability. A fact worth mentioning in this list is that when a software product is developed it is very easily duplicated. Also the facts that implementation of software that satisfies the customer appears to be particularly difficult, cost overruns are often experienced, and there is a trade off between customization and unique products (see Alajoutsijärvi *et al.* 1999: 3).

Intense interest has been focused on *software development process* and assessment. Humphrey (1989) states, that the reasons for this are clear: improvements both reduce cost and improve quality. Attention given to improving
process quality helps shorten time to market, makes software development more cost effective, and increases customer satisfaction. The advantages are a sharper competitive edge and a better bottom line. The software development process is the set of activities, methods and practices that are used in the production and evolution of a software product.

Paulk (1995) gives another definition for the software (development) process: “A software process can be defined as a set of activities, methods, practices, and transformations that people use to develop and maintain software and the associated products.” As an organization matures, the software process becomes better defined and more consistently implemented throughout the organization. This, in turn, leads to higher quality software, increased productivity, less rework, and improved software project plans and management. Fig. 1 illustrates an adaptation of the Deming chain reaction. The figure illustrates the scheme of things in the background when improving quality in software business.

Fig. 1. The Deming chain reaction.

There are plenty of problems in developing software (Youll 1992); e.g. schedule overruns (deadlines are not reached), major budget overruns, difficult project estimation, expensive maintenance, bad knowledge on reliability of product, and lack of information for effective process improvement. Large number of software projects are unfinished and stopped and the level of software quality is unknown. By creating more visibility in the current status of a project, the above problems
can be solved. Because of the better insight in current performance, corrective action can be identified earlier. Therefore, it is necessary to create more insight (visibility) into the way software is developed, in order to achieve better understanding of the development process, its activities, tasks and products.

Software development process is any process containing the following activities: requirements analysis and definition, system design, program design, implementation, unit testing, integration testing, system testing, system delivery and maintenance. Different approaches towards the order of activities in the software development process exist, such as the waterfall model, the spiral model (Boehm 1981), the evolutionary development model (iterative enhancement) (Basili & Turner 1973), evolutionary delivery (Gilb 1985), the rapid prototyping model and object oriented development.

There is a direct relation between a product and its process, but *a good quality process can give a bad quality product*, since other factors that are not part of the process also influence the quality of the product (Drenth 1995). Dunn (1990) has stated that “Good products are only one of management’s objectives. The other objectives are meeting schedule, meeting cost, and manageability. A quality process addresses all of these objectives”.

The impact of software in current products is rapidly increasing. The size and complexity of software products is increasing, and unless the error rates are reduced, the greater volume of code will mean a greater number of errors (Humphrey 1989). Therefore, the reduction of these error rates must be emphasized. Controlling and improving the quality of the product is an activity that must be executed and is becoming indispensable when the current increase in software application is taken into account.

According to Humphrey (1989) one of the best ways to evaluate a software organization (a firm producing software) is to examine the quality of its products. Product quality is thus a key measure of the software process. It provides a clear record of development progress, a basis for setting objectives, and a framework for current action. In order to improve the quality of a software (product), one has to first know the current situation. Without the knowledge on the current situation it will never be clear which improvements has to be prioritized, and it will not be possible to visualize the results of improvements, since they can not be compared to the original situation. The fact is that when no information is available on the current situation, there cannot be real ‘understanding’, although some people will claim they do. Collecting data on the current situation will improve understanding and this will result in the identification of improvement areas. As the metaphor of
Humphrey (1989) already explained: “If you don’t know where you are, a map won’t help”.

When an organization wants to improve the quality of its software products, it must integrate process quality and product quality (Drenth 1995). Quality must be ‘built in’ from design to product. A structured way to achieve this is for example to introduce software process assessment models like SPICE, CMM, Bootstrap, etc.

2.3.2 Software product quality characteristics

There are increasing expectations for quality, both in the consumer and professional markets. Bevan (1999) states, that it is no longer sufficient to just deliver products which have technical excellence – products also need to be easy to use and to fit in with the work practices and activities of the consumer and professional user. Traditional approaches to quality put emphasis on meeting the specified requirements which are primarily functional. Attempts have been made to broaden the perception of quality, for example in software quality model ISO/IEC 9126.

Many organisations would like to be able to identify those attributes that can be designed into a product or evaluated to ensure quality. ISO 9126 (1991) takes this approach, and categorizes the attributes of software quality as follows: functionality, efficiency, usability, reliability, maintainability and portability. To the extent that user needs are well defined and common to the intended users this implies that quality is an inherent attribute of the product. However, if different groups of users have different needs, then they may require different characteristics for a product to have quality for their purposes. Assessment of quality thus becomes dependent on the perception of the user.

Humphrey (1996) states that in a broad sense, the users’ views of quality must deal with the product’s ease of installation, operational efficiency, and convenience. Will it run on the intended system, will it run the planned applications, and will it handle the required files? Is the product convenient, can the users remember how to use it, and can they easily find out what they do not know? Is the product responsive, does it surprise the users, does it protect them from themselves, does it protect them from others, and does it insulate them from the system’s operational mechanics? These and a host of similar questions are important to the users. While priorities will vary among users, quality has many layers, and no universal definition will apply in every case. If the software does
not measure up in any single area that is important to the users, they will not judge your product to be of high quality. While few software people will debate these points, their actions are not consistent with these priorities. Humphrey (1996) states that rather than devoting major parts of their development processes to installability, usability, and operational efficiency, they spend them on testing, the largest single cost element in most software organizations. Furthermore, these testing costs are almost exclusively devoted to finding and fixing defects.

Humphrey (1996) argues that when the quality of the parts of a software system is poor, the development process becomes fixated on finding and fixing defects. The magnitude of this fix process is often a surprise. I argue, that the construction developed in Case company A (chapter 5) in this thesis succeeds to sheds light on this fix process problem. As a result of the magnitude of fix process, the entire project becomes so preoccupied with defect repair that more important user concerns are ignored. When a project is struggling to fix defects in a system test, it is usually in schedule trouble as well. The pressures to deliver become so intense that all other concerns are forgotten in the drive to fix the last defects. When the system tests finally run, everyone is so relieved that they ship the product. However, by fixing these critical system test defects, the product has reached only a bare minimum quality threshold. What has been done to assure the product is usable or installable? What about compatibility or performance? Has anyone checked that the documentation is understandable or that the design is suitable for future enhancement? Because the project’s development team has been so fixated on fixing defects, it has not had the time or resources to address the issues that will ultimately be of greater concern to the users (Humphrey 1996: 2–4).

ISO/IEC 9126 (1991) provides a general-purpose model which defines six broad categories of software quality: functionality, reliability, usability, efficiency, maintainability and portability. These categories are further broken down into subcharacteristics which have measurable attributes (Fig. 2). The ISO/IEC 9126 characteristics and subcharacteristics provide a useful checklist of issues related to quality. The actual characteristics and subcharacteristics which are relevant in any particular situation, will depend on the purpose of the evaluation, and should be identified by a quality requirements study.
Internal software product quality attributes are the measurable properties of a software product that influence its ability to satisfy stated and implied needs. One or more attributes can be used to assess a particular software quality characteristic or subcharacteristic. This is described in Fig. 3.

<table>
<thead>
<tr>
<th>Internal attributes</th>
<th>External attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>functionality</strong></td>
<td></td>
</tr>
<tr>
<td>accuracy</td>
<td>maturity</td>
</tr>
<tr>
<td>suitability</td>
<td>fault tolerance</td>
</tr>
<tr>
<td>interoperability</td>
<td>recoverability</td>
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<tr>
<td>compliance</td>
<td></td>
</tr>
<tr>
<td>security</td>
<td></td>
</tr>
<tr>
<td><strong>usability</strong></td>
<td></td>
</tr>
<tr>
<td>understandability</td>
<td>time behaviour</td>
</tr>
<tr>
<td>learnability</td>
<td>resource utilisation</td>
</tr>
<tr>
<td>operability</td>
<td></td>
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<tr>
<td><strong>maintainability</strong></td>
<td></td>
</tr>
<tr>
<td>analysability</td>
<td>adaptability</td>
</tr>
<tr>
<td>changeability</td>
<td>installability</td>
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<tr>
<td>stability</td>
<td>conformance</td>
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<tr>
<td>testability</td>
<td>replaceability</td>
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<tr>
<td><strong>efficiency</strong></td>
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<tr>
<td>reliability</td>
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<td>maturity</td>
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<td>fault tolerance</td>
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<td>recoverability</td>
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<td><strong>portability</strong></td>
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<tr>
<td>stability</td>
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<td>testability</td>
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<td>conformance</td>
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<td>replaceability</td>
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</tbody>
</table>

**Fig. 2. ISO/IEC 9126 quality model. (Bevan 1997a.)**

**Fig. 3. Quality characteristics, subcharacteristics and attributes. (Bevan 1997b.)**
Sufficient internal and external attributes need to be identified for each required subcharacteristic.

Bevan (1997) states, that the actual characteristics and subcharacteristics which are relevant in any particular situation will depend on the purpose of the evaluation, and should be identified by a quality requirements study. The ISO/IEC 9126 characteristics and subcharacteristics provide a useful checklist of issues related to quality, but other ways of categorising quality may be more appropriate in particular circumstances.

Figure 4 shows the ISO/IEC 9126 (1991) definitions of the software quality characteristics (the concepts presented in Fig. 2).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>functionality</td>
<td>a set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs.</td>
</tr>
<tr>
<td>reliability</td>
<td>a set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time.</td>
</tr>
<tr>
<td>usability</td>
<td>a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users.</td>
</tr>
<tr>
<td>efficiency</td>
<td>a set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions.</td>
</tr>
<tr>
<td>maintainability</td>
<td>set of attributes that bear on the effort needed to make specified modifications.</td>
</tr>
<tr>
<td>portability</td>
<td>a set of attributes that bear on the ability of software to be transferred from one environment to another.</td>
</tr>
</tbody>
</table>

Figure 4. ISO/IEC 9126 (1991) definitions.

The ISO/IEC 9126 view was derived from the ISO 8402 (1994) (Quality vocabulary) definition of quality: the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs. This is a “product” oriented view of quality (Garvin 1984): “an inherent characteristic of the product determined by the presence or absence of measurable product attributes”. In this view, the quality of a software product can be specified and built in as specific attributes of the code. The ISO/IEC 9126 definitions acknowledge that the
objective of these attributes is to meet user needs in the form of functionality, reliability, usability, efficiency, maintainability and portability. But, as Bevan (1997) states, ISO 8402 makes it clear that a product-oriented view of quality should not be confused with measures of the “degree of excellence” resulting from the presence of absence of required attributes. Yet the objective of quality from the user’s perspective is to achieve a degree of excellence in a particular context of use. Despite the apparent user orientation of ISO/IEC 9126, the definitions in terms of attributes imply that software quality should be specified and measured on the basis of attributes of the source code.

2.3.3 Benefits of improved software usability

In this chapter one characteristic of software quality, usability is taken under closer review to see what kind of implications it has on software quality. This helps to understand the closer dissection of quality in software lifecycle done in the next chapter, in which the relationship between internal and external quality, as well as the quality in use is expounded.

Most computer software in use today is unnecessarily difficult to understand, hard to learn, and complicated to use. Difficult to use software wastes the user’s time, causes worry and frustration, and discourages further use of the software. Why is the usability of most computer software so unsatisfactory and what are the benefits that more usable software could bring to the employer and supplier? According to Bevan and Macleod (1994), the benefits to the employer include the following: usable software increases productivity and reduces costs. Difficult to use software is time consuming to use, and not exploited to full advantage as the user may be discouraged from using advanced features. Difficult to learn software also increases the cost of training and of subsequent support. Usable software also increases employee satisfaction. Difficult to use software reduces motivation and may increase staff turnover. In Europe, employers have an obligation to meet the requirements of the Display Screen Equipment Directive (CEC 1990) which requires software in new workstations to be “easy to use” and to embody “the principles of software ergonomics” (see Bevan 1991a). According to Bevan (1991b), benefits to the supplier include the following: software suppliers are increasingly facing a market where users demand easier to use software and legislation and standards are putting pressure on employers to provide usable software. End-users are becoming more discerning. Promotional programmes, such as “Usability Now!” in the UK, have made purchasers more conscious of the
benefits of usability, and more inclined to give greater weight to ease of use when making purchases. Usability is increasingly providing suppliers with a market edge, which has promoted ease of use as a major selling feature.

The scope of opportunity for usability engineering’s contribution to the financial status of organizations and development projects can be demonstrated by discussing software life cycle; and analogous case may be made for human factors work in hardware development. The data suggest that user interface is 47–60 percent of the lines of system or application code. A graphical user interface (GUI) is minimally 29 percent of the software development budget and increases with available function (Rosenberg 1989). The user interface has been documented as commanding 40 percent of the development effort (Wixon and Jones 1992).

Pressman (1992) estimates the increasing cost of a change during development as one unit during project definition, 1.5–6 units during project development, and 60–100 units during maintenance after project release. Defining user requirements, testing usability prototypes, and performing usability walkthroughs early in development can significantly reduce the cost of identifying and resolving usability problems and can save time in software development.

Reducing the development time required to bring a usability-engineered product to market can result in substantial financial returns to the organization beyond the initial savings attributable to the time reduction. Increased sales or revenues is one long-term benefit of usability-engineered products.

The data shows that companies generally lose 33 percent of after-tax profit when they ship products six months late, as compared with losses of 3.5 percent when they exceed products development budgets by 50 percent. Speeding up development is a key goal for integrating usability effectively into product development and that a one-quarter delay in bringing a product to market may result in the loss of 50 percent of products’s profit. Siilasmaa (1998), states that in a software product the profitability will fall 33 percent if market access will delay 6 months. Respectively, the profitability will fall 22 percent if production costs will exceed 9 percent.15 (Siilasmaa 1998).

According to Bevan and Macleod (1994), usability-engineered software can accrue increased revenues from external customers due to the increased

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15 Other default values in this example were 5 years life cycle of the product and 20% annual growth of market demand.
marketability of a product with demonstrated usability, increased end user productivity, and lower training costs. Another goal for product development is speeding up market introduction and acceptancy by using usability data to improve marketing literature, reach market influencers and early adopters, and demonstrate the product’s usability and reduced training cost. For example, that speeding up market acceptance may increase revenues with 10 percent, the equivalent of getting the product to market three months earlier. The 10 percent in revenues reflect either a 10% higher volume in sales or a more valued product that is marketed at a 10 percent higher price.

Usability-engineered internal development projects can result in decreased training, support, service, product documentation, personnel costs, and increased user satisfaction. (Karat 1992). The management of a company do not usually mind spending money on the development of product usability, however, they care about the “value” of what they get. That is, they want to know what the benefits of usability engineering are16, what is it in usability engineering that brings about those benefits, and how you should plan to measure (i.e. justify) the benefits. Managers know that usability engineering evaluates the ease of use of products, but they are concerned that this testing will increase their development schedules, causing them to be late in shipping their products.

Usability engineering and other user-centered design (UCD) activities are becoming a more accepted part of a software development process. As products compete on ease of use and ease of learning rather than just on functionality, companies are beginning to realize that they need to focus more on the users of their products.

Ehrlich and Rohn (1994) state that in the past, development teams found computers easier to design because the users of computers were people like themselves – people who were excited about computers. Today millions of people use computers, usually as tools to get their jobs or activities done, and the users of computers no longer resemble the development team. In addition, as users are more varied in their background and their needs, companies are trying to capture increasingly larger segments of this varied population with a single product or a product line. Usability engineering provides methods to obtain feedback from customers so that the products can meet their needs.

16 The term “usability engineering” refers to the specific activities associated with making a product useful and usable, such as performing evaluations and observing customers. The term “user interface (UI) design” is referring to special activities associated with designing the user interface.

17 “User-centered design” (UCD) refers to the overall endeavor of making products easier to use.
Customers are becoming more particular about choosing products that are easier to learn and easier to use. Sales and marketing representatives from several companies believe that most people decide how usable a product is in less than an hour. Satisfied customers not only have brand loyalty and are much more likely to buy the same brand in the future with less researching the particular product, whereas dissatisfied customers are less likely to even consider the brand in the future even if marked improvements were incorporated into the new version of the product. According to Ehrlich and Rohn (1994), customers also influence their friends and families.

2.3.4 User Perceived Quality and Quality in Use

Assessment of quality becomes dependent on the perception of the user. Garvin (1984) defines *User perceived quality* as the combination of product attributes which provide the greatest satisfaction to a specified user. Most approaches to quality do not deal explicitly with user-perceived quality. User-perceived quality is regarded as an *intrinsically inaccurate judgement of product quality*. For instance, Garvin (1984) observes that “Perceptions of quality can be as subjective as assessments of aesthetics”.

However, as Bevan (1997) states, there is a more fundamental reason for being concerned with user-perceived quality. Products can only have quality in relation to their intended purpose. For instance, the quality attributes required of an office carpet may be very different from those required of a bedroom carpet. For conventional products this is assumed to be self-evident. For general-purpose products it creates a problem. A text editor could be used by programmers for producing code, or by secretaries for producing letters. Some of the quality attributes required will be the same, but others will be different. Even for a word processor, the functionality, usability and efficiency attributes required by a trained user may be very different from those required by an occasional user.

Reconciling work on usability with traditional approaches to software quality has led to another broader and potentially important view of quality which has been outside the scope of most existing quality systems. This embraces user-perceived quality by relating quality to the needs of the user of an interactive product.

ISO 14598-1 defines *External quality* as the extent to which a product satisfies stated and implied needs when used under specified conditions (Bevan 1997).
This moves the focus of quality from the product in isolation to the satisfaction of the needs of particular users in particular situations. The purpose of a product is to help users achieve particular goals, which is also apparent in the definition of Quality in use in ISO DIS 14598-1, according to which effectiveness, efficiency and satisfaction are the factors with the aid of which specified users can achieve specified goals in specified environments. As Bevan (1997) states, a product meets the requirements of the user if it is effective (accurate and complete), efficient in use of time and resources, and satisfying, regardless of the specific attributes it possesses. This standard, as well as the definition of usability (ISO 9241) are presented in the next paragraph. In his paper (1999) Bevan states, that quality in use is the user’s view of quality of a system containing software, and is measured in terms of the result of using the software, rather than properties of the software itself. Quality in use is the combined effect of the software quality characteristics for the user.

ISO 9126 quality model (see Fig. 2 in page 59) describes the various parts of quality in use (functionality, usability, maintainability, reliability, efficiency, and portability). ISO 14598-1 sees the quality in use in a broader context. The purpose of designing an interactive system is to meet the needs of users: to provide quality in use. This context is described in Fig. 5 taken from ISO 14598-1. Quality in use is (or at least should be) the objective, and software product quality is the means of achieving it.
According to Bevan (1997), the users’ needs can be expressed as a set of requirements for the behaviour of the product in use (for a software product, the behaviour of the software when it is executed). These requirements will depend on the characteristics of each part of the overall system including hardware, software and users.

The requirements should be expressed as metrics which can be measured when the system is used in its intended context, for instance by measures of effectiveness, efficiency and satisfaction. At this level, the required system characteristics could be minimum values for the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in specified environments.

External quality\(^{18}\) can only be assessed for a complete hardware/software system of which the software product is a part. External metrics are applied when

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\(^{18}\) ISO 14598-1 defines *External quality* as the extent to which a product satisfies stated and implied needs when used under specified conditions.
executing the software. The values of external measures necessarily depend on more than the software, therefore the software has to be evaluated as a part of the working system. Software which performs satisfactorily in one environment may show quality defects in another environment. External evaluation of quality characteristics should therefore take place under conditions which emulate, as closely as possible, the expected conditions of use. External measurements of characteristics are made when the code is complete, though as it may not be possible to emulate the exact conditions of use (e.g. network environment and user characteristics), external measures are often only indicators of the actual quality in use.

The required values of these external metrics provide goals for design. To achieve these goals the internal attributes of the system can be specified as internal requirements. These attributes of the software can be evaluated to produce internal metrics verifying how closely the internal requirements have been met. Although these attributes contribute to achieving quality in use, users and tasks vary so much that conformance to requirements for internal metrics is rarely sufficient to ensure quality in use. If the external quality requirements are not achieved, the results of the evaluation can be used as feedback to modify the internal software attributes in order to improve the external quality, and thus support a continual improvement process.

Bevan (1997) states, that for the purpose of development, internal quality requirements are defined which enable the quality of intermediate products to be verified. The internal properties (e.g. the specification or source code) of the software can be measured by internal metrics. Internal metrics are of most interest during the development process. They can be measured in their own right as essential pre-requisites for external quality. They can also be used as indicators of external attributes. Modularity and traceability are examples of internal attributes which can be measured. Achievement of the required internal quality will contribute to meeting the external requirements of the software in use. Internal software quality metrics can thus be used as indicators to estimate final software quality (see figure 6).
Bevan (1997) states that it is very important that internal software quality attributes are directly related to external quality requirements, so that the quality characteristics of software products under development (both intermediate and end item software products) can be assessed with respect to final system in-use quality needs. Internal metrics are of little value unless there is evidence that they are related to external quality.

When defining usability in ISO 9241-11 (guidance on usability), the ISO software ergonomics committee took an approach to usability based on the degree of excellence of a product. This standard provides the definition of usability that is used in subsequent related ergonomic standards (see e.g. Bevan 2001):

**usability:** the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

ISO 9241-11 explains how usability can be measured in terms of the degree of excellence in use: **effectiveness** (the extent to which the intended goals of use are achieved), **efficiency** (the resources that have to be expended to achieve the
intended goals), and satisfaction (the extent to which the user finds the use of the product acceptable). ISO 9241-11 also emphasizes that usability is dependent on the context of use and that the level of usability achieved will depend on the specific circumstances in which a product is used. The context of use consists of the users, tasks, equipment (hardware, software and materials), and the physical and social environments which may influence the usability of a product in a work system. Measures of user performance and satisfaction thus assess the overall work system, and, when a product is the focus of concern, these measures provide information about the usability of that product in the particular context of use provided by the rest of the work system.

It is important to note that while this definition provides a practical way to measure usability, it is also measuring the consequences of other software quality characteristics such as the functionality, reliability and the efficiency of the computer system. Changes in these characteristics, or other components of the work system, such as the amount of user training, or improvement of the lighting, can also have an impact on user performance and satisfaction. For this reason, the early drafts of ISO 9241-11 also defined a broader concept:

quality of use: “the extent to which specified goals can be achieved with effectiveness, efficiency and satisfaction in a specified work system.” However, this was removed from later drafts, as an unnecessary complication. The concept of the quality of a product in use (Bevan 1995a 1995b) did, however, provide the link between the ISO 9241-11 and ISO/IEC 9126 views of usability, and “quality in use” was incorporated as a high level quality objective into the revision to ISO/IEC 9126-1, and the related ISO/IEC 14598-1 standard (Software product evaluation – General guide).

quality in use: “the extent to which a product used by specified users meets their needs to achieve specified goals with effectiveness, productivity and satisfaction in a specified context of use.” The revised ISO/IEC CD 9126-1 now distinguishes three broad approaches to improving the quality of a product (Fig. 7):

1. Set criteria for process quality: attributes of the software development processes, for example by application of ISO 9001, or ISO 15504 (SPICE).
2. Set criteria for product quality: attributes of the software (internal measures) or the behaviour of the software when tested (external quality).
3. Set criteria for quality in use: the extent to which the code meets user needs for effectiveness, productivity and satisfaction in use.

![Diagram of Approaches to software quality. (Bevan 1997.)](image1)

According to Bevan (1997), software product quality can be measured internally (typically by static measures of the code), or externally (typically by measuring the behaviour of the code when executed). The objective is for the product to have the required effect in a particular context of use. *Quality in use is the user’s view of quality.* Achieving quality in use is dependent on meeting criteria for external measures of the relevant quality sub-characteristics, which in turn is dependent on achieving related criteria for the associated internal measures (Fig. 8).

![Diagram of Relationship between different types of quality. (Bevan 1997.)](image2)

Measures are normally required at all three levels, as meeting criteria for internal measures is not usually sufficient to ensure achievement of criteria for external measures, and meeting criteria for external measures of sub-characteristics is not usually sufficient to ensure achieving criteria for quality in use.

The software quality characteristics in the revision of ISO/IEC 9126 have been redefined in terms of “the capability of the software”, to enable them to be interpreted as either an internal or external perspective (Fig. 9). The definitions
also refer to “use under specified conditions” to make it clear that quality is not an absolute property, but depends on the context of use.

<table>
<thead>
<tr>
<th><strong>Functionality</strong></th>
<th>the capability of the software to provide functions which meet stated and implied needs when the software is used under specified conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>the capability of the software to maintain its level of performance when used under specified conditions.</td>
</tr>
<tr>
<td><strong>Usability</strong></td>
<td>the capability of the software to be understood, learned, used and liked by the user, when used under specified conditions.</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>the capability of the software to provide the required performance, relative to the amount of resources used, under stated conditions.</td>
</tr>
<tr>
<td><strong>Maintainability</strong></td>
<td>the capability of the software to be modified. Modifications may include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications.</td>
</tr>
<tr>
<td><strong>Portability</strong></td>
<td>the capability of software to be transferred from one environment to another.</td>
</tr>
</tbody>
</table>

Fig. 9. ISO/IEC CD 9126-1 definitions.

To summarize chapter two, it seems that there is quite a lot of research done on the field on quality costing; the majority of this research is presented in production economics journals, but also in the field of management accounting and software engineering. Examinations focusing the characteristics of software business and various quality standards have also been done. In the field of MA, no quality cost study seems to be carried out in software business environment. Due to the gap in our knowledge on the role of quality costing in software industry and quality cost measurement, further research is needed, especially made by interventionist approach.
3 Quality cost accounting in traditional and activity based costing environment

The purpose of the chapter 3 is to present a conceptual framework for measuring quality costs under traditional cost accounting environment and under ABC environment. First, the present approaches to measuring COQ are reviewed; second, the two-dimensional model of ABC and activity-based management (ABM) is explained; third, COQ approaches and ABC are compared and an integrated COQ-ABC framework is presented; and fourth, COQ measurement, COQ reporting, and uses of COQ information under ABC are discussed.

Cost of quality is an accounting technique introduced by Juran in 1951 (Hagan 1986) as a means of providing justification to management for investments in process improvements, or as Crosby (1979) has promoted the concept, “to get management’s attention and to provide a measurement base for seeing how quality improvement is doing”. However, the use of COQ has been expanded beyond its initial purpose of demonstrating return on investment of quality efforts. It has been widely used in manufacturing and service industries both for controlling the costs of quality activities and for identifying opportunities to reduce quality costs. (Houston & Keats 1996: 1)

Many companies in the world gradually promote quality as the central customer value and regard it as a key concept of company strategy in order to achieve the competitive edge (Ross and Wegman 1990). Measuring and reporting cost of quality is the first step in a quality management program. Even in service industries, COQ systems receive considerable attention (Bohan and Horney 1991, Carr and Tyson 1992, Ravitz 1991). Cost of quality systems are bound to increase in importance because COQ-related activities consume as much as 25 percent or more of the resources used in companies (Ravitz 1991). Cost of quality information can be used to indicate major opportunities for corrective action and to provide incentives for quality improvement.

Traditional cost accounting, whose main functions are inventory valuation and income determination for external financial reporting, does not yield the COQ information needed. While most COQ measurement methods are activity/process oriented, traditional cost accounting establishes cost accounts on the basis of the categories of expenses, instead of activities. Under traditional cost accounting, many quality related costs are lumped into overheads, which are allocated to cost centers (usually departments) and then to products through predetermined overhead rates. For example, among various COQ-related costs, the rework and
the unrecovered cost of spoiled goods caused by internal failures are charged to the factory overhead control account which accumulates the actual overhead costs incurred (Hammer et al. 1993: 155–164).

The cost accounting treatment described above cannot satisfy the needs of COQ measurement. Thus, Oakland (1993: 210) claims that quality related costs should be collected and reported separately and not absorbed into a variety of overheads. According to Oakland (1993: 197), prevention-appraisal-failure approach and process cost approach are two main approaches to measuring COQ. However, these approaches still cannot provide appropriate methods to include overhead costs in COQ systems. Accordingly, many quality cost elements require estimates and that is a prevailing belief in COQ literature. It is a danger that managers become too concerned with accuracy in COQ determination – a number-crunching exercise that will consume resources disproportionately. In addition, most COQ measurement systems in use do not trace quality costs to their sources (O’Guin 1991: 70), which hinders managers from identifying where the quality improvement opportunities lie. Nevertheless, these deficiencies could be overcome under activity-based costing developed by Cooper and Kaplan of Harvard Business School (Cooper 1988, Cooper and Kaplan 1988). Activity based costing uses the two-stage procedure to achieve the accurate costs of various cost objects (such as departments, products, customers, and channels), tracing resource costs (including overhead costs) to activities, and then tracing the costs of activities to cost objects (Tsai 1998: 719).

3.1 Principle elements of the PAF-approach

Quality cost measurement has its origin in the early 1950’s. Feigenbaum’s (1956) classification of quality costs into the familiar categories of prevention, appraisal and failure has been almost universally accepted (Plunkett and Dale 1987). New cost elements have been added e.g. Harrington (1987), but the concept is still based on the same premises as in the early 1950’s (Moen 1998). Many quality cost systems are based on the research of Juran, Crosby, and Feigenbaum. These authors developed the basics of COQ measurements by classifying quality cost types into prevention, appraisal, internal and external failure cost. Further, prevention and appraisal costs are the cost of conformance, while failure costs are
the cost of nonconformance.¹⁹ The quality cost model measures prevention and appraisal costs, comparing them to internal and external failure costs. Feigenbaum is considered to be the originator of quality cost categorization (Dale & Plunkett 1991: 26). Feigenbaum (1983: 111–112) divides quality costs into two main categories: costs of control and costs of failure of control.

Since the time Juran’s (1951) discussions about the cost of quality, many researchers have proposed various approaches to measuring COQ. Reviews of COQ literature can be found in Plunkett and Dale (1987) and Porter and Rayner (1992). In this section, the approaches of measuring COQ are briefly reviewed.

After Feigenbaum (1956) categorized quality costs into prevention-appraisal-failure (PAF), the PAF scheme became universally accepted for quality costing. Oakland (1993: 186–189) describes these costs as follows. Prevention costs are associated with the design, implementation and maintenance of the total quality management system. Prevention costs are planned and are incurred before actual operation. Appraisal costs are associated with the supplier’s and customer’s evaluation of purchased materials, processes, intermediates, products and services to assure conformance with the specified requirements. Internal failure costs occur when the results of work fail to reach designed quality standards and are detected before transfer to customer takes place. External failure costs occur when products or services fail to reach design quality standards but are not detected until after transfer to the customer.

In order to calculate total quality cost, the quality cost elements are identified under the categories of prevention, appraisal, internal failure and external failure costs. British standard (BS) 6143: Part 2 (1990) and ASQC (1974) have identified a list of quality cost elements under this categorization. These lists act as a guideline for quality costing. Most elements in these lists are not relevant to a particular industry, while many elements identified by practitioners are peculiar to an industry, or a company (Dale and Plunkett 1991: 28). Some typical COQ elements are shown in Error! Reference source not found.: 78.²⁰ In the initial stages of the quality costing exercise, some companies put emphasis on just identifying the costs of failure and appraisal activities. The methodology usually used is for each department, and it uses a team approach to identify COQ elements which are appropriate to each department and for which departments

¹⁹ Feigenbaum uses the terms Cost of control and Cost of failure of control instead of Cost of conformance and Cost of nonconformance.

²⁰ A table of quality cost elements specified for software industry is specified in Table 7. (Table 1 describes QC—elements which are not specified for a special branch of industry).
have ownership. Several techniques, such as brainstorming, nominal group technique, Pareto analysis, cause and effect analysis, fishbone diagrams, and forcefield analysis, can be used to effectively identify COQ elements (Dale and Plunkett 1991: 41, Johnson 1995). The quality cost measurement system developed will improve with use and experience and gradually include all quality cost elements. (Tsai 1998).

Plunkett and Dale (1988) state that one of the goals of total quality management (TQM) is to meet the customer’s requirements with lower cost. For this goal, we have to know the interactions between quality-related activities associated with prevention, appraisal, internal failure and external failure costs. This will help in finding the best resource allocation among various quality-related activities. Literature includes many notional models describing the relationships between the major categories of quality costs. Generally speaking, the basic suppositions of these notional models are “that investment in prevention and appraisal activities will bring handsome rewards from reduced failure costs, and that further investment in prevention activities will show profits from reduced appraisal costs”22. Fig. 10 presents the idea in which an increase in prevention activities leads to a reduction in the total quality costs.23

21 The undersigned would like to put quotation marks in the word all. There are no universally accepted accounting techniques how to calculate all quality costs.
22 The discussion of the shape of the quality cost models is in chapters 3.1.1. and 3.1.2.
23 Some other figures that describe the generic quality cost behaviour have a third (intermediate stage) QC –histogram between the two histograms presented in figure 10. This means that TQC will first rise because while prevention costs will rise the other quality cost components will be stable. The histogram on the right side of Fig. 10 portrays the resources saved as a result of the company’s quality improvement program.
Fig. 10. **Total quality costs can be reduced by investing in prevention activities.** (Sörqvist 1998.)

Plunkett and Dale (1988) conclude that many of the models are inaccurate and misleading, and serious doubts are cast on the concept of an optimal quality level corresponding to a minimum point on the total quality-cost curve. Besides, Schneiderman (1986) asserts that, in some circumstances, if enough effort is put into prevention, no defects at all would be produced, resulting in zero failure costs and no need for appraisal (also given in Porter and Rayner 1992). Thus, in these circumstances, the only optimal point is “zero-defects”.

<table>
<thead>
<tr>
<th>Categories</th>
<th>COQ elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention</td>
<td>Quality control and process control engineering</td>
</tr>
<tr>
<td></td>
<td>Design and development control equipment</td>
</tr>
<tr>
<td></td>
<td>Quality planning by others</td>
</tr>
<tr>
<td></td>
<td>Production equipment for quality – maintenance and calibration</td>
</tr>
<tr>
<td></td>
<td>Test and inspection equipment – maintenance and calibration</td>
</tr>
<tr>
<td></td>
<td>Supplier quality assurance</td>
</tr>
<tr>
<td></td>
<td>Training</td>
</tr>
<tr>
<td></td>
<td>Administration, audit, improvement</td>
</tr>
<tr>
<td>Appraisal</td>
<td>Laboratory acceptance testing</td>
</tr>
<tr>
<td></td>
<td>Inspection and test</td>
</tr>
<tr>
<td></td>
<td>In-process inspection (non-inspectors)</td>
</tr>
<tr>
<td></td>
<td>Set-up for inspection and test</td>
</tr>
<tr>
<td></td>
<td>Inspection and test materials</td>
</tr>
<tr>
<td></td>
<td>Product quality audits</td>
</tr>
<tr>
<td></td>
<td>Review of test and inspection data</td>
</tr>
<tr>
<td></td>
<td>On-site performance testing</td>
</tr>
<tr>
<td></td>
<td>Internal testing and release</td>
</tr>
<tr>
<td></td>
<td>Evaluation of materials and spares</td>
</tr>
<tr>
<td></td>
<td>Data processing, inspection and test reports</td>
</tr>
<tr>
<td>Internal failure</td>
<td>Scrap</td>
</tr>
<tr>
<td></td>
<td>Rework and repair</td>
</tr>
<tr>
<td></td>
<td>Troubleshooting, defect analysis</td>
</tr>
<tr>
<td></td>
<td>Reinspect, retest</td>
</tr>
<tr>
<td></td>
<td>Scrap and rework: fault of supplier</td>
</tr>
<tr>
<td></td>
<td>Modification permits and concessions</td>
</tr>
<tr>
<td></td>
<td>Downgrading</td>
</tr>
<tr>
<td>External failure</td>
<td>Complaints</td>
</tr>
<tr>
<td></td>
<td>Product service: liability</td>
</tr>
<tr>
<td></td>
<td>Products returned or recalled</td>
</tr>
<tr>
<td></td>
<td>Returned material repair</td>
</tr>
<tr>
<td></td>
<td>Warranty replacement</td>
</tr>
<tr>
<td></td>
<td>Loss of customer goodwill</td>
</tr>
<tr>
<td></td>
<td>Loss of sales</td>
</tr>
</tbody>
</table>

Note: Intangible external failure costs (not included in BS 6143: Part 2)

Fig. 11 illustrates the typical quality cost categories and Table 2 provides definitions of the four COQ categories with typical costs of software quality.
Fig. 11. Cost of Quality Categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
<th>Typical Costs for Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal failures</td>
<td>Quality failures detected prior to product shipment</td>
<td>Defect management, rework, retesting</td>
</tr>
<tr>
<td>External failures</td>
<td>Quality failures detected after product shipment</td>
<td>Technical support, complaint investigation, defect notification</td>
</tr>
<tr>
<td>Appraisal</td>
<td>Discovering the condition of the product</td>
<td>Testing and associated activities, product quality audits</td>
</tr>
<tr>
<td>Prevention</td>
<td>Efforts to ensure product quality</td>
<td>SQA administration, inspections, process improvements, metrics collection and analysis</td>
</tr>
</tbody>
</table>

More exact table on COSQ-element is presented in chapter 4.2.
SQA = Software quality assurance.

3.1.1 Quality cost models – “traditional” and “new”

Quality is a complex construct involving several attributes and is defined simply as conformance to design specifications (for manufacturing operations). The design specifications generally consist of nominal or target value and tolerance to accommodate process variation of some critical parameter of characteristic. Tolerance is often specified by an upper specification limit (USL)\(^\text{24}\) and a lower specification limit (LSL). (Diallo \textit{et al.} 1995: 20). This is illustrated in Fig. 12.

\(^\text{24}\) “USL” is used as a synonym for “UTL” (upper tolerance limit).
In the traditional view of quality, items such as subassemblies, parts, and the like are considered acceptable or unacceptable (defective) within the same standard. Parts or products whose critical measurements fall within the USL and LSL are considered acceptable, and those with measurements above or below these limits are considered defective or unacceptable. Such parts or products are scrapped or reworked to conform to specifications. No distinction is made between the level of quality of parts or products that have measurements equal to or close to the target value and equal to (or close to) the USL or LSL. Thus, this concept of quality leads to “pass” or “fail” classification. (Diallo et al. 1995: 20–21)

From a COQ perspective, traditional costing methods focus only on the costs incurred in the production of defective or unacceptable parts or products. That is, the production or rework cost (direct material, direct labor, and manufacturing overhead) of the units not meeting quality control standards (specifications) is considered a loss. The implied loss function is a discrete linear function with zero loss – if the part or product has measurements within USL and LSL – or full loss – if the product or part has measurements above the USL or below the LSL. The loss is divided into the category of normal and abnormal. (Diallo et al. 1995: 20–21)

Many prevailing accounting systems report the abnormal loss only, as feedback for control and corrective action. The premise is that while the abnormal loss (special causes) is controllable in the short run, the normal loss (common causes) is an inherent part of the chosen production process and cannot be controlled without costly process and/or product design changes. This philosophy is counter to the Total Quality Management philosophy that is being adopted by an increasing number of companies.
The advantage of the traditional COQ classification is that it provides a framework for quantifying and minimizing the total cost of quality. The classic model of optimum quality costs, presents a concave, U-shape total quality cost function. It also gives rise to the concept that effective strategic management of quality means choosing a quality level and mix of spending across the four categories that minimize total quality cost. As voluntary expenditures on appraisal and prevention are increased, the COC (lower defects rate) results in lower involuntary failure costs. The minimum total quality cost occurs where the marginal cost of prevention and appraisal equals the marginal cost of failure. The Classic Model of Optimum Quality Costs is presented in Fig. 13.

Fig. 13. Classic Model of Optimum Quality Costs.

The costs of achieving quality and the costs due to lack of quality have an inverse relationship to one another: as the investment in achieving quality increases, the costs due to lack of quality decrease. This relationship and its effect on the total cost of quality (TCOQ) are normally shown as a set of two-dimensional curves which plot costs against a measure of quality. In traditional COQ models, the TCOQ has a point of diminishing returns, a minimum prior to achieving 100 percent of the quality measure.

The traditional cost of quality model has been criticized in the recent research. A careful analysis of the traditional model of COQ reveals several problems. The model suggests that the optimal level of quality cost occurs at less than 100 percent conformance. The model depicts an increasingly steeper
appraisal and prevention cost curve that is an application of classical economic theory of diminishing marginal returns relative to reduction in defective output. As the proportion of defective production is reduced, failure costs decline at an increasing rate. While the general nature of cost curves appears reasonable, the exact shape of the cost curves is an empirical question. It is, however, reasonable to expect that the nature of the curves would be different under different manufacturing environments.

Yet despite the widespread implementation of quality cost systems and the continuing promotion of the concept in the accounting and operations literature, relatively little empirical research on the measurement, usage, or economics of quality costs has been undertaken (Ittner 1992: 10–11). There is relatively little empirical evidence on the relationships of the four traditional quality cost categories. In other words, the magnitude of the trade-offs between conformance and nonconformance costs, and the lag between increased conformance activity and reductions in quality failure. The lack of support has prompted a number of observers to conclude that because the economics of cost-to-quality relationships are not well understood, it is possible that quality cost information is irrelevant for decision making purposes. (Pomenon, Carr, Wendell 1994)

It is best to consider appraisal and prevention costs separately, because they have very different cost behavior and implications for cost control. Appraisal costs based on the classic inspection approach largely are inspection staff-hours. A graph of this approach may follow closely the traditional postulated prevention and appraisal costs curve. (Diallo et al. 1995: 22)

Technological advances in automatic gauging, together with other factors such as high labor costs, flexibility, and reliability, are resulting in a greater number of companies investing in in-line appraisal or measurement systems. The new gauging devices have increased the possibility of measuring parts more reliably for more conditions at a higher cycle rate. Thus appraisal costs in the new manufacturing environment are relatively flat (or fixed). Once equipment is in place, there is little variation in appraisal costs whether inspecting a few units or all of the output. (Diallo et al. 1995: 22)

In the behavioural area, many companies using modern technologies now realize that, no matter how diligent the inspectors, high quality cannot be “inspected” in. Quality is built in the production process. These companies are empowering assembly-line employees to be responsible for quality and virtually are eliminating the need for highly paid quality-control inspectors. Thus, overall costs of appraisal are significantly lower because of technological and
behavioural changes. In addition, with 100 percent in-line measurement, these costs are relatively flat (or fixed). In other words, the shape of the appraisal cost curve in the new manufacturing environment is not the increasingly steeper curve as assumed in traditional COQ model.

![Fig. 14. New cost of quality model.](image)

Considering prevention cost behavior, companies that spend more on prevention are finding that total COQ continue to fall. For them, prevention costs never reach the optimal level where the marginal increase in prevention cost is equal to the marginal decrease in failure cost. Considering failure cost behavior, some important external failure costs have been largely ignored in traditional costing systems. Contemporary COQ systems measure some of the external failure costs, such as warranty, product returns, and product liability. Other external failure costs, particularly contribution lost from loss of customer goodwill, due to poor quality or missed opportunities, have been difficult to measure, therefore these costs have been ignored. These “hidden” or indirect COQ become significant in a quality-based competitive environment, and are likely to be extremely high at conformance levels below 100 percent.

Few companies attempt to measure or estimate the impact of poor quality on current future sales. Instead of attempting to measure the opportunity costs of lost sales, many companies rely on nonfinancial measures such as returns and customer complaints to gauge the impact of poor quality on revenues. Unfortunately, these measures provide no indication of the financial magnitude of
lost sales due to various quality problems (Atkinson, Hamburg and Ittner 1994: 24).

For example, in Motorola, the portion of external failure costs related to lost sales was the bulk of the COQ savings. Because these estimates are so subjective, their credibility is crucial. Consistent calculation procedures must be maintained and disclosed. In addition to estimating the volume of lost sales, lost profit per unit valuation is problematic. Should it be based on lost contribution margin or lost revenues? Fortunately, despite of these problems, COQ measures have proven useful in successfully introducing TQM (Mackey and Thomas 1995: 106).

In the traditional COQ model, all products/parts considered good units are assigned equal value for quality even though one part/product may fall just within the tolerance limit while another may match the target value exactly. Japanese quality guru Taguchi disagrees with this approach. The argument of Taguchi is that a product that barely meets specification, is likely to fail in the hands of the customer. Consequently, the company runs the risk of losing not only that particular customer but several others as well. Taguchi links quality through variation reduction to costs using his Quality Loss Function. Based on his experience, he proposes a quadratic quality loss function as an approximation of the external failure costs. The implication of the function is that if management decides not to incur the voluntary expenses of reducing the variation, it involuntarily will incur several times that amount in the form of warranty costs, lost contribution because of customer ill will, and so forth. (Diallo et al. 1995: 24–26)

A revised (new) cost of quality model in Fig. 14, based on the above considerations, shows the relatively flat curve for appraisal and prevention costs compared with traditional curve for appraisal and prevention costs. The stable production process resulting from eliminating root causes of variation problems requires fewer and fewer preventive efforts. The achievement of new quality level means lower internal and external failure costs. Thus, total quality costs (including intangible and indirect costs of failure) never reach a minimum below 100 percent conformance level. Carr and Tyson (1992) also reach a similar conclusion and are very critical of efforts to trade off quality for cost, as suggested by the traditional quality cost model.

The problems with traditional and contemporary quality and COQ concepts, together with technological developments, increasing quality, and cost-based competition, indicate that any COQ system designed for achieving high quality with minimal costs cannot be based on outmoded concepts. Furthermore,
customer satisfaction has become a top priority for almost all businesses today. Many management control systems for manufacturing continue, however, to overemphasize throughput and short-run cost control within individual departments. These systems lead to goal congruence and goal displacement problems. That is, minimizing individual department costs does not minimize overall company costs, and managers resort to managing the numbers instead of focusing the activities that would lead to higher quality and lower costs. (Diallo et al. 1995: 24)

Research indicates that companies typically spend too little on prevention activities that would ensure robust product and process designs or that would correct design deficiencies and provide preventive maintenance, training, and so forth. Management accountants need to design cost systems that systematically accumulate or estimate “all” quality cost. The COQ classifications and other meaningful formats should be used to show the financial impact of problem solving efforts aiming at variation reduction.

The optimum quality level is indicated by the intersection of the curves representing The cost of conformance (costs of prevention and appraisal) and The cost of nonconformance (failure costs). Both set of curves are smooth and steadily increasing and, thus, reflect a gradualistic perspective. The critical point about the effect of adopting a gradualistic perspective is that optimum is always at some internal point rather than at an extreme. (Cooper 1996: 7–8).

Cooper (1996: 7–8) argues that the modern thinking holds that no defects are acceptable. Although there is still a single optimum defect level, it is zero. Trying to achieve this objective requires passing through several plateaus. The first step in this journey to quality is to accept that current practice is suboptimal. This chance in mindset allows employees and managers to observe the negative side of defects and realize that there are no offsetting savings.

The opinion of the undersigned to this “optimal conformance level” – discussion is that there is still far too little empirical evidence to cast off the traditional COQ-model. The empirical evidence has only shown that the new COQ-model may hold true in some companies or branch of business, but from this fact we can not draw the conclusion that the traditional model should be discarded. At least in software business, we are far from the situation in which the final products are defect free.

Albeit the literature is using the names such as “traditional” and “new” quality cost models, it has to be mentioned that the question is only about a shape
of the quality cost curves and as such I argue that we could as well talk about the same model.

### 3.1.2 Approaches to quality improvement

The classic quality cost model urges managers to increase prevention and appraisal expenditures (conformance costs) so that internal and external failure costs (non-conformance costs) can be reduced. Practioner-oriented publications continually advocate that managers should use the trade-offs portrayed in the classic model as a guide for allocating quality improvement actions. Similarly, researchers have applied the tradeoffs in the classic model to formulate quality control models in such areas as inspection plans. (Ittner 1992: 50)

According to Juran (1988), managers face two major objectives with respect to the optimal quality level portrayed in the classic model:

- When the historic level of performance is at the economic optimum, the objective is holding the optimum, i.e. holding the status quo.
- When the historic level of performance is not at the optimum, the objective is changing from the historic level to the optimum, i.e. changing the status quo.

Juran portrays the relationship between these quality levels with the diagram in Fig. 15 below.

![Diagram of quality levels](attachment:Fig. 15. Sporadic and chronic quality problems. (Juran 1988.).png)

Fig. 15. Sporadic and chronic quality problems. (Juran 1988.)
According to the diagram, the actual performance level fluctuates around a historic level. Periodically, however, the performance exhibits a significant or sporadic departure from the historic level which is due to some sudden change in the process. The elimination of sporadic causes of departure from historic levels of performance is commonly referred to as “firefighting” (Ittner 1992: 51–52).

Perhaps the greatest waste of resource in any organization is the amount of management time that is spent on “firefighting” – performing a task which only exists because somebody did not do the original job right the first time. This can represent between 20 percent and 95 percent of employees’ time. A major UK bank estimates that 49 percent of its employees’ time is wasted in this way. The cost of such waste to the organization is almost incalculable; it is not just the cost of salaries and overheads that is wasted, it is the cost of all the things that could have been done in the time so saved – new products designed, new customers gained, better management decisions made. (Porter and Rayner 1992: 74)

In contrast, when it is determined that the economic level is markedly different from the historic level, the difference between the two levels is considered a chronic problem. The job of the people involved is to eliminate the chronic causes of differences between historic levels of performance and optimum levels through quality improvement programs. (Ittner 1992: 51–52).

An implication of both the classic model and Juran’s framework of quality improvement is that non-conformance costs can only be reduced through increased expenditures on conformance activities. Morse and Roth (1987: 859) state that, to reduce non-conformance costs, more money must be spent on prevention and appraisal activities. Thus, a tradeoff exists between the types of quality costs.

Though the importance of prevention and appraisal activities to quality improvement is widely recognized, the claim according to which managers must continue to increase conformance costs in order to achieve quality improvements, has recently been questioned. Zero defects advocates (Deming, Schneiderman, Dawes) argue that in firms committed to continuous quality improvement, a fixed level of conformance expenditures can lead to ongoing reductions in non-conformance costs as quality improvement teams continuously identify and eliminate quality problems.25 The continuous cycle of identifying and eliminating the most serious quality problems leads to ongoing (albeit diminishing) reductions

25 The zero defects concept promotes the need for never-ending improvement.

Unlike some zero defect advocates, Harrington argues that conformance expenditures may even decline as quality improves. Within Harrington’s quality cost model, substantial prevention and appraisal costs are incurred at the beginning of the quality program as errors are systematically tracked down and actions taken to prevent them from recurring. These actions, in turn, cause the error level to decline, thereby allowing 100 percent inspection to be replaced by sampling. In this manner, both conformance and nonconformance costs continue to fall as the quality level improves. (Ittner 1992: 54–55).

The discussions above suggest three approaches to quality improvement. The first one is Firefighting and it means that many organizations consider the word improvement to be synonymous with corrective actions or firefighting required to alleviate sporadic problems. Consequently, organizations that employ firefighting methods of quality control increase conformance expenditures in periods with higher defect rates, leading to positive relationship between conformance and non-conformance costs. The second one is Optimal Quality Level. The classic tradeoff model suggests that prevention and appraisal activities must be increased to reduce non-conformance costs, leading to the following managerial implications. A: Increased conformance expenditures lead to lower non-conformance costs. B: Reductions in conformance expenditures lead to higher non-conformance costs. C: A fixed level of conformance expenditures produces no change in non-conformance costs. The third one is Continuous Improvement (new model). Advocates of continuous improvement philosophy argue that ongoing reduction in non-conformance costs can be achieved with stable or declining conformance costs. Consequently, companies committed to continuous improvement should exhibit declining non-conformance costs with stable or declining conformance costs. (Ittner 1992: 56–57).

Table 3 summarizes the expected behaviour of quality costs with respect to the three approaches.

<table>
<thead>
<tr>
<th></th>
<th>NCONF &gt; 0</th>
<th>NCONF = 0</th>
<th>NCONF &lt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONF &gt; 0</td>
<td>FIREFIGHTING</td>
<td></td>
<td>CLASSIC MODEL</td>
</tr>
<tr>
<td>CONF = 0</td>
<td></td>
<td>CLASSIC MODEL</td>
<td>CONTINUOUS IMPROVEMENT</td>
</tr>
<tr>
<td>CONF &lt; 0</td>
<td>CLASSIC MODEL</td>
<td></td>
<td>CONTINUOUS IMPROVEMENT</td>
</tr>
</tbody>
</table>
3.2 Measuring quality costs with the Taguchi approach

Quality cost measures, especially failure costs, have normally been driven by defect rates based on specification limits. These limits are often based on convenience, internal company opinions about customers’ needs and the performance of production equipment (Diallo et al. 1995). Another way of viewing costs and performance is by using Taguchi’s loss function. Taguchi’s loss function is based on the assumption that any deviation from the target value of a characteristic will result in a loss to the company. This loss is described by a symmetrical quadratic function (Taguchi et al. 1989):

\[ L(x) = k(x-T)^2 \]

where \( k = \frac{c}{d^2} \).

The function is described by the distance \( (d) \) from the target value \( (T) \) where the product becomes unfit for use, the cost \( (c) \) to the company at this point, and the proportionality constant \( (k) \). The function can also be used for a smaller-the-better and larger-the-better characteristic, which are only special cases of the target-the-best situation described in Fig. 12 on page 80. In recent years, the loss function proposed has been used to monitor external quality costs including a primary component of lost sales (Margavio et al. 1994) and intangible quality costs (Albright & Roth 1992, Kim & Liao 1994) like customer’s dissatisfaction, loss because of bad reputation, and lost market shares. The ASQC quality cost committee (ASQC 1990) has also in its general terms advocated the use of the loss function on the principles of quality costs. However, little has been done to describe how to determine the magnitude of the loss at the tolerance limit \( (c) \) and the distance from the target value to this limit \( (d) \). These values are critical for determining the proportionality constant \( (k) \) and thereby the overall validity of the loss function. The literature emphasizes that these values have to be estimated, but a good methodology has not been provided. To overcome this problem, a simplified activity based costing approach was developed by Moen in 1998. (Fig. 16).

26 See Fig. 12. Taguchi’s loss function. in page 80.
The purpose is to break down the result of not meeting customer requirements into manageable and measurable activities, and subsequently add up the cost for each activity to an overall cost for each cost category. One standardized form is used to analyze each of the four cost categories for each customer requirement, except for internal failure costs where the analysis is based on key process parameters. The consequence of inadequate performance is measured through activities that have to be undertaken to bring the performance back to an acceptable level. Each activity is divided into labor (time consumption), wasted material, process disturbances, and facility usage, both direct and indirect. Overhead costs are included. Shifts in performance indicates when additional activities, and by that additional costs, are necessary to regain acceptable performance (Moen 1998).

One asymmetrical loss function with multiple intervals is used for each cost category where the shift in performance in Fig. 16 gives shifts in the loss function (Fig. 17).
The cost at these shifts are the overall cost determined through the analysis in Fig. 16. The expected loss for one customer requirement or key process parameter (for internal failure costs) can be illustrated as the shaded area under the loss function \( L_i(x) \) and the actual performance of the characteristic \( g_i(x) \) in Fig. 17. The expected loss can then be calculated as:

\[
E[L_i] = \int_{-\infty}^{\infty} L_i(x)g_i(x)dx, \quad g_i(x) - N(\mu, \sigma^2).
\]

A normal distribution has been assumed for a target-the-best characteristic, but for a characteristic with a smaller-the-better or larger-the-better loss function, a Weibull or exponential distribution would have been expected. For all practical purposes the integration can be done between \( \pm 3\sigma \). Necessary input to the loss calculation is the shifts in performance \( (L_i) \) and the cost at these shifts. In addition, the expected value of the process influencing the characteristic and the standard deviation of this process are required. These values can be used to simulate how changes in process performance, either the centering or the range of variation, will influence the loss for the characteristic (Moen 1998: 338).

Moen (1998) has developed a new customer and process focused poor quality cost model to give a more accurate picture of the cost of (poor) quality, and to enable management to make long term strategic decisions concerning how to best satisfy their customers. Areas for improvement are identified through first determining customer requirements and their importance and subsequently translating these requirements to key process parameters. The most important key process parameters, regarding how to meet customer requirements, are monitored.
through the loss function. The loss function describes how sensitive a characteristic is to process deviation from the target value, and when it is linked to actual process performance, it becomes possible to predict the expected quality costs for each characteristic. This model, presented by Moen (1998), can also be used to simulate how changes in process performance will influence quality costs.

3.2.1 Example of estimating intangible quality costs

Intangible costs have been described as the most important costs needed for management, but they are unknown or difficult to calculate. However, it is believed that by using the QFD matrix (Fig. 18) it is possible to make quite accurate estimates of these costs. Intangible quality costs consist of customer dissatisfaction costs and loss of reputation costs, and they are calculated as follows (Moen 1998):

![QFD Matrix Diagram](image)

**Fig. 18. Estimating intangible quality costs. (Moen 1998.)**

1. An estimate of the *lost revenue of the current product or service* because one existing customer is lost. This can be estimated as re-purchase intention and the average number of re-purchases during a given time frame.
2. An estimate of *lost revenue from potential customers* that is lost because the dissatisfied customers advise against the current product.
3. *Lost sales of other products provided by the manufacturer* based on poor experience with one product. This element is strongly dependent on the product mix the company provides, and the similarity and coherence between
each product. The total cost of (1), (2), and (3) has been denoted $C_{tot}$, which
is an estimate of the potential intangible cost due to a dissatisfied customer
that leaves the company. Actual intangible quality costs, based on the
estimate of potential costs ($C_{tot}$), has been determined by using the QFD
matrix.

The customers’ rating of importance (described as 2 in figure above) of each
requirement (described as 1 in figure above), along with the customers’
perception of the company’s performance for each requirement compared to chief
competitors (3), have been used to calculate a cost index (4). This cost index is
used as an estimator of the probability that poor product or service performance
will result in an intangible cost. If the importance of a customer requirement is
low, the probability that a loss will occur is low, but if the importance is high, the
probability of loosing the customer is high. The performance of the company
compared to competitors will also influence the probability of a loss. The
difference between the company’s and their chief competitor’s performance has
been denoted $P_i$, which is a performance index. A negative $P_i$ indicates that the
company’s performance is better than their chief competitor, and it is assumed
that a loss will most likely not occur even if the customer is dissatisfied and the
requirement has a high importance attached to it. The customer has no alternative
supplier and will not gain anything by leaving the company. If the company’s
performance is low compared to the chief competitor’s, a loss will most likely
occur.

In the worst case the difference in performance ($P_1, P_2, ..., P_n$) can be five to
the disadvantage of the company for every customer requirement (Req #1, Req
#2, Req #n), which gives the maximum expected loss $C_{tot}$. The cost index $CI$
for each customer requirement can be expressed as: $CI_i = I_i \times P_i$

Where:

$I_i =$ Importance attached to requirement $i$ (2).

$P_i =$ The company’s performance for requirement $i$ where a negative $P_i$ indicates
better performance than the chief competitor.

$CI_i =$ Cost index for requirement $i$ (4).

$CI_{i,\text{max}} = I_i \times 5$ which equals worst case difference in performance ($P_j = 5$).
A loss factor \( f_{\text{loss}} \) can be described as the overall loss estimated in (1), (2), and (3) \( (C_{\text{tot}}) \) divided by the worst case cost index \( (C_{\text{max}}) \), that is when the difference in performance is five for every requirement to the disadvantage of the company:

\[
f_{\text{loss}} = \frac{C_{\text{tot}}}{C_{\text{max}}} = \frac{C_{\text{tot}}}{5 \times \sum I_i}.
\]

The expected annual loss for one product can be expressed as the loss factor times the sum of cost indexes (the probability that not meeting each customer requirement will lead to an intangible loss):

\[
E(L) = f_{\text{loss}} \times \sum C I_i.
\]

Where a positive \( P_i \) indicates that the performance of the chief competitor is better than the company, and a negative \( P_i \) indicates that the company performs better than the chief competitor. Negative values of \( P_i \) will, per definition, not result in a loss \((=P_i \equiv 0)\).

An example product is described by the requirements in Fig. 19 with their attached importance \((I_i)\). The customer’s evaluation of performance is given by \( P_i \). The sum of the three cost elements \((1), (2), \text{and} (3)\) is \( C_{\text{tot}} = $400 \) (not calculated), which is the total estimated loss due to one dissatisfied customer that leaves the company as a result of poor product or service performance.

<table>
<thead>
<tr>
<th>Customer requirement</th>
<th>Importance ( I_i )</th>
<th>Customer rating ( 0 \ 1 \ 2 \ 3 \ 4 \ 5 )</th>
<th>Performance ( P_i )</th>
<th>Cost index ( C_i I_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast delivery</td>
<td>3.3</td>
<td>2.1</td>
<td>6.93</td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td>5.2</td>
<td>1.1</td>
<td>6.72</td>
<td></td>
</tr>
<tr>
<td>Reliable</td>
<td>7.8</td>
<td>-0.5</td>
<td>-3.90 (=0)</td>
<td></td>
</tr>
<tr>
<td>Nice colour</td>
<td>2.0</td>
<td>1.5</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Easy to use</td>
<td>8.0</td>
<td>-1.5</td>
<td>-12.00 (=0)</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>1.5</td>
<td>3.0</td>
<td>4.50</td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>( \Sigma I_i = 27.8 )</td>
<td></td>
<td>( \Sigma C = 20.15 )</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 19. Customer incurred costs: an example. (Moen 1998.)
The loss factor can then be described as:

\[ f_{\text{loss}} = \frac{C_{\text{tot}}}{C_{\text{max}}} = \frac{C_{\text{tot}}}{5\times\sum_{i=1}^{n} l_i} = \frac{\$400}{5\times27.8} = 2.88, \]

which gives an expected annual intangible loss for the product:

\[ E(L) = f_{\text{loss}} \times \sum_{i=1}^{n} CI_i = 2.88 \times 20.15 = \$57.99. \]

By using this approach, the manufacturer can obtain a picture of the long-term consequences of not meeting customer requirements, and focus their improvement efforts on those elements that will lead to a reduction in intangible costs. By using the QFD matrix and a cost index based on the importance of each customer requirement, and the company’s performance compared to competitors, it has become possible to estimate the expected intangible loss for each customer requirement. When this estimate is included in the overall cost picture, the priorities for quality improvement will most likely change dramatically. An allegation is that companies that rely exclusively on traditional quality cost models are suboptimizing their processes, and the results of quality improvement may at the worst antagonize customer satisfaction and loyalty.27

### 3.3 Types of quality costs levels

According to Sörqvist (1998), when we begin to measure quality costs in practice within a company it will soon be evident that the degree of difficulty in measuring varies considerably between different cost categories. Certain losses are easy to measure while measuring others require a great deal of work. Many losses are in fact impossible to measure in practice. Some of these may be estimated while others will remain unknown. This is the reason why Sörqvist (1998), in his dissertation, considers it appropriate to divide QC:s into five levels: traditional quality costs (PAF-approach), hidden quality costs, lost income, customer’s costs and socio-economic costs. In spite of subsequently presenting all five levels of Sörqvist’s model, the empirical part of this dissertation accommodates the traditional quality costs (level 1) in the constructed model but also some quality

---

27 There is no evidence in the literature that the model presented by Moen (1998) has been used in practice. Naturally, some companies may have used it for benchmarking purposes.
costs in the second level in Sörqvist’s classification (rework often takes place directly when the personnel correct the fault without accounting for it separately). Still, it is very important to notice, that the quality costs reported usually (and also in the construction developed in this thesis) constitute only a small portion of the actual QC:s. This is demonstrated in Fig. 20.

The first level comprises traditional quality costs, or the obvious losses which are managed using existing quality cost systems, mainly in manufacturing companies. Many of these losses have incurred in the production base, where the personnel generally work on a time basis and have a possibility to make a distinction for a non-value adding time. In many service companies few of the traditional quality costs are known.

Traditional quality costs are largely due to sporadic problems\(^28\) which disrupt operations, while those caused by chronic problems remain hidden. These losses consist mainly of cost elements such as rejects, rework, guarantee costs, complaints, penalties and the costs associated with inspection personnel. Normally, costs are gathered from financial accounting system and the existing failure reporting system are used for the measurements. Admittedly, this provides a very simple measuring method, but using this means we only pick up a small proportion of the total losses (the top of the iceberg, as seen in the following figure) and then almost exclusively those in production.

The second level consists of the remaining losses which directly affect the business, but which are not revealed by the financial accounting system. Sörqvist (1998) calls these losses hidden quality costs. In the financial accounting system these losses are generally registered, for instance, under direct wages, direct material and production overhead. These types of losses include almost all the QC:s which are incurred on the white-collar side of the business, but also a higher proportion of the losses within production where only certain QC:s are distinguished and reported separately. One example of this is that rework often takes place directly when the personnel correct the fault without accounting for it separately. In this thesis, I also make anticipated contribution by developing a construction in which it is not possible to make such default corrections. Many of the losses arising as a result of chronic problem are at this level. The traditional QC:s that we normally measure may therefore be seen as the top of the iceberg.

\(^{28}\) See Fig. 15 on page 86.
Fig. 20. Traditional quality costs constitute only a small proportion of the actual QC:s. (Sörqvist 1998.)

The third level consists of lost income. This is the income lost by releasing goods and services, which do not satisfy all the requirements of the external customer, to the market. This can result in the customer experiencing failures and faults in the product, in the stated needs of customers not being satisfied, or in the products of a competitor offering characteristics that customers perceive to be valuable and which the company’s own products lack. In this way the company suffers loss of goodwill which leads to fewer sales and the loss of potential customers. In many companies it is likely that those losses amount to very substantial amounts.

It is very difficult to measure loss of income and it is often necessary to study this by carrying out estimates. Sometimes even this is impossible. To avoid making incorrect decisions in the analysis of quality costs, it is, however, essential to be aware of the existence of these losses. External quality costs could probably give indications of changes at this level. Parallel to estimates and measurements of economical losses, it is also important to study those effects with other methods (e.g. measuring customer loyalty and customer profitability).

The fourth level consists of customer’s costs. By this Sörqvist means those losses which affect the external customer due to poor quality in some stage of the process. These could be the losses incurred by the customer due to breakdowns in production, functional defects, market effects and so on caused by goods and services sold to them. These losses are significant since they are strongly related to costs for lost income. A poor quality product which causes heavy costs to the customer will usually erode the goodwill of the supplier.
Nowadays, the views of customers and suppliers have changed and companies now endeavour to co-operate and build long-term relationships with common goals. Such an approach means that a policy in which we are solely interested, in the short-term optimization of our company’s situation, is no longer viable. Taguchi describes this in a readily comprehensible way by means of Fig.21.

**Fig.21.** Taguchi shows that if a supplier maximizes his profit this will be at the expense of the customer. (Sörqvist 1998.)

Taguchi demonstrates that if the supplier wishes to make a financial gain by moving the target value of the process from an optimal situation towards the tolerance limit, the result will be that the producer’s gain is less than the customer’s loss, or that sub-optimization occurs. From this argument it would appear that there is a theoretical optimum for the entire customer/supplier chain, but in practice such an optimum will never be attained due to lack of information and rapid changes. However, by being aware of the total situation, it is possible to work in right direction and thereby increase the profitability of the total system. All in all, this optimum represents only a local point in a greater system consisting of the entire social system.

*The fifth level consists of socio-economic costs.* By these Sörqvist means the losses affecting the community at large due to poor quality of companies’
processes and products. Such losses may be the costs caused by the harm done to the environment by products with quality deficiencies, since environmentally friendly is, according to the definition of quality, a stated or implied quality requirement of a community. From the point of view of the company, these losses are important considerations, since even in the short term some of them have to be paid for in the form of environmental taxes, penalties and market effects. The effects of socio-economic costs on businesses are likely to increase in the near future as a result of widely held political belief in the western world according to which companies should compensate the community for the losses they cause (Sörqvist 1998: 36–39)

3.4 Drawbacks of the PAF-approach

According to Moen (1998), there are several shortcomings in the traditional approach to quality cost measurement. First, traditional quality cost systems are mainly internally company focused and reactive by nature. Improvement activities are prioritized according to easily identifiable measures like failures and rework, and negative feedback from the customer after problems have occurred. Customer requirements, needs and expectations are not used proactively to direct quality improvement, and increased customer satisfaction and loyalty is not included in the measure. Performance measurement and top management decisions are usually based on traditional accounting information, which is inadequate to monitor and direct quality improvement. Standard cost systems usually institutionalize waste by relating it to a pre-established standard. A substantial amount of failure costs (including rework) is normally hidden in these figures. A certain percentage of rejects may be considered necessary in a production process, and as long as these figures are not exceeded, no failure cost is recorded. For administrative activities no discrimination is made between doing something and doing it over (IAQ 1995).

The validity of the original quality cost categories has changed. Failure costs are eliminated according to the Pareto principle, according to which the most severe failures with the largest economic consequences (according to traditional accounting) are eliminated first. Minor problems are not addressed often because they are unprofitable to remove, but added up, they become unacceptable to the customer. Failure costs are driven by defect rates, which are based on specification limits. These limits are often based on convenience, internal
company opinions about customers’ needs and the performance of production equipment (Diallo et al. 1995).

Moen (1998) considers that the most severe problem with prevention costs can be found in the underlying philosophy. It implies that it is necessary to distinguish between normal, error-prone activities, and some extra effort to perform them error free. Error free design and work performance are normally the duty of everyone in an organization, and the extraction and definition of prevention activities is difficult, if not impossible (Porter and Rayner 1992). More recently, we have begun to refer more to quality costs to bring out the fact that it is poor quality that causes the costs. According to Sörqvist (1998), prevention costs are not a cost for poor quality but are rather an investment in good quality. It is of course possible to measure these costs parallel to failure costs. However, this would appear unnecessary since decisions have actually been made to incur these investment costs and they are therefore not unknown costs that we wish to study as a means of identifying problems and selecting appropriate improvement measures. It is difficult to determine what is really a prevention cost since costs incurred in the business which are not quality costs result in good quality. It could, in an extreme case, be claimed that the prevention costs comprise the costs of all activities in the business except quality costs. According to this argument, the result is arbitrary and Sörqvist (1998) argues that there is therefore little point in measuring prevention costs.

The idea behind measuring preventive measures used to be to allow us to compare costs incurred in quality improvements with (poor) quality costs, from which we would be able to determine the optimal quality level for business. In practice, however, this is impossible partly because of the definition problems mentioned above regarding prevention costs, and partly since in practice we have only managed to measure a small proportion of the actual quality costs. Sörqvist (1998, p. 34) argues, that the risk associated with such an approach is that of sub-optimization.

We should also bear in mind that it is the effects of preventive activities that are of value and not an investment as such. If our measures to improve quality are the wrong ones, even some of the prevention costs would not be value adding, and would therefore be a failure cost (Sörqvist 1998, p. 34).

For this reason most organizations which calculate quality costs do not calculate prevention costs at all.
Moen (1998) reminds, that the problem with *appraisal costs* is that they have no optimum value. A high figure may indicate badly performed production or an intrinsic necessity of the process. Understanding appraisal costs requires a thorough process understanding, and reporting an aggregated figure to top management serves no useful purpose. Appraisal costs that are a direct consequence of inadequate processes should be recorded as failure costs, and customer ordered inspection and testing should be considered as separate processes.

The main weaknesses and criticisms of the the PAF model (Oakland 1993: 200–201, Porter & Rayner 1992) are described as follows. First, it is difficult to decide which activities stand for prevention of quality failures since almost everything a well-managed company does has something to do with preventing quality problems. Second, there are a range of prevention activities in any company which are integral to ensuring quality but may never be included in the report of quality costs. Third, practical experience indicates that firms which have achieved notable reductions in quality costs do not always seem to have greatly increased their expenditure on prevention. Fourth, original PAF model does not include intangible quality costs such as “loss of customer goodwill” and “loss of sales”. Fifth, it is sometimes difficult to uniquely classify costs (e.g. design reviews) into prevention, appraisal, internal failure, or external failure costs. Sixth, the PAF model focuses attention on cost reduction and ignores the positive contribution to price and sales volume by improved quality. Seventh, as mentioned above, the classic view of an optimal quality level is not in accordance with the continuous quality improvement philosophy of TQM. Eight, the key focus of TQM is on process improvement, while the PAF categorization scheme does not consider process costs. Therefore, the PAF model is of limited use in a TQM program.

Tsai (1998), considers the overhead allocation in measuring cost of quality the most important, the aspect of overhead allocation in calculating COQ is seldom discussed in the literature. In practice, some companies add overheads to the direct cost of labor and material on rework and scrap, while other companies do not. If they do, “rework and scrap costs become grossly inflated compared with prevention and appraisal costs which are incurred via salaried and indirect workers” (Dale and Plunkett 1991: 45). O’Guin (1991: 70) states that most of COQ measurement systems in use are not (there are some exceptions) intended to trace quality costs to their sources such as parts, products, designs, processes, departments, vendors, distribution channels, territories, and so on. Accordingly,
the COQ information derived from these systems cannot be used to identify where the quality improvement opportunities exist. Dale and Plunkett (1991: 112) state that, “it is the general lack of information about how people, other than direct workers, spend their time which presents a considerable obstacle to the collections of quality costs”.

Goulden and Rawlins (1995) argue that the limitations of the PAF model within PSD can be considered to fall into two areas; the model itself, and the company culture. The PAF-model reinforced preconceived ideas, meaning that the model reinforced the view that the ultimate responsibility for the provision of quality lay with the quality departments, in that prevention is solely associated with quality assurance department and calibration. They also argue that PAF-model was open to misinterpretation. Certain costs could not be accommodated to the satisfaction of all parties, hence the development of informative and defective codes. For example, unplanned work could be viewed as a failure of the planning process, alternatively it could be argued that this represented work which would have had to be done and could not therefore be called failure. According to them, the model was also inappropriate for indirect functions. In manufacturing functions the identification of activities as prevention, appraisal or failure is fairly straightforward. However, in indirect departments (i.e. those departments not required to book time such as quality assurance, sales, accounts) the nature of work makes the use of the PAF categories more complicated.

3.4.1 Difficulties in collecting and measuring quality costs

Fundamentally, the first stage in collecting COQ is to identify the quality cost elements. For the PAF approach, COQ elements are identified under the cost categories of the selected categorization scheme. Most of COQ elements relate to quality-related activities. For the process cost approach, the cost elements of COC and CONC for a process are derived from the flowcharted activities of the process. Most cost elements of COC do not relate to quality-related activities of traditional COQ view. After identifying the quality cost elements, we should quantify the elements and then put costs (dollar values) on the elements which have been identified (Dale and Plunkett 1991: 40–41). In COQ literature, many authors30 pay attention to why COQ information is important and what should be included in a COQ system, and seldom discuss how to measure and collect quality

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30 The importance of COQ measurement is stated in almost every journal article considering the subject.
costs. Besides, Thorne (1990) recommends some relatively uncomplicated methods for calculating COQ, i.e. collecting quality costs by account, by defect type, by whole person, by labor hours, and by personal log (see also Johnson 1995).

Dale and Plunkett state that “the collection and synthesis of quality costs is very much a matter of searching and shifting through data which have been gathered for other purposes” (Dale & Plunkett 1991: 38). Some of quality costs are readily available from a cost accounting system (e.g. scrap and rework costs); some can be derived from the data of activity reports (e.g. repair and inspection costs). Nevertheless, a large portion of quality costs should be estimated by some ways. For example, the opportunity costs of lost customer goodwill and lost sales, which are intangible external failure costs, can be estimated by Taguchi’s quality loss function (Albright and Roth 1994). Other examples are the costs of producing excess inventories and material handling due to suboptimal plant layouts, which are indirect failure costs and can be estimated by expertise. In addition, calculating prevention costs needs the estimates of apportionment of time by indirect workers and staff who do not usually record how they spend their time in various activities.

Sörqvist (1998) has studied the methods of measuring and working with quality costs in 36 Swedish companies. The sample included both manufacturing and service companies, such as Volvo, SAAB, Scania, Ericsson, Sandvik, IBM, Telia, Teli, Sweden Post, and a number of smaller companies. The companies were chosen by means of a selection process which main criterion was the experience of measuring poor quality costs. The studies of companies were carried out at very different levels of intensity, depending on the companies experience, time and interest, and usefulness in the study. The following problems considering quality cost collection and measurement were found is his study:

Problem 1. Scope. Most of the QC:s measured in the majority of the companies studied were related to production, such as rejects, rework, claims, inspections and testing activities. The costs which arise in other parts of the company, which are for the most part dominated by white-collar workers, are only measured to a limited extent, in many cases not at all, as these are considered to be too difficult to measure. The measurements mainly focus on the problems

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31 There are no universally applicable accounting methods of measuring cost of quality. Because of this, the comparability of COQ between companies is extremely difficult. The problems considering quality cost collection and measurement are further discussed in the next few pages.
which are associated with poor product quality, while the effects of other deficiencies and insufficient features are often omitted. In other words, the measurements are not measuring total quality. The faults and deficiencies measured are mainly sporadic in character, whilst chronic problems\(^{32}\) tend to remain hidden.

**Problem 2. The object of the measurements.** Most of the companies studied had not decided in advance for what purpose they would use the measurement results, and consequently they have not selected the measuring methods accordingly. Some companies give the impression that their main goal is to receive regular reports and not to use the information as a basis for making improvements.

The utilization of the information obtained is often faulty and in most cases there is no reliable connection to improvement activities. All of this indicates a very tangible fixation on methods, where the focus is placed on measuring systems and methods rather than on results and potential for improvement. In some cases it would be true to say that the measurements had become an end in themselves, without any practical use.

**Problem 3. Definition.** A common problem when measuring poor quality costs\(^{33}\) is that considerable disagreement can arise over which costs should be included among the company’s poor quality costs. Some costs are regarded as more or less self-evident, while others arouse heated discussion. The latter could include, for instance, the cost of repairs paid by the customer for recently delivered products, the cost of inspections and tests requested by customers or authorities, or the cost of product development (where trial and error is often regarded as accepted practice).

In this field a crucial distinction can be made between those companies which are successful at measuring their poor quality costs and those which have failed. The companies which have succeeded with their measuring activities generally make quick decisions on these issues and then move ahead, while the less successful companies tend to prolong their discussions and fail to move on to the actual measurement stage. Even during the later stages of the measurements (e.g. analysis and presentation of results) the latter companies tend to revert to the relevance of various costs and thus, also forego many opportunities for improvements.

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\(^{32}\) About chronic and sporadic problems, see e.g. Fig. 15 on page 86.

\(^{33}\) Sörqvist uses the term *poor quality cost* instead of quality cost.
Problem 4. Responsibility. The question of whose account the various costs should be charged against, for example how to determine who has actually caused the costs, often leads to difficulties in connection with measuring poor quality costs. As with the previous problem, the successful companies make their decisions quickly, regardless of the decision they make, while the less successful companies also prolong this discussion. In general, companies which have succeeded with the poor quality cost measurements often use simple methods to determine whose account should be charged for the costs measured. In some cases they only measure the costs where they are incurred, and leave the rest for later analysis in connection with improvements, while in other cases they have clear and simple procedures for allocating costs.

Problem 5. Measuring methods. Companies often experience problems with measuring methods and discuss them frequently. Most companies have chosen to measure QC:s by designing measuring systems the employees should use to report problems and deficiencies. In some cases these measuring systems are based on the financial accounting system and other reporting systems, which are usually expanded to suit the new task. In other cases new measuring systems are designed, and incorporating report form or PC systems specially designed to measure poor quality costs.

The existing financial accounting system is usually considered to be unsuitable for reporting poor quality costs. The normal arrangement of accounts and cost centres in a financial control system is not suitable for measuring poor quality costs, as these are not distinguished. The financial control department’s practices and systems mostly appear to be intended to satisfy the requirements of official authorities and shareholders, and they are often poorly suited to internal purposes. Other failure-reporting systems are often difficult to use, since in many cases they are local and often incompatible with each other.

In some cases, problems arise which are caused by the reporting procedures being unclear, the knowledge of the users being inadequate and the opportunities for making mistakes numerous. The use of separate systems is often impeded by the belief of the intended users that the extra workload would be too heavy. In general, many problems are experienced due to the systems not being used in the manner intended, which affects the quality of the results.

Some companies have chosen to combine different types of measurement, for example, measurements of poor quality costs, customer satisfaction and work climate, as a means of obtaining an accurate picture for the decision-making situation. Sometimes these may be weighted in the form of an index.
Problem 6. Management. It has been demonstrated that if the company’s management is not properly involved, and does not make demands regarding the information, this can be one of the most important reasons why the reporting of poor quality costs fails to work. In many cases management has not used the information for measures and improvements, which has reduced the motivation of the personnel to report problems.

Problem 7. Personnel. The employees in some companies feel that reporting poor quality costs involves an additional workload, and they cannot see the benefits of the measurements. This could be due to the adaptation to local requirements being less than perfect, to the absence of support and resources when the reported poor quality costs are high, and to the lack of interest among management in requesting information.

In many cases employees experience discomfort or fear when reporting poor quality costs which have arisen at their workplace, as these could easily be interpreted as personal failures. In some cases, this has even caused employees to conceal certain awkward costs. Employees and trade unions have protested against the measurements in several companies.

The companies which have succeeded best have attached great importance to training their personnel so that understanding has increased, created personnel involvement in the design of the system, and underlined the importance of the measurements by demanding information and reacting quickly to problems and failures.

Problem 8. Precision. Studies carried out with the aid of statistical methods have shown that in many cases the capability of the measurements was poor. In several cases, management considered that the results of the poor quality cost measurements contained unreliable and incorrect information. Poor measurement results can easily cause the priority of the measurements being lowered, which makes the results even worse.

To avoid such situations, several successful companies have begun the measuring activities with measurements on a small scale, to accumulate experience and the ability to later introduce a capable measuring system. Some of the most successful companies have begun the work by mapping the company’s total poor quality costs on the basis of estimates, from which certain types of cost are then selected for further measurement.

Problem 9. Implementation. One important experience gained is that a company definitely has the best chance of implementing a measuring system at the first attempt. Companies which have already made unsuccessful attempts to
measure poor quality costs often experience immense problems when they use new methods for the next attempt, as the personnel already “know” what poor results this could achieve. This means that the introduction of the measurements must be properly planned and prepared.

A number of companies found that the introduction of a system for measuring poor quality costs is very time-consuming and requires several years of intensive work. Other companies have achieved good results in a short time, as simplified surveys have been made, based on estimates. The support of the financial control and controller functions in the company is often regarded as very important. This creates both greater acceptance of the results and access to competence and skills in the financial control field.

**Problem 10. Comparisons.** The magnitude of the poor quality costs measured varies widely – from a few per cent of the turnover to almost 20 per cent. Manufacturing companies generally appear to have higher relative poor quality costs than service companies, which is probably due to the fact that it is easier and usually more acceptable to make these measurements in production. The highest poor quality costs are usually found among those companies which have developed the best measurement techniques. They are better at revealing the level of poor quality costs in the company. This shows that **comparisons of poor quality costs should not be made between different companies, unless it can be ensured that identical approaches and methods have been used.**

### 3.5 Process cost approach (New customer and process focused poor quality cost model)

Some researchers argue that identification of quality cost elements in the PAF-approach is somewhat arbitrary. The PAF-approach may focus on some quality-related activities which account for the significant part of total quality cost, not on all the interrelated activities in a process. Goulden and Rawlins (1995) argue that under the philosophy of process improvement in TQM, analysts should place emphasis on the cost of each process rather than an arbitrarily defined cost of quality. In view of this, the process cost approach, described in the revised BS 6143: Part 1 (1992), is proposed. It recognizes the importance of process cost measurement and ownership. **The process cost is the total of the cost of conformance (COC) and cost of nonconformance (CONC) for a particular process.** The COC is the actual process cost of providing products or services to the required standards, first time and every time, by a given specified process.
The CONC is the failure cost associated with a process not being operated to the required standard (Porter and Rayner 1992). According to this definition, the content of this categorization (COC and CONC) is different from that of Crosby’s (POC and PONC) mentioned previously.

The essence of this model is that it can be used to measure the total cost associated with any process. It allocates costs to categories of conformance and non-conformance. Cost of conformance is the minimum cost of the process as specified (combining prevention and appraisal costs from the PAF model). Cost of non-conformance is the cost of inefficiency within the specified process (combining internal and external failure costs from the PAF model). The total cost of a process is the cost of doing all the activities without error or wastage plus the cost of the failure activities. Total process cost is usually expressed as the sum of the Cost of conformance and Cost of non-conformance. Categorization of costs need not necessarily be restricted to those of the two models above. Organizations could also consider other forms of categorization which will suit their business needs. (Bland et al. 1998).

The process cost model can be developed for any process within an organization. It will identify all the activities and parameters within the process to be monitored by flowcharting the process. Then, the flowcharted activities are allocated as COC or CONC, and the cost of quality at each stage (i.e., COC + CONC) are calculated or estimated. Finally, key areas for process improvement are identified and improved by investing in prevention activities and process redesign to reduce the CONC and the excessive COC respectively (Tsai 1998: 725). The British Standards Institution has included this methodology in the revised BS 6143: Part 1 (1992). Dale and Plunkett (1991: 43) state that this will help to extend the concept of quality costing to all functions of an enterprise and to non-manufacturing organizations, and that it also gets people to consider in more detail the processes being carried out within the organization.

A new proactive customer and process focused poor quality cost (PQC) model has been developed to overcome some of the problems in previous models (Feigenbaum 1956, Harrington 1987). The term poor quality cost has been used to stress that prevention and appraisal costs have been left out compared to Feigenbaum’s PAF model, since they are difficult to measure and have limited application in the strategic decision process. However, it is still important to measure these elements for internal operational use in each department. The model in Fig. 22 (developed by Moen 1998) divides PQC's into two main categories of direct and indirect costs. The direct element consists of cost
categories that are monitored and perceived within the company, while the indirect element contains costs that are first perceived by the customer, but subsequently returned to the company as lost market shares. The basis for both elements is customer requirements, needs and expectations. Both internal and external failure costs are made up by direct failure costs, consequence costs, and lack of process efficiency costs. Direct failure costs include the direct financial consequence of every failure that is discovered before shipment (internal) and all direct costs associated with claims, rejects, warranty administration, etc. as a result of problems discovered after shipment (external). Critical failures that have a direct influence on customer satisfaction are monitored by Taguchi’s loss function. Consequence costs include additional costs such as administration, disturbances in current and related processes, additional planning, etc. These costs are assigned to direct failure costs through a simplified activity based costing approach. Lack of (process) efficiency costs, which are costs due to inadequate process performance compared to chief competitors or theoretical performance, is determined through competitive or functional benchmarking.

Fig. 22. New customer and process focused poor quality cost model. (Moen 1998.)

Indirect PQC’s consist of Customer incurred costs, Intangible costs, and Environmental costs (compare to Harrington 1987). Customer incurred costs are the costs brought on the customer as a result of unsatisfactory quality supplied by the producer. This element embraces much of the same costs as internal failure at the producer. Intangible costs cover customer dissatisfaction costs and loss-of-reputation costs. Customer dissatisfaction costs occur when a customer refrains
from repurchasing a product due to dissatisfaction with the product’s overall performance. Loss-of-reputation costs occur when the customer refrains from buying any products from the manufacturer, based on poor experience with one specific product. The latter reflects the customer’s attitude towards the company rather than toward a specific product. Environmental costs include costs due to the short- and long-term environmental effect of the product.

The integration of the PQC model (Figure 22) is shown in Figure 23. The PQC system is based on tools and techniques that should be present in an organization that wishes to be a world class manufacturer. The dotted rectangle (➊) represents the company with internal functions, where traditional quality cost systems are mainly based on allocating costs due to scrap, failures and rework. The basis of the new system, instead of customer requirements, are the needs and expectations revealed through customer surveys, customer complaints and other kinds of customer feedback (➋).
Customer requirements have been translated to key process parameters by using quality function deployment (QFD); (➌). A key process parameter is a process parameter that directly influences the fulfillment of customer requirements. The QFD matrix has also been used to estimate intangible PQCs and lack of (process) efficiency costs.

PQCs for each cost element ➊ (except intangible costs) have been measured through the Taguchi loss function ➋, using actual performance of each key process parameter, and how the company meets customer requirements, as input.
This enables the company to predict PQC\(s\) at the present performance level, and also simulate how changes in performance due to quality improvement efforts will influence total PQC\(s\).

According to Moen (1998), there are still some approaches to measuring COQ apart from the PAF approach (chapter 3.4) and the process cost approach presented above. For example, Son and Hsu (1991) propose a quantitative approach to measuring quality costs, which considers both manufacturing processes and statistical quality control. In this approach, statistical terms of quality are translated to dollar terms. However, the quality cost model presented in their paper is restricted to a simplified manufacturing system which consists of only a machining area (with in-process sampling inspection) and a final inspection area (with 100 percent final inspection). Moreover, Chen and Tang (1992) present a pictorial approach to measuring COQ, which is patterned after that used in a computer-based information system design. The COQ variables considered in this approach include direct COQ variables (PAF costs and quality-related equipment costs) and indirect COQ variables (customer-incurred costs, customer-dissatisfaction costs and loss of reputation). It includes two major steps: 1) specifying the COQ variables as well as the significant relationships among the variables, and mapping the variables and relationships into an “influence diagram” showing the structure of a COQ system; and 2) converting the structure into a well defined “entity-relationship diagram” showing the input-output functions and their associated properties. The influence diagram used in the pictorial approach can provide an easy-to-understand COQ system for quality management practitioners, and the entity-relationship diagram can provide an effective framework for maintaining and modifying the COQ system.

In the next chapter, _Quality cost measurement under activity based accounting environment_, a generic cost of quality -model will be presented. The chapter will discuss of the strengths and weaknesses of the Prevention – Appraisal – Failure (PAF) -model in various business environments. In the chapter, sophisticated models of measuring COQ are presented. The accounting principles of ABC and their implications to cost of quality are discussed. The chapter also focuses on COQ measurement and continuous quality improvement under activity based costing environment. This is done by presenting an COQ-ABC framework.
3.6 Quality cost measurement in Activity-Based Costing environment

Activity-Based Costing (ABC)\textsuperscript{34} has maintained a high profile status as an important management accounting innovation for well over a decade\textsuperscript{35}. It has been promoted and adopted as a basis for making strategic decisions and for improving profit performance (Bjornenak \& Mitchell 1999). In addition, ABC information is now also widely used to assess continuous improvement and to monitor process performance. In this chapter, cost assignment view and process view of ABC are discussed. After that, in chapter 3.7, a relationship between activity/cost categories of cost of quality approaches and ABC is being done. It is important to notice the implications of various cost accounting environments on quality cost accounting.

3.6.1 Cost assignment view of ABC

Although ABC has found rapid and wide acceptance, there is significant diversity of opinions regarding the efficacy of ABC (McGowan and Klammer 1997). Several reservations have been expressed concerning its usefulness, relevance, and practicality (Innes et al. 2000). Despite managers’ insistence that management accounting systems pass the cost–benefit test (Foster and Young 1997), there still is no significant body of empirical evidence to validate the alleged benefits of ABC (Shima and Stagliano 1997, McGowan and Klammer 1997). Empirical research is needed to document the (financial) consequences of ABC implementation (Kennedy and Bull 2000, McGowan 1998). Furthermore, previous research has suggested that the benefits of ABC are more readily realized under enabling conditions such as sophisticated information technology, highly competitive environment, complex firm processes, relatively high importance of costs, and relatively low unused capacity and intra-company transactions (Cagwin and Bouwman 2002).

However, despite a strong and durable advocacy (Cooper 1988, Cooper and Kaplan 1991, 1992, 1998, Kaplan 1992), several reservations have been

\textsuperscript{34} The terms activity-based costing (ABC) and activity-based management (ABM) are sometimes used interchangeably. Strictly speaking, ABC refers only to determining the costs of activities and the outputs that those activities produce. Some researchers and practitioners prefer to use the term activity-based management (ABM) when describing how the activity information is used to support operating decisions.

\textsuperscript{35} Two decades at 2008
expressed concerning (a) the substance of its practical attraction (Bjornenak 1997, Gosselin 1997, Malmi 1999), i.e. that it may be a fad or fashion, engendering a bandwagon effect rather than a genuine and useful technical enhancement, (b) its decision-making relevance (Noreen 1991, Bromwich & Hong 1999), i.e. that several restrictive (and practically unlikely) conditions must apply before the ABC information can legitimately be used to generate relevant costs for decisions, and (c) the problematic and costly design, implementation and operation of the systems required for ABC in an organizational context (Cobb et al. 1992, Malmi 1997). These qualifications may contribute to an explanation of the relatively low adoption rates that have been consistently observed for ABC in surveys conducted in different countries (e.g. Lukka 1994, Armitage & Nicholson 1993, Ask & Ax 1992), and imply that even practical experience of ABC may not necessarily lead to its permanent adoption. However, most survey research to date has produced only snap-shot evidence of the extent of ABC adoption at one location and at one point in time. Survey replication in the same location has been uncommon and consequently little is known about how the adoption of ABC has actually progressed at a general level over time. (Innes et al. 2000).

According to Brimson (1991), the main shortcoming of traditional cost accounting is to distribute overhead costs over products by using volume-related allocation bases such as direct labor hours, direct labor costs, direct material costs, machine hours, etc. It will not seriously distort the product cost in the conventional manufacturing environment where overheads are just a small portion of product cost. In the modern manufacturing environment, however, the overheads will grow rapidly as manufacturers increasingly promote the level of automation and computerization, and the cost distortion of traditional cost accounting will be significant (Brimson 1991: 179). The main reason is that many overhead costs vary with volume diversity, product diversity, and volume-unrelated activities (e.g. set-up and scheduling activities), not with volume-related measures. For example, high-volume products consume more direct labor hours than low-volume products, but high-volume products do not necessarily consume more scheduling cost than low-volume products. Therefore, traditional cost accounting will overcost high-volume products and undercost low-volume products.

In view of this, Cooper and Kaplan suggested to use ABC to improve the accuracy of product costs. In the early ABC systems (Turney 1991: 77–80), overhead cost is divided into various cost pools, where each cost pool contains the cost of a group of related activities consumed by products in approximately the
same way. Each cost pool is distributed to products by using a unique factor that approximates the consumption of cost. This unique factor, called an allocation basis in traditional cost accounting, could be volume-related (e.g. direct labor hours and machine hours) or volume-unrelated (e.g. number of orders, set-up hours, and number of parts).

As follows, a two-dimensional model of ABC (Turney 1991: 81) is proposed in Fig. 24. This ABC model is composed of two dimensions: cost assignment view and process view.

![Two-dimensional model of ABC](image)

*Fig. 24. Two-dimensional model of ABC. (Turney 1991: 81.)*

The detailed cost assignment view of ABC is shown in Fig. 25. Activity based costing assumes that cost objects (e.g. products, product lines, processes, customers, channels, markets, etc.) create the need for activities, and activities create the need for resources.
Accordingly, ABC uses two-stage procedure to assign resource costs to cost objects. In the first stage, resource costs are assigned to various activities by using resource drivers. Resource drivers are the factors chosen to approximate the consumption of resources by the activities. Each type of resource traced to an activity becomes a cost element of an activity cost pool. Thus, an activity cost pool is the total cost associated with an activity. An activity center is composed of related activities, usually clustered by function or process. We can create activity centers by various ways according to different information needs. In the second stage, each activity cost pool is distributed to cost objects by using an adequate activity driver which is used to measure the consumption of activities by cost objects (Turney 1992). If the cost objects are products, then total cost of a specific product can be calculated by adding the costs of various activities assigned to that product. The unit cost of the product is achieved by dividing the total cost by the quantity of the product.

The resources used in manufacturing companies may include people, machines, facilities, and utilities, and the corresponding resource costs could be assigned to activities in the first stage of cost assignment by using the resource drivers time, machine hours, square footage, and kilowatt hours respectively (Brimson 1991: 135). The manufacturing activities include the following
categories of activities (Cooper 1990): unit-level activities (performed one time for one production unit, for example, 100 percent inspection, machining, finishing); batch-level activities (performed one time for a batch of products, for example, sampling inspection, set-up, scheduling); product-level activities (performed to benefit all units of a particular product, for example, product design, design verification and review); facility-level activities (performed to sustain the manufacturing facility, for example, plant guard and management, zero defect program). The costs of different levels of activities will be traced to products by using the different kinds of activity drivers in the second stage of the ABC cost assignment view. For example, machine hours are used as the activity driver for the activity machining; set-up hours or the number of set-up for machine set-up; and the number of drawings for product design (Tsai 1996b). Usually, the costs of facility-level activities cannot be traced to products with the definite cause-effect relationships and should be allocated to products with appropriate allocation bases (Cooper 1990). The information achieved from the ABC cost assignment view is usually used for the decisions of pricing, quoting, product mix (Tsai 1994), make versus buy, sourcing, product design, profitability analysis, and so on (Turney 1992).

Kaplan and Anderson (2004) have recently advocated *time-driven ABC*, in which the actual time for performing an activity is estimated instead of using percentage of time of total time spent on it. Time-driven ABC is partly an effort to overcome the labour and costs often associated with implementing and maintaining ABC systems. The capacity of most resources is measured in terms of time availability, which helps in distinguishing between used and unused capacity. Time-driven ABC also makes it possible to use time equations, which help in differentiating between the complexity of different products. Information for time equations can be easily available from the company’s ERP system, which makes updating also easier. Despite the obvious benefits of duration-based drivers in many environments, transaction-based drivers are still more commonly used. The problem has been that the measurement of durations has been laborious or even impossible (Varila *et al.* 2007).

A new variant of Activity-Based Costing, time-driven ABC, utilizes estimates as the sole type of cost driver. There has been little discussion, however, about the potential for errors introduced by their use, although experience indicates that employees’ estimates of the activities they perform and their duration are often inaccurate (Ittner 1999). Labro and Cardinaels (2006) argue that they were the first to systematically study measurement error on duration drivers, the contingent
factors that impact on it, and the costing system design parameters that can alleviate it. Given the widespread use of duration drivers and their potential for error in the design stages (Ittner 1999), it is important to understand the sensitivity and robustness of costing systems to these types of errors. Labro and Cardinaels (2006) find a strong overestimation bias when participants provide estimates in number of minutes, which may be problematic in the application of the new time-driven ABC (Kaplan and Anderson 2004). Time-Driven ABC advocates claim that a response mode in minutes is superior to one in percentages as it allows only allocating the practical capacity cost, rather than the full capacity cost (Kaplan and Anderson 2004).

3.6.2 Process view of ABC

The process view of ABC is composed of three building blocks: cost drivers, activities and performance measures. It provides information on why the activities are performed via cost drivers and on how well the activities are performed via performance measures. Cost drivers are factors that determine the workload and effort required to perform an activity (Turney 1991: 87), that is factors that cause a change in the cost of an activity (Raffish and Turney 1991). For example, the quality of parts received by an activity (e.g. the percent that are defective) is a determining factor in the work required by that activity, because the quality of parts received affects the resources required to perform the activity. Cost drivers identify the cause of activity cost and are useful because they point people to take action at the root cause level, i.e. they reveal opportunities for improvement. An activity may have multiple cost drivers associated with it.

Performance measures are used to indicate the work performed and the results achieved in an activity (Raffish and Turney 1991). They tell us how the activity is meeting the needs of its internal or external customers. There are five fundamental elements of activity performance: the quality of the work done; the productivity for the activity; the cycle time required to complete the activity; the cost traced or allocated to the activity; and customer satisfaction (Miller 1996: 94–5, Turney 1991: 88–89).

Performance measures differ from one activity to another and from one company to another. Performance measures may be financial or nonfinancial. The process view of ABC places emphasis on processes. A process is a series of activities that are linked to perform a specific objective. A business process often runs across artificial organizational boundaries, departments or functions.
Because of the interdependency of activities in a process, the work of each activity affects the performance of the next activity in the process. Accordingly, performance measures for one activity may become cost drivers for the next activity (Turney 1991: 190). For example, performance measures for designing new tools may include the number of change in specifications and the number of new drawings, and these performance measures are just the cost drivers for the succeeding activity, manufacturing new tools. This tells us that merely identifying activities without consideration of their relationship to other activities in the process will result in overlooking many improvement opportunities (Lawson 1994: 35).

The information achieved from the process view of ABC can be used as an aid in process/activity improvement. The potential improvement opportunities can be located by performance measurement and value analysis. First, the areas where the improvement is needed can be identified by comparing this period’s performance with performance goals or with best practices of comparable activities inside or outside the company. The latter comparison is called benchmarking (Turney 1991: 111). Second, the areas where the improvement is needed can be identified through the categorization of activities as value-added or non-value-added. An activity is value-added if it is judged to contribute to customer value or to satisfy an organizational need; otherwise, it is non-value-added. For the non-value-added activities, improvement initiatives should be directed toward eliminating or minimizing the activities. For the value-added activities, improvement initiatives should be directed toward streamlining, improving what is being done, and optimizing performance (Miller 1996: 92–93). However, the potential improvement opportunities should be prioritized by the Pareto analysis. We can rank the activities in descending order of cost achieved from the cost assignment view of ABC, and determine the significant activities that will provide the greatest opportunities for improvement. Usually, we will find that 20 percent of the activities cause 80 percent of the cost. Thus, these significant activities are worth improving in the first place.

After the top-priority areas of improvement are recognized, cost driver analysis can be used to examine, quantify, and explain the effects of cost drivers of the significant activities mentioned above. This will help direct improvement efforts to the cause of cost and avoid treating the symptom (Miller 1996: 93). For example, inspecting the incoming material is a non-value-added activity and its cost driver will be the quality of material received from suppliers. If we have sufficient confidence in the quality of material received from suppliers, we may
either conduct sampling inspections, or even have no inspections for incoming material. Otherwise, we may need 100 percent inspections. Therefore, the best way to reduce the efforts of incoming material inspections is to choose suppliers that provide high-quality material or to help our suppliers establish the quality control/assurance systems.

Using ABC to improve a business is called activity-based management (ABM). As defined by the consortium for Advanced Manufacturing International (CAM-I) (Raffish & Turney 1991), ABM is a discipline that focuses on the management of activities as the route to improving the value received by the customer and the profit achieved by providing this value. This discipline includes cost driver analysis, activity analysis, and performance measurement. ABM uses the cost and nonfinancial/operational information acquired from ABC in various analyses. For example, ABM uses the cost information of activities, products, customers, and other cost objects, supplied by the cost assignment view of ABC, to perform strategic decision analysis (such as pricing, product mix, sourcing, customer profitability analysis), activity-based budgeting, life-cycle costing and target costing. In addition, ABM uses the information provided by the process view of ABC to support cost reduction, downsizing, process/quality improvement, benchmarking, business process reengineering (BPR), and TQM.

3.7 Comparison between COQ approaches and ABC

In this chapter a relationship between activity/cost categories of cost of quality approaches and ABC is being done. It is important to notice the implications of various cost accounting environments on quality cost accounting. Tsai (1998) has investigated the approaches between COQ and ABC. The PAF approach of COQ is activity-oriented, the process cost approach of COQ is process-oriented, and ABC is activity-oriented for the cost assignment view and process-oriented for the process view. Accordingly, the PAF approach of COQ regards COQ-related (or PAF-related) activities as improvement objects, and the process cost approach of COQ and ABC regard processes/activities as improvement objects. A summary comparison between the COQ approaches and ABC is given in Table 4 below.
<table>
<thead>
<tr>
<th>Aspects of Comparison</th>
<th>PAF approach</th>
<th>Process cost approach</th>
<th>ABC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Activity oriented</td>
<td>Process-oriented (process view)</td>
<td>Activity-oriented (cost assignment view)</td>
</tr>
<tr>
<td>Activity/cost categories</td>
<td>Prevention</td>
<td>Conformance</td>
<td>Value-added</td>
</tr>
<tr>
<td></td>
<td>Appraisal</td>
<td>Nonconformance</td>
<td>Non-value-added</td>
</tr>
<tr>
<td>Treatment of overhead</td>
<td>No consensus method to allocate overhead to COQ elements under current COQ measurement systems and traditional cost accounting</td>
<td>Assigning overhead to activities by using resource drivers in the first stage of cost assignment view</td>
<td></td>
</tr>
<tr>
<td>Tracing costs to their sources</td>
<td>No adequate method to trace quality costs to their sources</td>
<td>Tracing activity costs to cost objects by using activity drivers in the second stage of ABC cost assignment View</td>
<td></td>
</tr>
<tr>
<td>Improvement Objects Tools for Improvement</td>
<td>COQ-related activities</td>
<td>Processes activities</td>
<td>Processes/activities</td>
</tr>
<tr>
<td></td>
<td>Quality circle, Brainstorming, Nominal group technique, Cause and effect Analysis, Fishbone diagram, Forcefield analysis</td>
<td>Process/activity value analysis, Performance measurement, Benchmarking, Cost driver analysis</td>
<td></td>
</tr>
<tr>
<td>Information Outputs</td>
<td>The cost elements of PAF categories, Total quality cost and the costs of PAF categories/elements and their percentages various bases</td>
<td>The COC and CONC elements of the processes investigated, Total process cost, COC, and CONC of the processes investigated and their percentages of various bases</td>
<td>The costs of activities and processes, The costs of value-added and non-value added activities and their percentages of various bases, Accurate costs of various cost objects (e.g., products, departments, customers and channels) Activity-based performance measures, Cost drivers of Activities</td>
</tr>
<tr>
<td>Related management technique</td>
<td>TQM</td>
<td>ABM</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Comparison between COQ and ABC. (Tsai 1998: 733.)
As for activity/cost categories, the COQ approaches and ABC have the following classifications: PAF approach – prevention, appraisal, internal failure, and external failure; process cost approach – conformance and nonconformance; ABC – value-added and non-value-added.

Some authors classify prevention and appraisal costs as the cost of conformance, and internal and external failure costs as the cost of nonconformance. However, the content and meaning of conformance and nonconformance costs of the PAF approach are different in nature from that of the process cost approach. Under the ABC perspective, only prevention costs in the PAF approach (Ostrenga 1991) and only some of conformance costs in the process cost approach are value-added, and their relationships are shown in Fig. 26.

![Fig. 26. The relationship between activity/cost categories of COQ approaches and ABC.](image)

Thus, the cost of nonconformance either in the PAF or in the process cost approach would be eliminated or minimized through investment in prevention activities. The cost of conformance in the process cost approach would be reduced by streamlining or redesigning the process.

As for information outputs, the fundamental cost information outputs achieved from the PAF approach include the costs of PAF-related activities, whereas the outputs achieved from the process cost approach and ABC are the costs of activities and processes. While all these three methods provide the costs of activities, ABC creates a variety of information outputs.

From the discussion above, we can see that there are many similarities in process perspective between the process cost approach and ABC. In addition, the similarities between the two methods can also be found in the steps of process

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36 According to the reviewer of the thesis, appraisal costs could also be seen as value-added costs. There could also be a dash line between ‘appraisal’ and ‘value added’ in Fig 26.
improvement by the process cost approach and by ABC/ABM, as shown in Table 5 below. In this Table, the corresponding steps are in the same rows, which indicates that the two methods deal with the same thing by using different terminology.

### 3.7.1 Integrated COQ-ABC framework

From the explanation in the previous sections, we know that ABC can supply various cost and nonfinancial information to support COQ programs. Moreover, ABC can provide more accurate costs of activities and processes than traditional cost accounting, which make COQ information more valuable for TQM. Hence, it is better to integrate the COQ approaches with ABC. Figure 27 shows an integrated COQ-ABC framework by Tsai (1998). In this framework, we may adopt the PAF approach or the process cost approach for COQ measurement. Strictly speaking, COQ-related activities for the PAF approach or flowcharted activities for the process cost approach should be incorporated into the building block “activities” of the ABC model. That is, ideally, the ABC and COQ blocks in this framework should be merged as one. Furthermore, there are the following characteristics in the integrated COQ-ABC framework. ABC and COQ systems should share the common database in order to avoid data redundancy and inconsistency. The related management techniques of ABC and COQ are ABM and TQM, respectively; and ABC system can provide cost and activity/process-related information for ABM, COQ/TQM, and business process reengineering (BPR). BPR is another management technique for process improvement. The major difference between BPR and ABM/TQM is that BPR overthrows and improves current business processes in a fundamental and radical way. This can be seen from the definition of BPR: “BPR is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed” (Hammer and Champy 1993).
Table 5. Steps of process improvement by the process cost approach and ABC/ABM.

<table>
<thead>
<tr>
<th>Process cost approach</th>
<th>ABC/ABM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Choose a key process to be analyzed</td>
<td>1. Define critical business processes and specify key and significant activities</td>
</tr>
<tr>
<td>2. Define the process and its boundaries</td>
<td>2. Select process owners</td>
</tr>
<tr>
<td>3. Construct the process diagram:</td>
<td>3. Define the process boundaries</td>
</tr>
<tr>
<td>(1) Identify the outputs and customers</td>
<td></td>
</tr>
<tr>
<td>(2) Identify the inputs and suppliers</td>
<td></td>
</tr>
<tr>
<td>(3) Identify the controls and resources</td>
<td></td>
</tr>
<tr>
<td>4. Flowchart the process and identify the process owners. The process owners form the improvement team</td>
<td>4. Form and train process improvement teams</td>
</tr>
<tr>
<td>5. Allocate the activities as COC or CONC</td>
<td>5. Flowchart the processes</td>
</tr>
<tr>
<td>6. Calculate or estimate the quality costs (COC + CONC) at each stage. Estimates may be required where the accounting system is unable to generate the necessary information</td>
<td>6. Analyze activities:</td>
</tr>
<tr>
<td>(1) Define activity outputs/measures</td>
<td>(1) Define activity outputs/measures</td>
</tr>
<tr>
<td>(2) Identify the customer/user of activity outputs</td>
<td>(2) Identify the customer/user of activity outputs</td>
</tr>
<tr>
<td>(3) Perform value-added analysis</td>
<td>(3) Perform value-added analysis</td>
</tr>
<tr>
<td>(4) Identify cost drivers</td>
<td>(4) Identify cost drivers</td>
</tr>
<tr>
<td>(5) Determine activity performance measures and goals</td>
<td>(5) Determine activity performance measures and goals</td>
</tr>
<tr>
<td>(6) Define other activity attributes:</td>
<td></td>
</tr>
<tr>
<td>– Primary versus secondary activities</td>
<td></td>
</tr>
<tr>
<td>– Core, sustaining, and discretionary</td>
<td></td>
</tr>
<tr>
<td>– Cost behavior: fixed or variable, direct or indirect, avoidable or unavoidable</td>
<td></td>
</tr>
<tr>
<td>(7) Gather activity data required for activity/cost object costing and for activity/process improvement</td>
<td>(7) Gather activity data required for activity/cost object costing and for activity/process improvement</td>
</tr>
<tr>
<td>7. Construct a process cost report</td>
<td>7. Perform activity/process cost assignment</td>
</tr>
<tr>
<td>8. Prioritize the failure costs and select the process stages for improvement through reduction in costs of nonconformance (CONC). This should indicate any requirements for investment in prevention activities. An excess cost of conformance (COC) may suggest the need for process redesign</td>
<td>8. Summarize processes and costs for management</td>
</tr>
<tr>
<td>Process cost approach</td>
<td>ABC/ABM</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------</td>
</tr>
<tr>
<td>9. Review the flowchart to identify the scope for reductions in the cost of conformance. Attempts to reduce COC require a thorough process understanding, and a second flowchart of what the new process should be may help.</td>
<td>9. Draw up the process improvement plan: (1) Locate the potential improvement opportunities by performance measurement and value analysis (2) Prioritize the improvement opportunities by Pareto analysis and select the significant activities that will provide the greatest opportunities for improvement (3) Design and select the improvement alternatives by cost driver analysis, process redesign, new process design (process innovation), and others</td>
</tr>
<tr>
<td>10. Monitor conformance and nonconformance costs on a regular basis, using the model and review for further improvements (i.e. continuous improvement)</td>
<td>10. Implement the process improvement plan</td>
</tr>
<tr>
<td>11. Monitor the process improvement results by installing performance measurement and feedback control systems to ensure that the desired results are achieved and to provide feedback for continuous improvement</td>
<td></td>
</tr>
</tbody>
</table>

Sources:
Figure 27. Integrated COQ-ABC framework. (Tsai 1998: 736.)
The common goal of ABM, TQM, and BPR is continuous improvement by using various respective tools. In fact, all these tools can be used in ABM, TQM, and BPR. The common objectives of ABM, TQM, and BPR are to promote productivity, to eliminate waste, to reduce throughput time, to reduce cost, and to improve quality. The ultimate missions are to profitably improve the value received by the customer and to increase the equity owned by the shareholder.

### 3.8 COQ measurement and reporting under ABC-environment

As mentioned earlier, there is no consensus method to allocate overheads to the COQ elements and no adequate method to trace quality costs to their sources under the current COQ measurement systems and traditional cost accounting. These deficiencies can be overcome by using the cost assignment view of ABC (Fig. 24: 115), either in the PAF approach or in the process cost approach. Overhead costs are traced to activities by using resource drivers in the first stage of the ABC cost assignment view. Then, activity costs are traced to their sources (i.e. cost objects) by using activity drivers in the second stage of the ABC cost assignment view.

*For the PAF approach*, the activities of the ABC model would be COQ-related activities (prevention, appraisal, internal failure, and external failure) and COQ-unrelated activities. In the first stage of the ABC cost assignment view, resource costs (including overhead costs) of the company are traced to various COQ-unrelated and COQ-related activities (Table 1) by using resource drivers. The resources used by COQ-related activities may be people, computers, equipment, material (parts), supplies, facilities, energy, and so on. If a resource is dedicated to a single COQ-related activity, the resource cost is directly traced to that COQ-related activity. If a resource supports several COQ-related and/or COQ-unrelated activities, the resource cost must be distributed among these activities by using an appropriate resource driver. The resource driver of people-related costs (salaries and benefits) will be time. If a COQ-related activity uses worker’s partial time, this COQ-related activity will receive worker’s salary and benefit according to worker’s usage percentage of time. As another example, the resource driver of energy costs will be kilowatt-hours. The cost of any specific COQ-related activity will be achieved by adding all the resource costs (i.e., activity cost elements) traced to that COQ-related activity. Therefore, each of the four components of total COQ can be obtained respectively by accumulating the costs of all the activities related to that COQ component. Finally, total COQ is the
sum of the four components’ costs. Accordingly, total COQ, four COQ components, and the costs of detailed COQ-related activities can be achieved from the first stage of the ABC cost assignment view.

For the process cost approach, the activities of the ABC model would be the flowcharted activities of various processes, including COC-related and CONC-related activities. The method of tracing resource costs (including overhead costs) to activities is the same as described above. The results achieved in the first stage of the ABC cost assignment view would be the costs of flowcharted activities, total process costs, COC, and CONC of various processes.

The treatment of overheads in ABC is different from the practice of including full overhead costs in direct labor charges to quality-related costs. It will produce more accurate quality costs and solve the usual problem in current COQ systems: double-counting.

Another deficiency, mentioned before, of the combination of current COQ systems and traditional cost accounting is the lack of information on how indirect workers, whose costs are one part of overhead costs, spend their time on various activities. This deficiency makes prevention the most difficult ones of the categories to cost because it depends heavily on the estimates of percentage of time spent by indirect workers and staff (Dale and Plunkett 1991: 44). In practice, these estimates are often derived from information gathered from interviews or questionnaires (Turney 1991: 277). Nevertheless, the information acquired from interviews and questionnaires may be subject to certain reservations because “the way that people actually spend their time, after all, can often be quite different than the way they think that they spend it” (Miller 1992). To overcome this deficiency, Tsai (1996a) suggested to use work sampling to estimate the percentage of the indirect worker time spent on each activity. Work sampling (Richardson 1976), which utilizes the random sampling techniques, allows one to understand the characteristics of a process by collecting data on portions of a process rather than the entire process. This technique is particularly useful in the analysis of nonrepetitive or irregularly occurring activities. With the aid of computer software (Lund 1990), it is feasible to use work sampling to provide more accurate data of first stage resource drivers for indirect workers in the integrated COQ-ABC systems.

We can trace COQ to its sources (such as parts, products, designs, processes, department, vendors, distribution channel, territories, etc.) through the second stage of the ABC cost assignment view. If we, under the PAF approach, need to know the COQ information by departments or products, then we could regard
departments or products as cost objects and trace the various COQ-related activity costs to departments or products by using appropriate activity drivers in the second stage of the ABC cost assignment view. Most activities related to prevention costs are sustaining activities and their costs are not easily traced to departments or products. It is because of no explicit cause-and-effect relationship between prevention activities and departments (or products). On the other hand, cause-and-effect relationships do exist between departments (or products) and most activities related to appraisal, internal failure, and external failure costs. Therefore, these costs could be traced to departments or products appropriately. Similarly, we could trace external failure costs to distribution channels or territories (used as the cost objects).

From the above discussion, we know that the COQ reports for the PAF approach can be prepared under ABC in the following ways. 1) COQ reports are associated with detailed COQ-related activities for the whole company. 2) COQ reports are associated with activities related to appraisal, internal failure and external failure costs by departments, products, or product lines; or 3) COQ reports are associated with activities related to external failure costs by distribution channels or territories.

These are just some illustrative COQ reports. These COQ reports usually provide monthly costs, year-to-date costs, variances to budgeted costs, and a comparison with the previous years’ cost data. These COQ reports may include the COQ percentage of various bases such as sales revenue, manufacturing cost, units of product, and so on (Simpson and Muthler 1987). In addition, trend analysis can be used to compare present COQ data with historical COQ data in order to know how COQ changes over time.

In order to prepare the above COQ reports, we could use activity centers to group the related activities under ABC. There may be hundreds of activities in a company. Activity centers allow us to easily locate activities with identical characteristics. If we group the company’s activities by processes, then we will have the COQ activity center and several other activity centers. Within the COQ activity center, four nested activity centers can be established, i.e., prevention, appraisal, internal failure, and external failure activity centers (as shown in Fig. 28).
Again, we could, within a sub-activity center, set up a nested activity center on demand. This will create hierarchies of COQ information and give us the different levels and breadths of COQ information. This will form a multi-tier COQ reporting system. We could use attributes, which are labels describing the type of activity, to create activity centers on demand in the integrated COQ-ABC information system (Turney 1991: 271–273). If the COQ activity center is divided according to the company’s organizational structure, then we could, by adopting the concept of responsibility accounting, provide department managers with the COQ information and related nonfinancial information which are specific to them. The COQ responsibility reports will help responsible managers to identify the major costs of nonconformance incurred in their departments and actuate improvement projects to eliminate or reduce these costs.

For the process cost approach, the COQ reporting method is the same as described above except that PAF-related activities are replaced with the COC-related and the CONC-related activities.

3.8.1 Use of COQ information

Under the integrated COQ-ABC framework, the quality system and the ABC system must be integrated to produce COQ information and the related operational information of activities and processes. The information achieved can be used in various aspects (Dale & Plunkett 1991: 59–68, O’Guin 1991: 71–75). Some of the important uses of COQ information are described as follows.
To identify the magnitude of the quality improvement opportunities

Activity based costing, together with other techniques such as work sampling, can trace resource costs (including overhead costs) to various activities in a rational way which avoids double counting. Thus, ABC can create the accurate costs of the PAF-related activities for the PAF approach and of the COC- and CONC-related activities for the process cost approach. The prime purpose of the quality improvement is to gradually eliminate or reduce the cost of poor quality, i.e. to improve the activities related to the appraisal and failure costs for the PAF approach and to the CONC for the process cost approach. Activity based costing will tell management the accurate cost of poor quality and indicate which activities are the most expensive through the Pareto analysis. Accordingly, management can identify the directions and magnitude of the quality improvement opportunities. This information is useful in the investment justification of the quality improvement alternatives such as investment in prevention activities or equipment.

To identify where the quality improvement opportunities exist

By integrating the ABC system and the quality system, the cost of poor quality can be traced to its sources. Hence, the integrated system can identify where the quality improvement opportunities exist and provide the following benefits (O’Guin 1991: 72):

- By tracing quality losses to product attributes, parts, processes, engineering, and vendors, management can take corrective actions toward the right direction.
- By tracing and costing vendor returns by vendor and parts, purchasing managers will understand the true costs of buying from particular vendors. This will avoid forcing purchasing managers to buy strictly on price.
- If scrap costs result from worker errors, the scrap costs are assigned to the process’s overheads. This will provide management with clear pictures of who is causing defects and how much they cost.
- The integrated system arms the quality department with defect and rework cost information. Some defects are more costly than others and some mean much more to the customers than others. Thus, the system can tell the quality department where to concentrate its quality improvement efforts.
By tracing warranty and return costs to their products, it will eliminate the tendency for product managers to rush a product through testing, or ship defective goods to achieve their sales targets.

Before tracing quality costs to their sources, we should dig out their root causes by using the cost driver analysis of the ABC process view in order to direct improvement efforts to the cause of cost and avoid treating the symptom. Table 6 gives a list of some possible cost drivers of the four COQ components. For example, the root causes of the internal failure rework could be design error, defective purchased material, deficient tooling and maintenance, and worker error. If we find out that the real root cause of excessive rework cost is defective purchased material, then we could effectively solve the problem by helping to improve the supplier’s quality system or searching another supplier. As another example, if excessive in-process inspections are due to complex design, then we can encourage designers to simplify the design by using the number of different part numbers as a performance measure or activity driver.

Table 6. Some cost drivers of COQ components. (Ostrenga 1991: 43.)

<table>
<thead>
<tr>
<th>COQ components</th>
<th>Cost drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention</td>
<td>Investment in reducing overall COQ-related activities</td>
</tr>
<tr>
<td>Appraisal</td>
<td>Set-up frequency</td>
</tr>
<tr>
<td></td>
<td>Tight tolerance activities</td>
</tr>
<tr>
<td></td>
<td>Complex design</td>
</tr>
<tr>
<td>Internal failure</td>
<td>Design error</td>
</tr>
<tr>
<td></td>
<td>Defective purchased material</td>
</tr>
<tr>
<td></td>
<td>Machine reliability</td>
</tr>
<tr>
<td></td>
<td>Tooling age and conditions</td>
</tr>
<tr>
<td></td>
<td>Worker error</td>
</tr>
<tr>
<td>External failure</td>
<td>Order entry errors</td>
</tr>
<tr>
<td></td>
<td>Incorrect assembly instructions</td>
</tr>
<tr>
<td></td>
<td>Product failure</td>
</tr>
<tr>
<td></td>
<td>Worker error</td>
</tr>
</tbody>
</table>

To plan the quality improvement programs

A quality improvement program should depict quality improvement actions, improvement targets, and quality cost budgets. Improvement targets may be set after quality improvement actions are evaluated and selected. Under this circumstance, improvement targets are set and quality cost budgets are prepared.
according to the savings of required activity driver quantities for each quality-activity of the selected quality improvement actions. On the contrary, quality improvement actions may be worked out according to improvement targets set by management just like the approach of target costing. In this scenario, management may establish quality improvement targets for every unit of the organization. Management may request purchasing to reduce vendor quality costs by 20 or 40 percent in a year. The amount of rework, which is the activity driver of rework activity, may be targeted to be cut by 30 percent. Target quality costs are derived from the quality improvement targets under the present operational conditions. Then, various quality improvement actions are evaluated one by one till the ones, which budgeted quality costs are not greater than target quality costs, are found. In either case, quality cost budgets are constructed incorporating improvement targets by using the budgeted activity driver quantities based on improved activities and the moving average rates (or the last period’s rate) of activity drivers. This method can be applied in either the PAF approach or the process cost approach (Sharman 1996).

To control quality costs

Since management establishes quality improvement targets for every unit of the organization, management can then track actual performance to these targets after one period’s operation. If improvement targets are not met, variances between actual and budgeted quality costs will emerge. The variances may represent unanticipated quality loss. The variances force management to exploit what is causing the variance and encourage management to eliminate the source of quality loss. This feedback allows management to continuously plan quality improvement programs and control quality costs (O’Guin 1991: 74).

The method described above is the budget control of quality costs. It may report quality costs monthly. However, it is not fit for daily operation control. Turney (1991: 197–199) demonstrated how ABC was used for total quality control by utilizing daily COQ reporting in a printed circuit board (PCB) plant. The ABC system was used to prepare a report on the cost of poor quality for each activity immediately after each of the three daily shifts and to show graphically the trend in physical defects and cost. The report allows management to focus immediately on the quality problems with the biggest cost impact. The ABC system also daily prepares a top ten offenders list that reports the ten products with the highest cost of poor quality on the previous day. It pinpointed the poor
quality products and provided the greatest potential for redemption. When a product unit on this list was scrapped, a report, which showed the cause of the problem as well as the cost, was prepared and sent to the person most likely to correct the problem. This use of ABC made quality problems visible within a matter of hours, or even minutes. Turney suggested linking ABC with computer-integrated manufacturing (CIM) to prepare COQ reports for real time and cost-effective control.
4 Cost of software quality

4.1 Introduction to the cost of software quality

Humphrey (1997: 2) states that the current state of software quality is best described by the commonly held view that “it is impossible to remove all defects from software products.” This statement, while widely accepted, is incorrect. Many defect-free software products have been developed. A more accurate way to state the current situation is that “It is generally impossible to prove that all defects have been removed from a software product.” There are several reasons for this. Many software products are extraordinarily complex. It is not possible to exhaustively test these products. Thus, if one relies exclusively on testing, it is truly impossible to demonstrate that a software product is defect free.

While the software industry has had a troublesome history, there is no reason for it to follow different quality principles from those used in other technologically intense industries. Humphrey (1997: 2) concludes that a modern commercial aircraft, for example, have very complex hardware and software systems. One cannot definitively prove that all design and manufacturing defects have been removed from a large aircraft. This, however, does not prevent aircraft manufacturers from warranting their products or from taking full responsibility for product quality. Many other industries produce high-quality products and take full responsibility for any resulting defects. No technologically intense industry, other than software, relies exclusively on product testing to remove defects. It has been known for more than 20 years that testing is an expensive and ineffective way to eliminate defects from any product, including software. He adds, that when leading manufacturers in other industries strive for high quality, they focus on the development and manufacturing processes. They use defined and measured procedures and established statistical methods. Many organizations routinely produce products that are, for all practical purposes, defect free. While they do not guarantee that their products are defect free, they do provide warranty and support services to minimize their customers’ damage and inconvenience. They recognize that defects are not acceptable and, to the extent they can, they bear the full costs of fixing or replacing defective products. This is not true for software.

Software quality can be viewed as an economic issue. We can always run another test or do another inspection. In large systems, every new test generally exposes a host of new defects. It is thus hard to know when to stop testing. While
it is important to produce a quality product, each test costs money and consumes time. Economic issue is thus an important issue not only because of the test decision, but also because of the need to optimize the life-cycle cost of software quality. The key for doing this is to recognize that we must put a quality product into test before we can expect to get one out.

The cost of software quality largely concern the costs of defect detection, prevention, and removal. The cost of finding and fixing a defect includes the costs of several elements. First the source of the problem has to be determined. Then the problem source has to be isolated and determined exactly what is wrong with the product. After this the requirements, design and implementation of the product has to be fixed. Then the fix has to be inspected to ensure it is correctly made. The fix should also be tested to ensure it fixes the identified problem and to ensure it does’t cause other problems. Finally, the documentation should be changed as needed to reflect the fix. While every fix will not involve every cost element, the longer the defect is in the product the larger the number of elements that will likely be involved. Finding a requirements problem in test can thus be very expensive. Finding a coding defect during a code review, however, will generally cost much less. Our objective thus should be to remove defects from the requirements, the designs, and the code as soon as possible. Reviewing and inspecting programs soon after they are produced minimizes the number of defects in the product at every stage. Doing this also minimizes the amount of rework and the rework costs. It is also likely to reduce the costs of finding the defects in the first place.

One of the most costly activities in software development is reworking or redoing what has already been done. For some reason, we have come to accept mountains of rework as part of our every day activities. In some cases, we may not even think of it as rework. For example, we spend precious schedule time on fixes for code defects when software doesn’t perform as expected (functionality or error) or on redesign of a user interface because the customer expects something different from what we provide (insufficient/incorrect customer requirements). (Brodman 1998: 4)

There are not many published fix time data required to identify software defects. The following are some that are available. An unpublished IBM rule of thumb for the relative costs to identify software defects: during design, 1.5; prior to coding, 1; during coding, 1.5; prior to test, 10; during test, 60; in field use, 100. At TRW the relative times to identify defects is: during requirements, 1; during design, 3 to 6; during coding, 10; in development test, 15 to 40; in acceptance
test, 30 to 70; during operation, 40 to 1000. (Boehm 1981). At IBM the relative time to identify defects is: during design reviews, 1; during code inspections, 20; during machine test, 82. (Remus 1979). At JPL Bush reports an average cost per defect: $90 to $120 in inspections and $10,000 in test. (Bush 1990). Freedman and Weinberg (1982) report that projects that used reviews and inspections had a tenfold reduction in the numbers of defects found in test, and a 50 to 80 percent reduction in test costs, including the costs of the reviews and inspections.

The cost of conformance includes appraisal costs and prevention costs. Appraisal costs are those associated with evaluating or testing the product or service to determine if it is faulty. Prevention costs, on the other hand, are those derived from the proactive steps one takes to reduce or eliminate rework. Therefore, according to Brodman (1998: 4) appraisal costs are assigned to software quality assurance activities, activities associated with multiple levels of testing (unit, component, system), while prevention costs are assigned to activities such as conducting inspections and/or walkthroughs and the activities associated with the software process improvement program.

Clearly defect identification costs are highest during test and use. Thus, anyone who seeks to reduce development costs or time, should focus on preventing or removing defects before starting test. This conclusion is reinforced by the PSP data on the fix times for the 664 C++ defects and 1377 Pascal defects that was found by Humphrey (1996: 3–4) in the development of more than 70 small programs. These data show that fix times are 10 or more times longer during test and use than in the earlier phases. While this pattern varies somewhat between the defect type, the principal factor determining defect fix time is the phase in which the defect was found. A question often raised about these data is; how do we know that the easy defects are not being found in the inspections with the difficult ones left for test? While this question cannot be resolved without substantially more statistical data, there is some evidence that inspections are as good as or better at finding the difficult-to-fix defects than is test. (Humphrey 1996)

In the PSP, the pattern of fix times between reviews and test time is essentially the same regardless of defect type. Organizations that do inspections report substantial improvements in development productivity and schedule performance (Humphrey 1991). The PSP data show that reviews are two or more times as efficient as testing at finding and fixing defects. This is true of Humphrey’s own data, students’ data, and working engineers’ data. The fix
advantage of reviews over tests is also true, almost regardless of the phase in which the defect was injected.

While the fix time can often be longer for code design defects and much longer for requirements defects, the times to identify the defects appear to be the same. The reason for this appears to be that even trivial typographical defects can cause extraordinarily complex system behavior. Once these symptoms are deciphered, however, the fix is generally trivial. Conversely, very complex logic problems can have relatively obvious system consequences but be quite difficult to fix. It is also likely that the relative costs of finding and fixing sophisticated logic problems is a function of the application. Data suggests that defects in real time systems or control programs can average as much as 40 hours each to be found and fixed in a system test. This data is very important and we need to gather such data on our own work to determine the appropriate values for our environment. (Humphrey 1996: 4–7)

4.2 Benefits of using quality cost accounting in the SW-business

Plunkett and Dale (1990) point out that cost of quality accounting can be used for a number of benefits, e.g. provide cost data for motivational purposes, provide a basis for budgeting the quality operation (Kaplan and Ittner 1988, 1989, Albreigh and Roth 1992, Rust 1995, Shah and Mandal 1999), compare process improvements and identify the most cost effective ones (Wallace and Fuji (1989). COSQ provides one measure of comparing the success of projects. Even within a given organization, the software process may vary widely from one project to another. The many factors, tangible and intangible, which characterize a project make it difficult to compare projects. COSQ can be measured within and across projects and provides a means of comparison. COSQ can be used to identify quality improvement candidates. Examination of the COSQ components often reveals higher quality costs in particular area. For example, high appraisal costs due to integration testing may indicate a lack of consideration for interfaces during design, or it may indicate late design changes. Analysis of the causes of these costs can provide the basis for quality initiatives in development processes.

COSQ can also be used to reduce the quality costs by altering the process in a particular project. Once the relationships and trade-offs among the COSQ components are understood, then adjustments can be made on a project-by-project basis. Weller (1993) offers an example of a project in which inspection data and partial unit test results were the basis for decision to skip the bulk of unit testing,
resulting in significant savings. This decision was confirmed in the low defect discovery rates produced by integration testing. Although this example uses only two of the COSQ categories, it illustrates a cost-benefit made once the trade-off between the two categories was understood.

The works of Knox in Raytheon’s Equipment Division (RES) demonstrate still one of the benefits of measuring and using COSQ: justification for quality initiatives. Examples of return on investment (ROI) in quality improvement initiatives speak most clearly to managers responsible for maintaining a profitable organization. Important questions then arise concerning whether and how much to invest in specific software quality improvement initiatives. It is useful to approach these questions from a financial return on investment (ROI) perspective. We refer to this as the Return on Software Quality (ROSQ) (Slaughter et al. 1998: 67).

The rationale behind ROSQ is that software quality expenditures must be financially justified. Increasingly, the chief financial officers in many companies are promoting disciplines for financial evaluation to encourage investments that yield the greatest response for limited resources. Such disciplines are particularly important in the context of software engineering, as software expenditures account for larger portions of capital budgets. According to Slaughter et al. (1998), software quality is an investment that should provide a financial return relative to the initial and ongoing expenditures in the software quality improvement initiatives. One way to evaluate software quality improvement efforts is to consider them in terms of specific initiatives. Examples of software quality improvement initiatives include implementation of design reviews, testing and debugging tools, code walkthroughs, and quality audits. Initiatives require an initial investment – the software quality investment (SQI) – that includes the initial expenses for training, tools, effort, and materials required to implement the quality initiative. There are also ongoing expenditures for meetings, tool upgrades, and training that are required to maintain the quality process once it is in place. We call this software quality maintenance (SQM). Finally, each software quality improvement initiative should result in annual revenues. These software quality revenues (SQR) can be derived from the projected increases in sales or estimated cost savings due to the software quality improvement.

The return on the software quality initiative is the net present value of the software quality revenues and costs or cash flows (NPVCF) divided by the net present value of the initial investment and ongoing maintenance costs for the software quality initiative (NPVIC). More formally, by selecting a financial
discounting factor \( r \) that reflects the company’s weighted average cost of capital, we can calculate the ROSQ over \( T \) periods of time for which the project yields value for the firm. Related to the concept of financial ROI is the SQPI, which is the ratio of the present value of the difference between the software quality revenues and costs divided by the software quality investment.

A value greater than 1 for the SQPI implies that the initiative will create value that exceeds its investment. SQPI provides a method for comparing the return on a number of initiatives. When there are limited funds for investment, only the highest value SQPI initiatives are selected (Slaughter et al. 1998: 68–69).

### 4.3 Elements of COSQ information

The implementation of cost of quality reporting and its use in a quality improvement program is discussed by Crosby (1988), Juran and Gryna (1980), Groocock (1974), and Evans and Lindsay (1993). Several points can be made with regard to measuring and using cost of quality information specifically for software process improvement. According to Houston and Keats (1996: 6) these are accounting and gathering the quality cost data, gathering the quality metrics, data analysis, and presenting the results.

Gathering quality cost data assumes that costs have been accounted using task and expense categories which can be summed into the four major categories of quality costs. Many software organizations track costs in a manner amenable to quality costing, but many others do not. In the latter case, a preliminary step of defining and installing such a chart of accounts is required. A sample of such a chart of quality costs is provided in Table 7. The quality categories in a software organization’s chart of accounts must be tailored to reflect its software process. (Houston and Keats 1996). To realize the full benefit of COSQ, it must also allow for the addition of process improvement tasks.

In the best cases, quality costs can be taken directly from departmental accounting reports. In other cases, it may be necessary to resort to basic accounting and engineering records, such as schedules, time reports, defect reports, and purchasing records. In the worst cases, one may fall back on interviews with members of the software organization in order to construct estimates of each quality cost category. Curtis and Statz (1996) point out that a controlled, scientific study is unlikely and that incomplete data can suffice in beginning a software cost benefit analysis.
One of the pitfalls of a COSQ program is “controversial cost categories” (Gryna 1988). Usually the question is about which costs are normal operating costs and which are quality costs. They mention the following points which should be kept in mind. (Houston & Keats 1996: 6). The trend among quality specialists has been to view quality costs as those incurred to directly prevent, appraise, and address the failures of poor quality. Arguments over controversial categories have been known to sabotage cost of quality programs. The largest quality costs are those which are most easily discerned, for example reviews, SQA, testing, and rework. Therefore, it is often safe to exclude controversial categories without unduly affecting the TCOSQ. Consistency throughout a COSQ program is more important than thorough inclusion of quality costs because consistency allows for clear identification of improvements and candidates for improvement.

Concerns may also arise as to how quality costs should be categorized. Again, Houston and Keats (1996) emphasize that consistency is important. For example, in Table 7 the costs associated with formal inspections (peer reviews) are treated as prevention costs rather than as appraisal costs. This is a matter of interpretation, depending on when a work product is considered ready for appraisal. Although manufacturing inspections are conducted on pieces after they are produced, in software production, inspections may be incorporated in the production process. For documentation, this means that a document is not complete until it has undergone a peer review and been revised. The same is true for code, especially when code inspections precede unit testing, clearly an appraisal activity. Kaner (1996) gives another example of categorization problems. Design reviews are part prevention and part appraisal. To the degree you are looking for errors in the proposed design itself when you do the review, you are doing an appraisal. To the degree that you are looking for ways to strengthen the design, you are doing prevention.

Table 7 on the next pages describes a Sample COSQ Chart (adapted from Hagan 1986).
Table 7. A Sample of COSQ Chart.

1 Prevention Costs
   1.1 Requirements
      1.1.1 Marketing research for customer/user quality needs
      1.1.2 Customer/user quality surveys
      1.1.3 Product quality risk analysis
      1.1.4 Prototyping for customer review
      1.1.5 User requirements/specification reviews/inspections
   1.2 Project
      1.2.1 Project quality planning
      1.2.2 Project process validation
      1.2.3 Quality assessment of development platform and tools
      1.2.4 Platform and tools development for quality
      1.2.5 Developer quality training
      1.2.6 Quality metrics data collection
      1.2.7 Design for quality: software component reuse
      1.2.8 Formal inspections / peer reviews
      1.2.9 Project configuration management
      1.2.10 Supplier capability assessment
   1.3 Reuse library
      1.3.1 Salaries
      1.3.2 Expenses
      1.3.3 Training
      1.3.4 Platform and tools
   1.4 Configuration management administration
      1.4.1 Salaries
      1.4.2 Expenses
      1.4.3 Training
      1.4.4 Platform and tools
   1.5 SQA administration
      1.5.1 SQA salaries
      1.5.2 SQA expenses
      1.5.3 Software process and standards definition and publication
      1.5.4 Metrology: data maintenance, analysis, and reporting
      1.5.5 SQA program planning
      1.5.6 SQA performance reporting
      1.5.7 SQA education/training
      1.5.8 Process improvement
      1.5.9 SQA process compliance audits
2 Appraisal Costs

2.1 Supplied product testing

2.2 Project appraisal costs
   2.2.1 Verification and validation activities
   2.2.2 Testing: planning, platforms, setup, test data generation, test execution and logging, reporting, test data evaluation
   2.2.3 Product quality audits

2.3 External appraisals
   2.3.1 Process maturity evaluation
   2.3.2 Field performance trials
   2.3.3 Special product evaluations

3 Internal failure costs

3.1 Product design defect costs
   3.1.1 Causal analysis and reporting
   3.1.2 Design corrective action
   3.1.3 Rework and retest due to design corrective action
   3.1.4 Work products wasted due to design changes

3.2 Purchased product defect cost
   3.2.1 Defect analysis cost
   3.2.2 Cost of obtaining product fix
   3.2.3 Cost of defect work-arounds
   3.2.4 Rework

3.3 Implementation defect costs
   3.3.1 Defect measurement and reporting
   3.3.2 Defect fixing
   3.3.3 Causal analysis and reporting
   3.3.4 Project process corrective action
   3.3.5 Fix inspection
   3.3.6 Retest and integration

4 External failure costs

4.1 Technical support for responding to defect complaints
4.2 Product returned due to defect
4.3 Maintenance and release due to defects
4.4 Defect notification costs
4.5 Upgrade due to defect
4.6 Service agreement claims (warranty expense reports)
4.7 Liability claims (insurance and legal reports)
4.8 Penalties (product contract reports)
4.9 Costs to maintain customer/user goodwill due to dissatisfaction (sales reports)
4.10 Lost sales due to quality problems (field salesperson reports)

Sources of quality cost data: ordinarily quality cost data for the majority of categories would be obtained from salary and expense reports. Exceptions are in the external failure category and are shown in parentheses.
Houston and Keats (1996) point out that plotting COSQ costs against a quality measure (for example KLOC\textsuperscript{37}) provides the COSQ curve and reveals trends in an organization’s quality processes. This addresses most of the goals of quality costing: justification, motivation, budgeting, and process improvement cost effectiveness. However, the Pareto analysis, based on the principle that quality costs are localized (80 percent of the quality costs are incurred by 20 percent of the quality failures), can be used to identify candidates for process improvement. When the COSQ are categorized by product and process sources, typically one or two sources will be shown to incur much higher costs than the other sources.

When we are talking about COSQ presentation, Juran and Gryna (1980) suggest that the relationships which have the greatest impact on management are: quality costs as a percent of sales, quality costs compared to profit, and/or quality costs compared to the magnitude of the current problem. The technique used by Knox and by Dion, showing COSQ as a percent of total development costs, is appropriate to software for several reasons. First, sales and profit often do not have a direct relationship to the actual cost of a software product. Second, all but a small percentage of software production costs can be measured in labor hours, so the costs can be readily shown in either hours or dollars. Third, the state of the art in software development is such that comparing quality costs to production costs illustrates the magnitude of the current problem. Though quality costs as a percent of development costs can show significant effects of process improvements (as in the case of Raytheon and in the case of BDM international described in next section), it does not show the optimum cost of quality. The optimum can be seen when quality costs are shown as absolute costs against a quality measure.

4.4 Findings of the empirical COSQ-research done in software companies

There is not much empirical research done in the field of cost of quality in software business, also called as cost of software quality -research. As follows, some empirical research done in the field is demonstrated in this chapter to show the reader the power of cost of software quality and to the results gained from the cost of software quality cases done before.

\textsuperscript{37} Kilobyte lines of code.
Houston and Keats (1996) have studied the results of the research done on the topic of cost of software quality. They found that while the costs of software quality assurance and process improvement have been a topic of concern for over 20 years (Alberts 1976) and the COQ categories have often been used broadly in discussions of software quality (Daugherty 1988), very limited data has been available in the open literature for discussing the cost of software quality (COSQ) (Hersch 1993, Knox 1993). Knox’s COSQ model (1993), the Raytheon studies (Dion 1993, Haley 1996) and Slaughter’s, Harter’s and Krishnan’s studies in BDM International (1998) are notable exceptions in that they explicitly use the cost of quality model. Due to the limited amount data available on COSQ, Knox used the emerging COQ model developed in manufacturing environments and extended it across the SEI CMM\textsuperscript{38} to produce a theoretical COSQ model. Starting with a total COSQ (TCOSQ) at 60 percent of development costs (based on two industry figures) for CMM level 1 organizations, Knox used manufacturing experience to hypothesize that CMM level 5 organizations can cut this COSQ by about 67 percent. He then rationalized the four component costs at each CMM level. His model suggests that for level 3 organizations, COSQ is about half of development costs. This is illustrated in Fig. 29 (Houston & Keats 1996: 1).

\textsuperscript{38} Capability Maturity Model developed at Software Engineering Institute in Carnegie Mellon University
During the same year that Knox’s paper appeared, Dion (1993) used the COQ model as a means of interpreting the results of quality initiatives undertaken at Raytheon’s Equipment Division (RES). Haley (1996) updated this study. The COSQ results are shown in Fig. 30. Appraisal and prevention costs were shown separately in the 1993 paper, but not in the 1996 paper. Starting at CMM level 1, RES introduced a software process improvement program in August 1988. Using the results of tracking 15 projects, they achieved CMM level 3 practices in a little over three years. Their results agree well with Knox’s model: in the level 1 stage, COSQ at RES fluctuated between 55 and 67 percent of total development costs and by the time of reaching level 3 process maturity, their COSQ had dropped to approximately 40 percent of total project cost. Today the TCOSQ in the organization is approximately 15 percent of development costs and the rework due to both internal and external failures has been reduced to less than 10 percent of development costs.
A third source of COSQ data the Price Waterhouse study (1988) which analyzes the costs and benefits of software quality standards in a survey of 19 software suppliers in the United Kingdom. The study estimates the cost of a quality control effort (prevention and appraisal costs) to be 23 to 34 percent of the development effort. The study also estimated failure costs at 15 percent of development effort for a TCOSQ of 38 to 49 percent of development effort. It must be noted that this study excluded the costs of unit testing and rework because the suppliers could not separate these costs. With increases in the estimates to account for this oversight, TCOSQ in a software organization with a quality system can range from 40 percent to 55 percent of development costs with a conformance costs to nonconformance costs ratio from 1.5 to 2.

Comparing these figures to the RES graph, they generally agree with a period late in 1990 when RES was approaching CMM level 3 RES’ TCOSQ was about 45 percent of development and its ratio of conformance to nonconformance costs was 1.5. Turning to Knox’s model, it predicted that a CMM level 3 organization would have a TCOSQ of 50 percent, but with a conformance to nonconformance cost ratio of 0.5. It appears that Knox’s model is a fair predictor of TCOSQ for
maturing software organizations, but that actual conformance costs are much higher and nonconformance costs much lower than what the model predicts.

Houston and Keats (1996) emphasize, that the BDM studies are not comparable to those above, because the COSQ was calculated as quality costs per lines of code over the life of a project.

Typical manufacturing COQ, ranging from 5 to 25 percent of company sales, contrasts significantly with COSQ (Plunkett and Dale 1990). From the data above, we can expect COSQ, with the present state of software engineering practice, to range from 20 to 70 percent of development costs. Even accounting for the margin between production costs and sales, COSQ appears to be roughly twice manufacturing COQ. Also, the optimum manufacturing COQ is often in the range of 95 to 100 percent of conformance to quality standards. The open literature lacks data for COSQ as a function of conformance to quality, but the data above suggests that software producers have yet to reach such an optimum.

According to Brodman (1998: 5), The COQ analysis used by Raytheon’s Equipment Division is a viable mechanism for measuring the overall effect of software improvement. By using it to monitor and reduce software COQ, productivity and predictability can be increased. It can also be used to isolate software scrap and drive it to zero. Applying the COQ approach also provides early feedback and can help to improve an organization’s standard process.

Subsequently, the observations and experiences gained from two companies, Raytheon and BDM International, are presented more closely as an example of the sparse research published in the area of quality costing in software business.

**Observations and experiences gained from “Case Raytheon”**

According to Brodman (1998: 4), Raytheon was the first company to shine a spotlight on COQ as a method for calculating return on investment (ROI) from software process improvement perspective. Raytheon found it difficult to break quality cost categories into subcategories, define the subcategories, and map project activities and costs to them. The work breakdown structure (WBS) used on the software projects did not map well to the COSQ categories, and the company’s definitions of each subcategory, which were rather brief for reasons of simplicity, were subject to misinterpretation. Raytheon addressed the first problem, “by working toward both a short- and a long-term solution”. In the short term, the company continued to collect project costs using the conventional WBS, and project leads periodically and manually remapped all costs to COSQ.
subcategories. In the long term, Raytheon developed a common WBS to provide as close a mapping to the COSQ as possible. This was expected also to entail a revision of the cost accounting system and possibly the time card reporting system as well. The second problem was to refine the definitions as the company gained experience using them. This literally required five iterations of the initial data-gathering exercise before the company obtained a satisfactory level of consistency.

Following are some of the experiences RES gained by using the COSQ model: 1) Many questions arose about how to allocate costs to subcategories. There was quite a variation in the methods used to break the actual costs down to the defined cost bin. These were resolved by refining the sub-category definitions and by analyzing and comparing the suballocation algorithms used by the six project leaders. 2) Initially it was necessary to have the project leader instead of an administrator generate the data because the project leader possessed first-hand knowledge of project particulars, as well as good engineering judgment. 3) The data showed that the average cost of rework decreased following the start of the process improvement initiative. In the two years before the initiative, rework costs averaged about 41 percent of project costs. In the two years following, that value had dropped to about 20 percent, and the trend was continuing downward.

Brodman (1998: 4) emphasizes, that, rework savings were achieved at the expense of a small increase in appraisal or prevention costs, as expected. For example, appraisal costs rose when informal reviews were replaced by formal inspections, and prevention costs rose when inspection training was instituted. Also, rework costs associated with fixing defects found during design rose from about 0.75 percent to about 2 percent of project cost. Those associated with fixing defects found during coding rose from about 2.5 percent to about 4 percent of project cost. The major reduction in rework costs was that associated with fixing source code problems found during integration, which dropped to about 20 percent of its original value. The second largest contributor to rework reduction was the cost of retesting, which decreased to about half its initial value. This clearly indicates that the additional costs of performing formal inspections and the training that must precede it. This is justified on the basis that finding problems earlier in the process results in a more efficient integration.

Houston (1998: 5) found that categorizing these costs between prevention and appraisal varies somewhat with different authors for the reasons just mentioned. Regarding software quality assurance activities, he would add a distinction used by the American Society for Quality (ASQ): it considers quality administration
(such as quality program planning, reporting, and education) as preventive and audits of product and production processes as appraisal).

Regarding the performance category added by Raytheon, no concrete examples of its activities are offered. It is added so that all project costs can be allocated to a quality cost category. This is a departure from the ASQ approach, however, because it would mean that total COQ is equal to total project costs. Taking this total costs view of COQ defeats its original purpose of showing the contributions of quality improvement to product profitability.

Quality costs represent the expenses when an organization has the opportunity to reduce spending by improving its quality-inducing processes. This is especially true today in software development; software quality is the most difficult of the project dimensions to define and is often sacrificed to budget, schedule, and functionality. Measuring and monitoring COQ helps to define product quality but only if it is not watered down by including all other development costs. There is one other disadvantage of equating COQ and total project costs. Cost of software quality is often shown as a percentage of development costs. This allows a company to see the financial benefits of software process improvements across projects and over time. This benefit disappears, however, if all project costs are accounted as quality costs.

Raytheon’s difficulties with misinterpretation of quality categories shows the importance of an organization having a good COQ chart of accounts when it starts measuring COQ. This is emphasized in the lessons the company learned. Although most of the categories in a chart may not be used at the outset, a good chart provides the definition required as quality activities mature and accounting questions arise.

Raytheon said that COQ is not sufficient as the only method of measuring results of process improvements. “I am sure that is true, but I am coming to the conclusion that it is the easiest and most cost-effective way for a level 1 or 2 organization to begin seeing the results of software process improvement because it is straightforward and does not require a large effort to start. As interest in COQ builds, more effort can be invested in it, as Raytheon’s experience shows” (Houston 1998: 5).

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39 Raytheon added another cost category: performance costs. These simply include all the costs that are absolutely necessary in developing the software product even in an error-free environment. In other words, this category is the cost of doing it right the first time. With this addition, all project software costs can be allocated to one of the four cost categories.

40 Level in this context means a CMM-level (Capability Maturity Model).
Observations and experiences gained from BDM International

A number of interesting observations emerged from the empirical research of Slaughter et al. (1998) done in the field of software quality. In some cases, for example in BDM International, was found that defect density improved with each software quality initiative, but at a decreasing rate. This could reflect the company’s strategy for quality improvement, which was to focus on eliminating the major problems first. An implication of this finding is that much of the effect of quality improvement may be realized from the initial quality improvement efforts.

To reduce defect rates over the life of the software project, four major software quality improvements were implemented. All of these were software process improvements. The company’s basic objective was to drive failure costs to zero by implementing quality initiatives that would dramatically reduce defect rates. For example, key problem areas were identified that were causing the majority of the defects (see Slaughter et al. 1998: 69–70). The impact of software quality initiatives over the 10-year development period of the project was that defect density improves after each quality improvement, but the data (collected) suggest that the improvement diminishes, that is, the largest reductions are toward the beginning of the project. It means that process improvements reduce the defect density at a decreasing rate. The behavior of total quality costs as well as conformance and nonconformance costs associated with the project was associated (pp. 70–71). Conformance costs included (in this project) the initial and ongoing expenditures for software quality initiatives, baseline configuration management, design reviews, system-level testing, and quality assurance audits. Nonconformance costs included (in this project) software debugging, configuration management migrations of software fixes, regression testing, operations support for retesting, and additional audits and reviews to defects. Based on the analysis of Slaughter et al. (1998), BDM’s software quality costs reveals that conformance costs per line of code were relatively fixed over the life of the project. The authors speculate that conformance costs may be difficult to change in general, as they may involve relatively fixed components, counter to the claims of Crosby (1979). It could also be, as Campanella (1990) notes, that companies must be diligent in re-evaluating and adjusting their appraisal and preventive efforts so that they do not overinvest in conformance activities as quality improves.
The authors found that the larger returns from quality improvement occur early in the project (both ROSQ and SPQI are highest then) and the rest of the project can benefit from these improvements. It was indicated that defect density improves after each quality improvement, but the data suggest that this improvement diminishes, that is, the largest reductions are toward the beginning of the quality improvement project. The managerial implication of this case project is to avoid making large investments in software quality toward the end of a project. The findings suggest that it may be profitable to invest early in software quality improvement initiatives that have synergies with future initiatives or that make future improvements possible. For example, investing in a software metrics program at time t may enable use of other quality techniques like the Pareto analysis and Statistical Process Control at time t + 1.

The intent of the analysis in this case study was to emphasize that software quality improvement should be viewed as an investment. The authors argue that it is possible to spend too much on software quality. Thus, it is important that companies financially justify each software quality improvement effort. Finally, the authors suggest that it is important to monitor software conformance and nonconformance costs so that conformance policies can be adjusted to reduce the total costs of software quality. Slaughter et al. (1998) emphasize that further studies of software conformance and nonconformance costs to clarify this issue would be helpful. The authors do not give any comments or recommendations how these results could be generalized to other companies.

To summarize the chapter, there is no reason for software industry to follow different quality principles from those used in other technologically intense industries. Software quality can be viewed as an economic issue. The cost of software quality largely concern the costs of defect detection, prevention, and removal. Mountains of reworks has been accepted as part of daily activities. Cost of quality accounting can be used for a number of benefits at this industry. However, even there is not much empirical research done in the field, the research has shown that COQ analysis is a viable mechanism for measuring the overall effect of software improvement. Moreover, the upcoming cases in chapters 5 and 6 can shed light how to measure cost of quality in this industry even more efficiently, by presenting an idea of real-time quality cost measurement.
5 Case A. Constructing a real time cost of quality measurement model

5.1 Case selection

In this chapter, the central focus is on the empirical research design. The research design is an explanation of the delivery of the empirical research done in the field. In this study, two case companies were selected. Multiple cases are employed to strengthen the market test for the construction developed in Case A. According to Yin (1989: 52) the methodology framework is the same in both single and multiple case design. It is not typically possible to pass semi-strong or strong market tests within a medium-term time span in a constructive study. For this reason, the construction developed in Case A is tested by using more detailed nuances within the weak market test category suggested by Labro and Tuomela (2003) in order to analyse the level of progress of the construct. The possibility of constructing a real time cost of quality measurement system developed in Case A is also tested in another case company, Case B, to make the market test stronger, and the boundary conditions how to construct such a system in a totally different working environment are also charted. Of course, more case studies (a third case) could have provided more information about the phenomenon and this could be acknowledged as a limitation. Future case studies of the phenomenon will yield more generalizable results. However, in this kind of research when studying a new phenomenon, real time cost of quality measurement, a sufficient amount of cases could also even be one. Selection of cases is an important aspect of building theory from case studies (Eisenhardt 1989: 536). At one extreme, some researchers focus on single organizations or sites; at the other extreme, some have much larger samples.

Ahrens and Dent (1998: 3) emphasize, that small sample studies typically have different objectives than large sample studies; and researchers with a technical focus aim to capture different aspects of the relationship between systems and organization from those with an organizational focus. Small samples typically permit closer engagement with the field than large samples. Rich descriptions of organizational practice build on such closer engagement.

I will consider the main reasons when selecting Case A to be the willingness of the company management towards the project, the company’s working environment on high technology embedded software business, and the company’s
interest to develop quality management and cost accounting procedures. Case B was selected to study the explanation power of the construct.

Eisenhardt (1989: 537) states that the cases may be chosen to replicate previous cases or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types. While the cases may be chosen randomly, random selection is neither necessary, nor even preferable. Perry (1998) advises researchers to select information-rich cases, while Pettigrew (1989) recommends choosing a case which represents situations in which the object of interest is clearly observable. Similarly, Stake (1995) highlights maximizing what we can learn. Common to all these is a theoretically purposeful selection and to maximize the amount that can be learned. Also, a contribution to science should be possible, i.e. visible.

5.2 Description of the Case Company A

Case Company A designs and produces embedded software products. The information technology industry can be classified as follows: hardware products, hardware maintenance services, software products & services, and processing services & Internet services. Software firms are designated as a separate entity under the heading ‘software products and services’. Software products and services are further divided into four segments: professional software services (production of customized SW), enterprise solutions, packaged mass-market SW, and embedded SW. Embedded SW is part of a customer’s product or system, which is something other than mere software. Today the main product category in which embedded SW is used is what is known as ‘intelligent products’. This segment includes embedded SW development services and the production of packaged SW used in embedded products, such as operating systems (Hoch et al. 1999). The company’s products, traffic information management systems for public transportation, can be classified as part of embedded SW segment.

The case company (later called A) in this research was the first company in the world to launch a fare collection system based on contactless smart card technology in 1991. The company’s competitive edge is based on comprehensive knowledge of the public transportation branch and the skills in contactless smart card technology. Today the company focuses on producing traffic information management systems for public transportation. The fare collection system alone cannot meet the needs of public transport operators today. The volume of traffic information in demand has increased and therefore the need to process it is now
bigger. To these needs the company offers its customers a solution. Being situated in a Technology Park in Finland, the company is surrounded by an innovative and effective environment in which it can act in the demanding branch of information technology. A has a technology network which ensures important contacts to other IT companies and to a university. This gives the company good potential for future development. A was founded in 1986. The company’s headquarters are in a major city in Finland. A has provided over 70 public transportation installations throughout northern and central Europe.

5.2.1 Starting point of the empirical project

The empirical part of the dissertation process was started in October 2001. Among other projects, I was a contact person on a student mentoring project at the University of Oulu. In this project, we had closing speeches at the premises of one of our student mentor. At the beginning of my own speech, I also touched upon my research work as senior assistant at the Faculty of Economics and Business Administration. After the meeting, one student mentor, a financial manager at Case Company A, became interested in my research and asked me if I would be interested in some collaboration. This manager raised the problem of quality cost accounting in the company. I gave him a research report based on my licentiate thesis “Quality cost measurement as a tool for top management in contemporary software business environment”. The licentiate thesis offers an extrapolation of the management and service industries’ COQ Model for the business of software development. After a few phone calls and e-mail messages he asked me to come to his company for discussions. I had a meeting there with him, managing director of the company, and the quality manager. After that, I collected the ideas discussed and sent him a research project proposal and we started a project called “Laatukustannus- ja projektilaskennan kehittämishanke”, the development project of quality costs and project cost accounting on October 1st 2001.

The idea in the background when starting the project was to improve the company’s earning capacity by measuring, controlling, and cutting the company’s quality costs. At the beginning of the project the project group was formed. The supervisor of the project was the managing director of the company. He gave the green light for the study. The persons in the project group were the researcher, controller, software development manager, testing manager, quality manager and the manager of the hardware department. The initial goals of the project were to
define the quality cost elements in A, to draw a map of the actual state of project cost accounting and find the main development targets, and finally to prepare the adoption of the procedures that would be agreed in the project group. I worked as a researcher on this project from October 2001.

5.2.2 Working methods during the fieldwork phase

The amount of working time which the researcher would spend on the company premises was agreed in principle, but it was flexible. The researcher worked on this project 2 working days per week from October 1st 2001 to February 28th 2002 on the company’s premises. After this period, a new commitment was made to continue co-operation. A new commitment resulted for the greatest part directly from the fulfilment of the first step. From March 1st to June 30th 2002 the researcher stayed at the company 1 day per week. I consider this kind of commitment necessary because otherwise the researcher cannot gain a deep understanding of the issues researched (cf. Lukka 1999). The initiative for the project came from the financial manager of the company, who was responsible for developing financial and management accounting. He ranked high enough in the company hierarchy to be able to ask other staff to help in collecting the required data.

Labro and Tuomela (2003) argue that the negotiations and tentative problem scanning should be carried out in co-operation with several people from different functions and hierarchical levels. However, the potential for co-operation is not only dependent on the case firm manager’s willingness to participate in the study. When examining the possibilities for joint development work the values of different participants should also be carefully assessed. At the beginning of the project in Case Company A, a project group was built up of the key persons. The group consisted of the following people: researcher (the undersigned), controller of the company, acting manager of SW department, testing manager, quality manager, and manager of HW department. The key people chosen by the project group who were also interviewed were three software designers, the manager of the project department, the manager of A-customer key accounts department, a customer service engineer (A-customer project), a customer service manager, two hardware engineers, and a service manager. Each interview lasted from one hour to two hours. The researcher reported to this group during the project, and also to managing director of the company. Mattessich (1995) emphasizes that in order to sustain the credibility of the constructive research, the researcher’s and manager’s
values should be made explicit. Puolamäki (2000) argues that if the values of the researcher(s) are in (sharp) contrast with those of managers, co-operation should not be initiated. In Case A, the objectives of the project were discussed and jointly accepted in project group before starting the project.

Labro and Tuomela (2003) argue that in order to make any research worthwhile, the results have to be presented to the wider community (cf. Ijiri 1975, Kaplan 1998). In the context of CRA, Lukka (2000) emphasizes the importance of ensuring commitment to the publication of the research findings. Any publication issues that might subsequently arise should be settled in the very early phases of co-operation. In Case A, the issues of publishing were discussed with the financial manager and also written also into the contract. A confidentiality agreement was signed at the very beginning, covering all data later made available during the project, but allowing the researcher to summarize the results in a disguised form. This means that the researcher may present the research process, the construction and his research findings, but should first let the company to go through the report. The constructed model itself was not subject to the confidentiality agreement (cf. e.g. Labro and Tuomela 2003).

Labro and Tuomela (2003) propose five critical issues in the preparatory phase that need to be dealt by all constructive researchers: 1) Ensuring that the practical problems are recognized by several actors in the case organization and that they are enthusiastic about solving these problems. 2) Ascertaining that the case organization is able to commit enough resources to the development work. 3) Identifying managerial values and ensuring that these are not too much in contrast with those of the researcher(s). 4) Providing case firm participants with enough information about the CRA so that they understand the fundamental features and objectives of this kind of research. 5) Agreeing on publication and confidentiality issues. Case firm representatives should read the material through, not only for confidentiality reasons but especially because this improves the validity of the findings (see Atkinson and Shaffir 1998).

The research co-operation spanned quite a long time. The fieldwork phase covered a period of two years: participating in a related development project, the development and implementation of the construct in the company, and following the usage. In the field, triangulation had a critical role (cf. e.g. Tuomela 2000). A number of interviews with several key persons (see Appendix 1) were conducted and a considerable amount of groundwork (see Appendix 2) was done before beginning the actual development work. In Case A, the approach was first to become acquainted with the company including the products, to hold discussions
with the workers, read accounting data, learn the processes etc. The number of key persons interviewed (decided in project group meeting) was 15. The interviews lasted from 1 to 2 hours. The 15 employees interviewed can be grouped as follows: four of them were responsible for SW (software) specifications, three of them were responsible for SW development, four were responsible for SW maintenance, one was responsible for HW (hardware) specifications, two were HW developers, and one was responsible for HW maintenance and service.

McKinnon (1988: 38) states that the researcher may experience data access limitations, which will be imposed by research hosts. Either irrespective of, or because of, who the researcher is, the research hosts may impose restrictions on mobility and access to certain documents, events or people. In my study, a non-disclosure agreement (NDA) was signed at the very beginning (in both case companies). Beside its negative consequences it may cause for this research (inability to publish the companies names in these case studies), the positive side of signing was that all information the researcher needed was given in both companies and the researcher noticed no restrictions on mobility and access to certain documents, places (e.g. restricted R&D facilities with unpublished products, etc.), events, or people. McKinnon (1988: 38) states that (in case data access limitation exists) although the researcher’s aim may be to study a specific process or phenomenon, they may be faced with the prospect of being barred from witnessing specific aspects or dimensions of the process; i.e. the researcher may be studying less than the complete phenomenon they claim to be studying.

The working method in the project entailed conducting and transcribing the interviews described above, but also unofficial discussions in the company and writing reports. The project group meetings, lasting 1 to 3 hours, were held regularly, seven in total. The interviews were not tape-recorded as the researcher was not able to picture in advance what sort of issues would emerge during the research process. It was felt that not using a tape-recorder would perhaps make it easier for interviewees to express themselves more freely. However, interview reports were written after each interview on the same day to avoid research biases (see e.g. Granlund & Malmi 2002: 303) Labro and Tuomela (2003: 424) perceived in their study that the aim of practical problem solving was likely to increase the commitment of the persons interviewed and hence reduce observer-caused distortions. The persons interviewed are likely to put more effort into the answers when compared with a traditional descriptive research agenda where there is nothing at stake for the interviewee. This point was also noticed at our
study. Observer-caused effects may be described as the reactive efforts of the observer’s presence on the phenomenon under study (McCall & Simmons 1969: 78). McKinnon (1988: 37) states that a common criticism of the field study method is that the researcher’s presence in the setting will cause the participants to change their behaviour and conversations and that, as a result, the researcher is not observing the natural setting, but one which is disturbed by the researcher’s presence. According to Simon and Burstain (1985: 246), the field researcher’s presence must, by definition, alter the setting since it now contains another person with another role (researcher). In the study, I did not consider observer-caused effects a big problem. As McKinnon (1988: 37) argues, the benefit of a substantial time in the field is that it can effectively overcome the problem of observer-caused effects. Although subjects in the setting may seek to appear different from their usual selves to the researcher, the longer the researcher remains with them, the less they are able to do so. I argue that the amount of time spent in Case Company A is enough to eliminate this kind of bias.

The researcher’s role gives rise to three types of limitations on access to data in the field (Zelditch 1962). First, the researcher is only on site for a limited period of time and cannot observe what happened before they arrived or after they leave. Hence, the researcher is not in a position to observe the historical background of the phenomenon, which may be important in terms of understanding its current form. This kind of limitation was of course noticed by the researcher at the beginning of the empirical research phase in both case companies. In Case Company A, I tried to avoid such bias by beginning the empirical “period” in the company with a large set of interviews (see Appendix 1) where 15 company employees in all levels of the hierarchy were interviewed and reported. To get a “true and fair” picture of the company’s situation regarding the themes at the interviews, the reasons for the problems in profitability, project costing and project pricing procedures, the company’s quality system, opinions on SW development and HW development, etc. were gone through. The intermediate report (12.2.2002) included 20 pages of quotations from the interviews conducted. This was made to obtain a general and comprehensive understanding of the topic, in other words, to understand what has happened in company history before the researcher arrived. The researcher’s intermediate project report was produced and presented at the project group meeting at 15th of February 2002. At this report the summary of those 15 interviews was presented. The subjects treated in the interviews were grouped into different themes in the report. Based on the intermediate report that concluded the opinions of the key persons at the
interviews, the researcher made a list of the development suggestions for the rest of the project (March–June 2002). The persons in charge were named in the company for each development suggestion.

5.2.3 Description of the result of the preliminary phase

The main content of the intermediate report consisted of the quotations of the interviewees classified according to the thematic areas mentioned above. For the sake of anonymity the names of the employees of the company have not been published in the citations below. The citations from the interviews are given in italics. I have used the formulation that the people interviewed used, but also deleted the citations in which there are derogatory statements about other employees, swearwords etc. The people interviewed were Petri H., Pekka V., Kai N., Mikko Y., Markku N., Sanna L., Risto R., Antti J., Pasi V., Riku N., Timo H., Jarmo M., Pete M., Risto S., and Hannu A. As follows, a resumé of each thematic area will be presented.

The financial success of the company and the employee’s opinions concerning the reasons for the weak financial success

There were several reasons for the poor financial success; the main reasons mentioned at the intermediate project report are listed below.

Understanding customers:

“*We have the philosophy of “understanding” the customers. The customer is the ‘king’ at the company. This is a good thing to a certain point but in this company it has been understood wrong. We should understand business. I understand that the company culture will not change fast”.* (Field notes, test manager.)

Pricing problems:

“*We try to do business at any price. To get a contract we sell things that do not yet exist. We have not been involved enough in the importance of specifications of the system we sell. This leads to custom-designed systems that are difficult to maintain. We have not been able to consider all of the fixed costs*”. (Field notes, customer service manager.)
Problems in making contracts:

“We have agreed what will be dispatched but we haven’t put it on paper. Our contracts have not been detailed enough”. (Field notes, customer service manager.)

“There has been big difficulty in contracts making techniques. Contracts should be more clear and detailed. There has been too much ‘grey area’ in contract texts. The company must pay more attention to making the contract texts. A jurist should be used when needed. There have been verbal agreements and verbal promises to customers”. (Field notes, software designer.)

“Especially in the X-project (name changed), the way of working procedures has caused problems. X is a difficult customer because on the customer side there are a lot of government officials those who don’t have the courage to take responsibility. The customer has a huge bureaucracy. Business agreements have failed, the requirements have had to be amended” (Field notes, SW designer. She adds: “The approach to work that A has earlier used (company culture meaning that company A can trust to oral business agreements) is not working any more in this kind of customer environment. The company has learned a lot from the mistakes made at X-project. At X-project, there has been generated a lot of quality costs, especially rework costs”.

Systems maintenance problems:

“Knowledge has been personified to few people at A. This has impeded software maintenance. Knowledge has not been transferred in the right way to all employees. Difficult cases have not been reviewed afterwards. We should identify the bad projects afterwards and learn from them” says the test manager. He adds: “software product thinking has been lacking. We have not had the courage to cast off the unprofitable projects – but we should have been done so. For instance the Danish project should have got rid of in time. We have made foolish contracts; this company can’t denounce the contracts!”’. (Field notes, test manager.)

Budgeting problems:

The revenue budgets have been optimistic, the co-operation between sales/marketing and R&D-department has not been operated in a desirable way. There have been problems in the contents of the contracts:
“We have been selling hardware and got turnover. It has been important to get turnover. The most problematic projects have been X-, Danish and German projects”. (Field notes, software designer.)

“Partnership-agreements have not been useful, partners have not been reliable. Our aim is to get rid of the worst projects; Danish, X, and Hungary so we can make the company more healthy”. (Field notes, controller.)

Software problems, especially reuse problems:

The company has built custom-designed software from the beginning of it’s history. First assembler, then C++ in the BISTRO-project. Too much custom-designed systems; nobody has controlled R&D as a whole.

“We have made custom-designed software, too many versions, too many parameters”. (Field notes, director of HW department.)

“We have done reuse from old software, the problem has been that old software has not been designed for reuse. Software development costs have not been considered”. (Field notes, test manager.) The controller of the company emphasizes that software problems have delayed the projects. “The activities have been constructed on the conditions of HW-development”.

Bad demand situation, only few customers:

“The company has formerly been in a state of ‘poor demand’. This means that the company was forced get net sales. For this reason contracts that are known to be unprofitable are taken”. (Field notes, manager of the R&D department.)

“The export market has not developed as A desired. The market is waiting for standardization. Our product development has been delayed, new products have not been finished on schedule”. (Field notes, customer service manager.) He adds: ”We make no mass-produced articles, there are few customers. We haven’t been able to make money. This means that every business agreement is behind a stone. The customers don’t come to A to queue up our merchandise. We should make the sales volume bigger but the problem is that the number of potential customers is abridged”.

162
The opinions concerning the actual state of product pricing and project cost accounting:

Cost accounting has been done based on the best knowledge at that time, though the absorption cost prices have in many times been taken ‘from the hat’. The company should have invested more in price setting. Nowadays the pricing is more or less defective. The projects have no decent actual cost calculation of the actual costs. The company has also very easily taken R&D projects even if there is a big risk that they will be unprofitable. Investment decisions are not calculated enough. One of the main products, and its HW and SW has been totally reconstructed (more memory capacity has been constructed). The determination of the price for this main product has had problems (Intermediate report 12.2.2002).

According to X, Case Company A accept the price that the customer says (s)he is ready to pay. The determination of prices must change in the future. The determination is difficult because it is hard to sell the products that don’t exist (have not yet been developed). The new product palette -thinking is thought to abolish this problem. The researcher’s development suggestions for pricing determinations: the company has to do marketing research, the specification must be compact, the product development costs should be estimated upwards rather than downwards. The R&D-costs have in the most cases been estimated downwards, likewise the timetables. More effort should be put into price setting. (Intermediate report 12.2.2002).

The contracts are made first, the project manager will step in just when the contract is already clinched. Things should not be like this. Pricing decisions have been based on actual cost calculations, the fixed costs have not been fully included in pricing decisions. Before the company has been selling equipments; it has not been able to charge the SW maintenance because software is expected to belong to as one part of the equipment. The company has sold software and could not take charge of it. The gross margin of sales are small (margins seem to be good prosentually but the company has not been able to direct the fixed costs to the projects). (Intermediate report 12.2.2002).

A lot of contractual penalties have also been incurred. This should be taken into account in making the pricing decisions (A should also estimate the price of a risk). Contractual penalties are incurred because the customer demands a certain date of delivery. The company has to put a date for delivery into a contract because otherwise there will be no deal. The company has had to offer with a
short time period in order that it would get a deal. The contractual penalties may even be 20% of net sales. One half of the penalties were due to delay and the other half is because of defects in functionality (the product does not work as stipulated). (Intermediate report 12.2.2002).

The determination of prices has been based on an “it seems to feel” principle. The cost of HW could be calculated, but the cost of SW has been “anticipated”. There has only been 1,5 years chargeable maintenance in A. So far, the maintenance has been free of charge to customers. A year ago the company tried to introduce a monthly based maintenance billing system but the results were bad. In the new system a company charges a %-basis maintenance payment that includes error corrections, software maintenance, some software upgrades, error occurrence detection and fixing, and a modest amount of telephone support. The major upgrades are furthermore chargeable. This is a good way of thinking. (Intermediate report 12.2.2002).

Based on these opinions collected from 15 interviews concerning the actual state of product pricing and project cost accounting above, the researcher made the following development suggestions (considering these thema areas in A). The suggestions were presented at the intermediate report.

- Go through the investment costs and actual cost calculation practices in R&D-projects. Besides, clarify how, when, who, and to whom the differences is projects should be reported.
- Go through the determination of prices system for the future. Confirm that the determination of prices procedure is similar in all products in the future.
- The company should invest more resources in management accounting. We have to consider if this requires acquiring more personnel to accounting function. According to the researcher, the earning capacity of the new projects is a “live or death”-question in A. in the future. (Intermediate report 12.2.2002).

**The opinions concerning department of R&D-development (SW-development)**

The main phases of software process in A are requirements definition, design, and implementation. The final outcome of the definition phase at A is the requirements document. The requirements are also inspected as a rule. The design phase includes SW design and the design is done with Rational Rose software.
The implementation phase includes coding. The coding phase should be ‘a piece of cake’, but of course it depends on the size of the software. After coding the code is inspected by other SW engineers. The aim of inspection is to find and eliminate the bugs and ‘silly’ implementations of the code. After code inspection follows the integration testing which can be e.g. module–module-testing, driver terminal – dual interface reader -testing, or driver terminal – dual interface reader – background system -testing. In coding phase the company tries to use existing SW-components. After testing follows the maintenance phase. There is uncertainty in A as to what actually maintenance means and when this phase actually begins. The maintenance should be informed when making customer contracts. There should be facts about what belongs to maintenance and how long time the free of charge maintenance will last. Maintenance phase typically includes rework of the code bugs; that means a new release. (Intermediate report 12.2.2002).

There were quite a lot of problems mentioned at the interviews. One problem mentioned was the link between sales department and SW development. The expert knowledge of the sales personnel with relation to products was insufficient. The boundary between the R&D department and the project department has been unclear. There has been lack of co-operation. (Intermediate report 12.2.2002).

“Sales department sales ‘whatever under the sun’. Sales department has got in touch with the software designers like ‘we need this kind of changes’. Sales has promised such characteristics that cannot be achieved with the current resources in R&D (especially on the schedule given by sales). This has caused timetable problems when the sales department has promised something to a customer; something that cannot be done. We would like better connection between sales and R&D. R&D has also done some things which have not been defined in the requirements definition phase”. (Field notes, software engineer.)

The project organization was also seen problematic. The philosophy of building products, not only customized software, should solve many problems. The wastage rate of personnel has been quite big in R&D department. Trainees have been used quite much. (Intermediate report 12.2.2002).

“Cheap employees for the company; but how about the quality of code?” (Field notes, software engineer.)
“The programming language is new, the database is new. We have employed quite a lot of people in the last two years. We have tried to get experienced software engineers, but we haven’t found them. That’s why we have hired inexperienced people. That’s one reason why we have big quality costs (rework). There has also been high turnover of workers and firing cases”.
(Field notes, controller.)

There were also problems in version management. The software used was not designed for reuse. (Intermediate report 12.2.2002).

“There are version management problems on the coding side. The software changes doesn’t hold still when employee’s change. For instance, on X project, an error that was fixed three years ago, now springs up again. An update version had been done based on other version in which the bug still existed”.
(Field notes, software engineer.)

“Poor quality results mainly from the R&D department. The version management is bad. The fixing of one defect can cause 4 new bugs. Software should be modularly programmed to avoid this. The R&D department don’t run in time, the planning of work is poor. The department don’t adhere to promised timetables”.
(Field notes, software engineer.)

There were also problems in inspection practices. They have only been made occasionally.

“The requirements are inspected in every project in the future. Earlier this has not been done, we have only commented the requirements definitions. 1–2 persons in every department inspect the documents”.
(field notes, software engineer.)

At the R&D department there are employees who do requirements definitions. This work should be done somewhere else (in sales). Customer requirements definition should not be R&D’s business. Requirements definition causes costs to R&D department that do not belong in that department. Sales/marketing should be able to do requirements definitions. (Intermediate report 12.2.2002).

At present the company inspect the codes. The instructions tell to do the inspections, in practice it is not a necessity (e.g. haste and the like). The instructions tells to inspect everybody’s codes. At the coding phase, code inspections are made by Parasoft Codewizard (C++) that inspects the layout of the code, and Parasoft Insure ++ inspects the memory errors. The inspection is made
when about 5000 lines of code have been completed (or the code is finished by the encoder). The encoder gives his/her code to another person for inspection. Two persons inspect the code, after this a note of inspection is put into the code. The note is also put into the project document. The codes are not taken to the official SW version if they have not been inspected. (Intermediate report 12.2.2002).

MS-DOS-programming has also caused problems. For instance, the Dos-based depot system is difficult to code. (Intermediate report 12.2.2002).

There have also been problems in the estimation of workload and trust in verbal agreements. The inspection process has been primitive but nowadays it is a more systematic process. The current software process has been inspected, the whole personnel has had an effect on it. The specifications are inspected. (Intermediate report 12.2.2002).

Based on these employee’s opinions concerning R&D-department and opinions of improving the department’s activities above, the researcher made the following development suggestions (considering these theme areas in A). The proposals were presented at the intermediate report.

– Clarify the inspection process. (Based on the master’s thesis of Pekka V.)
– Clarify the interfaces and responsibility areas of software process
– Clarify who as the permission to command the R&D-process.
– Clarify the documentation management
– Consider whether a manager responsible of the whole department is needed
– Start quality development work based on SPICE, CMM, eg. Model. We should also develop quality metrics. The company must make time and resources for this kind of development effort.

The opinions concerning quality issues, issues of functionality of the existing quality system, opinions of the quality cost system construction process, and improving activities concerning to these issues:

The overall quality system of the company was not considered to be satisfactory at the time of the interviews.

“As regards quality issues, we have mainly taken care that we can fulfill the needs of the DNV:s (Det Norske Veritas Oy) certificate. We want to keep it on the wall”. (Field notes, software engineer.)
“The internal auditing of the quality system should be done. The auditing should also be continuous. Now the quality system is unconnected and it will not be used. We would also need continuous discussion of the functionality of the quality system. There could be a team of 5–6 persons who would say if what the company is doing is in compliance with quality system. This group could also inspect quality documents”. (Field notes, software engineer.)

It was seen that “a quality system can not be optional” (as nowadays). The quality system was not used frequently by software engineers. “I haven’t read any quality system document!”. (Field notes, software engineer.)

There were also comments like “Quality issues are not on the right track, we don’t use the quality system much. The changes made to the quality system are not informed to employees”, “the connection of the individual documents to our quality system limps”, “quality documents are not read”, and “we haven’t had any use for our quality system and the system hasn’t been used very much. One task of the quality manager would be to get the self-controlling teams (quality circles) to be active”. Also quality assurance of a subcontractor has not been done. The information on the defects comes from the customers. There was also a lack of continuous quality training. (Intermediate report 12.2.2002).

“There should be quality training for employees; especially project managers. I think our quality manager should train the employees. At least in other companies this happens”. (Field notes, software engineer.)

There were operative instructions for many situations in quality system, but the instructions were quite complex. If employees should always conform to these instructions, the situation would ‘blow over’. The system was also seen to be inflexible. The base of the quality system has taken from the base of the bigger company. (Intermediate report 12.2.2002).

The version management was also a big problem. There were too much memory-resident things, e.g. various versions of documents etc. For example when updating software the documents have to be updated. This has caused terrible bumbling around and rework when the customer has had another document version as thought.

“The quality system does not answer the question who decides which software versions are installed into the product”. (Field notes, software designer.)
“Poor quality is mainly due to the R&D department. The version control limps. The correction of one defect may generate 4 new defects. Software should be modular so this could not happen. The work planning is poor, the promised timetables will not hold”. (Field notes, project manager.)

Almost all the employees interviewed thought that measuring quality costs is necessary. No one was actually against the measurement. There were comments like “quality cost measurement is a damn good thing”. (Intermediate report 12.2.2002).

“The basic terms of quality costing are quite difficult to understand by coders, particularly the prevention and appraisal costs (why they are quality costs).”… “Quality costs should be considered as normally related to the SW process. Separating quality costs from normal activities is very difficult, but however it is possible. For example, it could be done by inputing the project’s working hours. When entering the worktime into the working hours follow-up (system) we could enter the project, the task inside the project, and the hours used”. (Field notes, software engineer.)

There were quite a lot of definitions among employees as to what should be considered as quality cost. “I think the costs of software quality are mainly rework in requirements definition and in software design”. “Bugs are also quality costs”. (Field notes, software engineer.) “Prototype testing is quality cost as it goes over a certain line. In projects there should be only one protocircle as a normal activity”. (Field notes, HW development manager.) “I think the costs of software quality are mainly rework in requirements definition and in software design”. (Field notes, software engineer.)

“In case the requirements definitions are all right and if the software doesn’t work, then it is quality cost of R&D department”. (Field notes, software engineer.)

Rational ClearQuest (QC) -software\(^{41}\) was seen very positively in measuring and improving quality issues.

\(^{41}\) Rational ClearQuest –software is a workflow automation tool (in particular bug tracking system) from the Rational Software division of IBM. The product was originally designed for tracking defects (bugs) in software development projects. The tool can be linked to Microsoft Project to create ordered steps for resources assigned to specific goals.
“In Rational ClearQuest we have the version control (of the coders), the others cannot make the changes. Rational links the changes. There are also test- and default reports in Rational. The errors are registered as defect type; what defect, what SW version, etc. The coder acknowledges the error in the system when the fixing of the defect has been started and also when the defect has been fixed. All the time we know in what phase we are. Rational should also be linked to MS Project software. The testing of BISTRO was carried out through Rational”. (Field notes, customer service manager.)

“Measuring QC is a good thing. Rational CQ is a good tool to do it. The COSQ are difficult to measure because software is not manufactured, it is developed. For this reason a certain % of bugs should be considered as a normal mode of operation”. (Field notes, project manager.)

Based on these employee’s opinions concerning quality, company’s quality system, quality cost measurement, and opinions of improving activities above, the researcher made the following development suggestions considering these thematic areas in A. The suggestions were presented at the intermediate report.

- Put all project documents to same system. The project documents should be linked to the quality system.
- Adopt similar document bases for all projects.
- Name the documents identically
- Update the document lists
- Clarify who are document owners and who have the right to change documents.
- Give the quality manager the right to use his whole working time for quality issues. Give the responsibility for quality training to the quality manager.
- Clarify how to update the quality system
- Update the working instructions.
- Use Rational ClearQuest software as a base for constructing the quality cost measurement system. The version management system, testing, and error notes should also be put in QC.
The opinions concerning the testing process

The testing process can be described as follows. First a ‘smoke test’ (2–4 hours) is done. In this test the most important things are tested; e.g. that the new version goes onto the old (the transactions are all right, the functionality of the software is all right etc). Earlier, about 30% was returned from the smoke test, nowadays less frequently. It means that software has been improved. The normal testing takes about one week, the analyzing of test results takes a couple of days. The documents are also read. Error messages are put into Rational CQ -software. The defects will be tested again after they have been fixed. If new defects have been found, the test plan is extended. There is no classification of defects but in the future the defects will be classified as a fatal defect, functional defect, and cosmetic disturbance. The following problems concerning the testing process were seen at the interviews:

- Testing process was not seen to be systematic. “The testing process has been very elementary. Testing has not been systematic, there have been may versions of SW. Version control has been bad”. (Field notes, software engineer.) Another coder adds: “Testing process has improved but still it is undersized. There is incongruity between the number of coding- and testing people”. (Field notes, software-engineer.)
- The requirements definition was also seen as a problem in testing. “The testing department should also participate in the requirements definition of the software. Usually, functional requirements are OK but there are problems in requirements specifications. Also the other documentation (operation instructions of the devices) should be tested”. (Field notes, test manager.) He adds: “Everything is reflected to specs. About half of the defects are due to imperfect requirements”.
- Testing process was seen to be a part of normal operation but it can also be seen as rework. “In testing we cannot always say if some issue is a defect or not because the issue cannot be found in specs, e.g. if the customer must press *-button before the software carries out a certain task”....“A good coding method should include a module test done by the coder before the software is given to the testing department. Naturally, the testing department tests the module whether the module works versus the functional requirements. The aim is to hasten the testing process”. (Field notes, test manager.)
“The coder tests his/her own code. The coder can also test the SW/HW integration. Integration testing has caused problems. There can be many types of integration testing. In projects, integration testing means testing between various subcontractors’ subsystems.” (Field notes, quality manager.)

“We should have delivered a proto to the customer, or at least say that this device is a prototype, so the customer would not imagine that the device we sold is completed. The problem is that the customer is testing, A is not. The devices should be better tested before being delivered to the customer. We should have usage tests in the vehicles. The problem is that the company management has wanted the products to be completed on a very tight time schedule”. (Manager, HW department.)

The researcher made a development suggestion that the company should clarify which part of testing belongs to the R&D department and which part to the testing department.

Making the intermediate report helped the researcher to analyse the gathered data. Eisenhardt (1989: 539) emphasizes that analysing data is the heart of building theory from case studies, but it is both the most difficult and the least codified part of the process. Since published studies generally describe research sites and collection methods, but give little space to the discussion of analysis, a huge chasm often separates data from conclusions. As Miles and Huberman (1984: 16) wrote: one cannot ordinarily follow how a researcher got from 3600 pages of field notes to the final conclusions, sprinkled with vivid quotes though they may be.

Appendix 1 clarifies the chronological progression of the project. The events mentioned on this list are only the main events of the research project. Not all the small negotiations, phone calls, daily questions and smalltalk discussions with the employees while working one or two days per week at the company premises in this project from October 1st 2001 to 30th May 2002 are reported, because this work was not designed to be an action research project in which every small daily event has to be reported.

Labro and Tuomela (2003), based on their experiences in the field, suggest that sufficient time should be devoted to getting acquainted with the case organization and letting the people at the case organization familiarize themselves with the researcher(s). Speaking of field research more generally, McKinnon (1988: 44) makes the point: prior to having any real information, people in the
setting will approach the researcher’s arrival with feelings ranging from genuine interest to annoyance, disinterest, and fear of exposure, or they may see the researcher as a means of promoting their own political agendas. Hence the researcher’s first concern on the research site should not be data collection; rather it should be preparing the ground for data collection. This involves, firstly, that the participants understand clearly why the researcher is there and, secondly, creating the conditions under which they will be allowed to the social relationships of the setting. McKinnon (1988: 44) points out that the researcher needs to gain the confidence, trust and respect of the participants and to be seen as personable and genuinely interested in them. While this may sound like motherhood statements and the description of the researcher somewhat idealized, appropriate social behaviour on the researcher’s part is essential for securing access to reliable and valid data.

Labro and Tuomela (2003) also rise an issue of any qualitative research to experience reality as others do (Atkinson and Shaffir 1998). When becoming deeply involved in an organization and in the trials and errors of company development practices the researcher him/herself participates in the experiential learning cycle (Kolb 1984) which should allow a more profound understanding of the case events. Labro and Tuomela (2003) also acknowledge the potential for a severe participant bias on the part of the researcher. This is something he/she should be aware of when embarking on a CRA study in order to minimize it. They suggest (2003: 424) that in terms of internal validity the drawback of participant observer bias is outweighed by the reduction in observer-caused distortions, the timeliness and length of the research process and better access to all kinds of data. According to Simon and Burstein (1985: 224) observer bias is a tendency to observe the phenomenon in a manner that differs from the true observation in some consistent fashion. Moreover, the CRA enables issues to be tackled the moment they occur, rather than relying on somewhat distorted explanations by company people afterwards. McKinnon (1988: 37) distinguishes observer bias from observer-caused effects, where the observer’s presence actually changes the phenomenon under study. With observer bias, it is what the observers see and hear (or think they see and hear) that is of concern. It is the distorted effects of the researcher’s selective perception and interpretation. Observer bias may enter in the split second following the occurrence of an event as the researcher registers it as an initial impression, subsequently as the event is interpreted in the context in which it occurred, and later as the event recorded and transcribed into field notes. McKinnon (p.37) states, that the approach to overcoming observer bias must
proceed on an acceptance of its existence, and to be directed towards what actions the researcher can take to protect the collection and analysis of data from the contaminating effect of their own bias. She argues (p.40) that a substantial length of time in the field serves to lessen the potential for observer bias. In the study, I did not consider observer bias a big problem, because the data collection process was meticulous, involving long periods in the field. The interviewees had time to get used to the presence of the researcher in both case companies. As McKinnon (1988) states the longer the researcher spends in the studied context, the less vulnerable the study is to factors that jeopardize its reliability and validity. In the study, I also noticed the point raised by Lukka (2005) that the interventionist researcher being thoroughly immersed with the practical flow of life also decreases the risk that s/he is treated as a ‘tourist’ in the field. In Case A, observer bias was also noticed, but the researcher tried to avoid it by not remaining aloof as a so-called ‘objective’ observer but actively drive the process together with the project group.

According to McKinnon (1988: 38), Complexities and Limitations of the Human Mind -distortion means that the statements subjects make may not be able to be taken at face value. The threats to validity and reliability are of two types. First, the subject may consciously seek to mislead or deceive the researcher, perhaps reporting events in a manner most flattering or acceptable to him/herself. This is similar to an observer-caused effect, but differs in that such deception is not caused by or restricted to the researcher. Rather it is a deception that the subject seeks to maintain for all others. Second, subjects may be trying to be honest and accurate in their dealings with the researcher, but their statements and reports are affected by natural human tendencies and fallibilities. People forget things, they pay varying amounts of attention at different times to their own behaviour and to the behavior of others, and, like the researcher, they also have their own sets of biases which shape their perceptions and opinions. McKinnon (1988: 41) argues that the length of time has further benefits for combating data access limitations and human mind effects. The longer the researcher remains in the field, the more likely it is that they will be granted, or can negotiate, access to events, activities and people which may have been denied on initial entry to the setting. During the research process, I did not consider “human mind” bias a big problem – at least bigger than usually in qualitative research because of the long research period.
5.2.4 The change process

After the preparatory phase, the work done was reported and presented to project group members and to all interviewees of the project group members on February 15th 2002. The researcher continued the close co-operation in the form of additional interviews with the caucus of the project group (financial manager, test manager, researcher). The main objective of these interviews was to deepen understanding of how to develop quality cost measurement of the company. One main turning point of the project was the presentation of the testing manager of the company at 8th March 2002. At that time he presented the new software (Rational ClearQuest) to software developers of the company. The meaning of the software was to be a substitute for the “old” Microsoft Excel -based software which had been used to record every software bug noticed.

After the presentation, the idea of a real time cost of quality measurement system came to the researcher’s mind for the first time. I noticed that it was now only a question of programming work and such an innovation could be executed. The early development work of the system was very much dependent on the researcher. However, the researcher received very encouraging feedback on these suggestions from company management. Company management gave strong support to the idea of real time measurement of quality cost. At that time, the research effort was strongly focused on the development of the quality cost system of company. This expectation came from the company management. The managing director was even taking about patenting the construct. The test manager put very much of his working effort to programming a construct based on the ideas of real time cost of quality accounting. This construct was made on the basis of the Rational ClearQuest -software. The question now was what kind of devices and software would be needed to construct a real time cost of quality measurement construction. As follows, the defect fixing procedure constructed in the company will be presented. After that, the development process of the constructed real time quality cost measurement system – RQC will be reviewed.

In a software company, including embedded software manufacturers like Case Company A, quality costs are typically based on working hours; e.g. correction of bugs (rework). For this reason it is important to be able to clarify where the working time is used. Quality costs related to employees can be measured by calculating a cost per each working hour that the company pays for. The detection, clarification, and fixing of the defects in the software is also important. In the company, Rational ClearQuest (CQ) software had been modified
and taken into use as a defect database. This software replaced the earlier defect database run in Microsoft Excel. By using CQ, the defects are registered using intranet or normal user interface. In the basic state of the software a new defect can be entered using Submit/New defect. Fig. 31 illustrates the states developed for defect fixing process at company A.

![Diagram of defect fixing process states](image)

**Fig. 31. Description of the states developed for defect fixing process at company A.**

The software automatically registers the employee and time, and also sends defect notification of the defect to selected employees. The so-called Change Control Board (CCB), an innovation made in the company to manage the defect management process, which consists of selected employees of the company, manages the tasks in Submit- or Postpone-state by changing them to Request-state. The tasks can either be abandoned (Closed), frozen to be done later (Postponed), or ordered to a certain employee to do the defect fixing (Assigned). The Owner of the task can take the ordered task by changing the task from Assigned to Open-state or give the task to another employee, (Reassigned). After the defect has been fixed or the problem has been solved, the task can be moved to Resolved-state. If the task is a more complicated than first thought, the owner of the task can move it to Postponed-state. The employee responsible for the application can verify the defect fix and move it to Closed-state or, if he/she finds that the fixing is still defective, move it to Open-state. By using this defect correction monitoring system, it is possible to monitor and list the stages of defect fixing. No single defect will be “forgotten in the desk drawer” and for this reason not to be fixed.
5.3 The Description of the constructed quality cost measuring system RQC

At Case Company A, the old Excel-based model used for defect detection and fixing was substituted with a new Rational ClearQuest-based model. This meant that after a short test period no defect fixing was allowed, and was not technically possible, without entering ClearQuest-system. As such, the change to a new defect correction and monitoring system and the possibility to monitor and list the stages of defect fixing made it much easier to continue the quality cost measurement project because no single defect would be “forgotten” any more and for this reason not be fixed. It meant that every working hour outside the “normal” software development is going through the RQC system.

There had been a lot of discussion and meetings considering quality cost reporting in the company. For example, the questions to whom quality cost report would be delivered and how often, were considered. The possibility of sending quality cost reports automatically via e-mail was also considered. In addition, the type of quality cost information needed; for example by projects, by SW products, by customers, by quality cost types (prevention costs, appraisal costs, internal and external failure costs), by defect types etc, was discussed. The possibility of giving each person the kind of report he/she desires was taken into discussion but the choice was abandoned for comparison purposes. After negotiations (3.4.2002) the product, the customer, and the project, were chosen to be the cost objects. If needed, every manager could print an other type of report from the system by using query program (Chrystal Reports-software). The projects could go through the quality costs in their project meetings. All departments except sales, administration, HW-department and CEO entered their costs (working hours) in the system. For the management group, quality costs was intended to be reported at a rougher level (appraisal costs, internal failure costs, external failure costs). In the system it is possible for the project managers to see real time quality cost data (a daily basis) by SW-versions (e.g. BP_A1.3.0 in Table 8), by software updates (e.g. BP_A1.4.0), by calender time, by types of quality costs, and by defect types.
Table 8. Customer/software matrix.

<table>
<thead>
<tr>
<th>Software</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP_A1.3.0</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP_A1.3.1</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>BP_A1.3.2</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>BP_B2.1.0</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP_B1.3.0</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BP_C1.1.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Number 1 in the Fig. 32 indicates a new product, number 2 indicates the improvements, number 3 indicates the hotfixes, and number 4 indicates the company’s internal development version. The figure portrays an example software made for customer A, and the version of the software 1.2.3.4.

![Fig. 32. A new product, improvements, hotfixes, and internal development version.](image)

Failure costs in the quality cost report are the reported working hours (salary + indirect employee costs). Appraisal costs, *the reported working hours of inspection and testing*, can also be taken equally from ClearQuest -software. The cost of an employee’s working hour consists of salary plus indirect employee costs (37%) consisting of costs fixed by law as pension contribution based on the Employees’ Pensions Act, unemployment insurance contribution, holiday pay (holiday period’s salary and holiday remuneration), etc.

Considering failure costs, the decision was made for confidentiality reasons that the real salaries + indirect employee costs were not used in this system. According to the financial manager, it is not a good practice for employees to see each other’s real salaries. Because of this, employees were classified to four categories. These categories are 1 Trainee, 2 Junior Designer, 3 Senior Designer,
Manager, and 0 Unclassified. For each of the categories the hourly earnings were calculated. The system was also tested with real salary costs. The difference between estimated and the real salary cost was ±2% compared to bookkeeping in April 2002 (salary costs calculated by using categories minus salary costs calculated by actual salaries).

In this project, quality costs caused by software are included in the developed system. Quality costs caused by hardware development are not included in. It would be technically possible in case the company wished to invest money in developing the system further in the future. Normally, if the aim were the maximum coverage of all quality costs of the company, the costs of the testing devices and the code inspection software would also be included (as appraisal costs) but not in this case because this system was only designed to measure quality costs of software development. This is because the costs of testing devices and investing in code inspection software can also be seen as a normal investment to software process, as sunk costs. It was also decided to exclude prevention costs because it is difficult to distinguish the normal development and the development work made for quality purposes, see e.g. Moen (1998), Porter and Rayner (1992), and Sörqvist (1998). Sörqvist (1998) argues that there is therefore little point in measuring prevention costs. In this system the following quality cost elements are measured. Appraisal costs: reviews considering system, requirements, design, test plan, test scripts, testing first time (test build 1). Internal failure costs: re-reviews, re-tests (test build 2-), fixing code defects, fixing documentation defects, reworking any documentation. External failure costs are not collected because they cannot be collected automatically by any system. Examples of these are warranty expenses, contractual penalties, and products returned due to defect.

Measuring and reporting the cost of quality is traditionally based on ex post-calculations. The idea of real time software quality cost system (RQC) was invented by the researcher and the model was developed and tested in the project group in Case Company A. A real time cost accounting is a new innovation and this kind of a COQ model has not been reported before in the accounting literature. The model makes it possible to measure selected quality cost elements in real time. The selected quality cost elements were designed for full coverage of the problems that occur in software development. As described above, we found that it is not possible to measure automatically all quality costs of a company. But that was not the purpose of this study. The purpose was to study how to measure quality costs on a real time basis in the software industry and to find out how to use quality cost measurement as a management accounting.
tool. This case the study was divided into several phases. The first phase was the definition of the company’s quality costs and the construction of the COQ measurement system in the company. The aim was to develop and test a real time cost of quality system in the case company. We found that it was possible to construct a real time system by integrating the software debugging database, software inspection database, working hours database, and software testing databases.

By using RQC-model it is possible to see real time Cost of Quality information by software product versions, software product updated versions, by calendar time (detected defects, defects assignet to defect debugging, fixed defects), by customer, by quality cost categories: (appraisal cost, internal failure cost, external failure cost), and by defect type (e.g. parameter defect, coding defect, unknown defect, Bios defect, hardware defect, design defect). It is also possible for the managers to monitor the defect fixing procedure of every defect by using the “change control board” procedure in the RQC-model. The defect status can be requested, submitted, assigned, opened, resolved, closed, or postponed, as described in Fig. 33. The managers can follow the defect fixing status of their projects and thus make better estimates of the accomplishment of their projects. In case of approaching a busy project deadline, the managers can move labour force from their other projects to an urgent project. They can also see information like defect correction hours of the project / total working hours.
5.3.1 Examining the scope of the solution’s applicability

There are several advantages of using the constructed model. First, the model makes the software development process more disciplined. It helps the company to get rid of the firefighting (cf. Ittner 1992: 65) culture (timetables are not kept, a large amount of working time is used to correct the failures, etc.) because the software testing and defect fixing procedure is now controlled and no single defect is forgotten. The model also generates measurement data to its database. Besides the real time use, the data can be used retrospectively in comparing the relative success of projects. The model will also help to monitor the software development process even when the project is half-finished. Quality costs can be presented by defect type in the software development projects. This helps to monitor timetables and costs in the projects. In Case Company A, the model was implemented after some additional aspects to make it user-friendlier, such as an option to use it via Intranet from the other city, e.g. entering the working hours done in another city.
Sörqvist (1998) has listed the problems considering quality cost collection and measurement in his study (described in chapter 3.4.1). The RQC-model gives some advice on how to deal with some of these problems, especially to problems 2 (The object of measurements), 4 (Responsibility), 5 (Measuring methods), and 7 (Personnel). Regarding problem 2, object of measurement, Sörqvist (1998) argues that some companies give the impression that their main goal is to receive regular reports and not to use the information as a basis for making improvements. In Case Company A, the model constructed lists not only the (quality) costs, but also serves as an information basis for making improvements by listing the root causes of the problems (e.g. verbal descriptions of each failure, the person, and the date and time the failure was noticed). Regarding to the problem 4, responsibility, Sörqvist (1998) raises the question of whose account the various (quality) costs should be charged against. The constructed model can help to answer to this question because it charges the costs e.g. by products, projects or software versions. Regarding problem 5, measuring methods, he argues that most companies have chosen to measure quality costs by designing measuring systems the employees should use to report problems and deficiencies. By using the model constructed, it is not possible to report problems and to make any corrections by not using the constructed model. Problem 7, personnel, means that the employees in some companies feel that reporting quality costs involves an additional workload, and they cannot see the benefits. The model developed means no additional workload for the employees. The construct presented in this chapter also contributes to Dale and Plunkett (1991) by presenting guidance on quality cost collection especially from the viewpoints of ease of collection, level of detail, and accuracy of data.

As Humphrey (1996) argues, the magnitude of this fixing process is often a surprise. As a result, the entire project becomes so preoccupied with defect repair that more important user concerns are ignored. When a project is struggling to fix defects in a system test, it is usually in schedule trouble as well. The idea of RQC measurement is based on the fact that employee-based costs can be allocated to projects of other cost objects (e.g. customers) by using a real time working time follow-up\textsuperscript{42}, which is used in many companies.

\textsuperscript{42} The employees usually enter their working hours in the system before they shut down their computers at the end of the working day. In this case, real time measurement means the exactness of one day. (Technically, it would be possible to follow the working time usage at hourly based, if such orders would be given by the company management.)
Second, the interest in the construct was expressed to the researcher by academics at conferences and workshops. The managing director of the company A was also talking about patenting the construct, and the company’s willingness to cover the costs, but this did not happen. One main reason for this was that the test manager of the company, who was doing the programming work in the midst of the construct, moved to another company. While the researcher was no longer actively working at the company, the introduction of the construct as an active, continuous everyday tool in Company A did not happen. The final finishing of the construct would have also required more financial investments to software and it was no longer the main interest of the company management. The managers were satisfied with the new defects detection, clarification, testing and fixing process developed based on the construction based on Rational ClearQuest software, as there was no need to see the quality costs real time besides of the testing effort that showed that the construction will work in practice. The information on the amount of “quality cost” working hours was enough, not the linkage to the wages database to get the monetary information of quality costs (wages × working hours × coefficient of indirect salary expenses), or the particulars of each worker’s salary information. However, it can be seen that the construct passes the weak market test because a great part of it is in everyday use and the whole construction is used ad hoc if needed by multiplying manually the wages by the hours worked (because of the missing software linkage). This was done by Microsoft Excel -software (see Appendix 2, archival material).

Labro and Tuomela (2003: 430–431) argue that more nuances are needed within the weak market test category to analyse the level of progress of the construct. As a construct moves toward the upper-right-hand corner of the matrix, the weak market test gets stronger. Fig. 34 shows the RQC-construct developed in Case Company A displayed in the matrix developed by Labro and Tuomela (2003).
Fig. 34. RQC construction described at different dimensions of the weak market test framework. (Adapted from Labro & Tuomela 2003.)

Even before the market test is passed, it is possible to define different degrees of non-implementation (bottom-left hand corner of Fig. 34). Passing the weak market test would mean, at a minimum, that at least one manager occasionally uses the construct for his or her own practices. In the upper-right-hand corner the extent and intensity of usage is at its maximum for a weak market test, i.e. the construct is the only system regularly used throughout the organization. A grey area is entered when a construct is used only once. In some cases this could be regarded as not passing the weak market test (the results obtained with the construct are compared with existing knowledge and it is found to provide little or no new information). But if the construct initiates notable action, even if only once used (e.g. decision to divest because of the new reality created by the construct), it
meets the weak market test criterion. In this case, the whole construct has been used ad hoc in the software development of the company A and the whole construction except the daily Euro-convertibility is in more regular use.

At the follow-up meeting of the project with the controller of the company (see Appendix 2), the use of the *whole construct* was discussed. At that time, the whole personnel of the company has been furloughed for three months because of the claims of the board directors of the company to reduce fixed costs by 500,000 euros. For this reason no development projects, including RQC have made progress (Memorandum, meeting with the controller). For this reason, RQC was used only ad hoc. The results are similar to the findings of Sower et al. (2002 and 2007) who suggest that organizations planning to implement a COQ system should ensure that management supports the program.
6 Case B. Testing the possibility for constructing real time cost of quality measurement in another company

6.1 Case selection and the objectives in Case B

In Chapter 5, it was argued by Labro and Tuomela (2003: 438) that at the core of the CRA is the pursuit of novel innovations. Transferring an existing technique from one field of science to another can be considered novel if it requires adding completely new knowledge and features to the model. Applying an existing construct as such to another organization may be good consulting work or part of an innovation action research (Kaplan 1998) but it should not be considered as to be constructive research. As such, the Case study B does not try to apply an existing construct developed in A to Case B but to chart the potential and boundary conditions to construct such a system in a totally different environment. The results indicate that such a system could be constructed irrespective of the cost accounting environment or the software used. Case B could be called innovation action research (Kaplan 1998) but not in its pure form where a construction is moved to another organization. However, innovation action research is something that can only be done after constructive research (as in Case B), or some other process, has produced new constructs (Lukka 2000). The purpose of this second case is also to strengthen the general understanding of software quality and issues related to realization of quality based risks in an embedded software company. The case study also examines measuring related to the quality of diverse systems from the point of view of case B and its customers and to find new business opportunities for B.

Labro and Tuomela (2003: 416) point out that previous articles do not indicate how researchers can find companies with interesting problems. A potential problem is, at least on the basis of the examples that Kaplan provides (related to studies on the refinement of activity-based costing and balanced scorecard), that an immense research programme with access to a variety of leading-edge companies is needed – a challenge that most researchers are not able to meet (Labro and Tuomela 2003: 437). It is not easy for a researcher to enter to any company he/she wants.

After I had finished working at Case Company A an opportunity occurred for the researcher to attend a TEKES funded project. The manager of Case B asked
me if I would be interested in participating in that project. I found the opportunity interesting for several reasons. First, because Company B was also a company that was involved in embedded software as was Case Company A. As such, that was the most important point of the case selection. Second, the interest of the company management in quality costing issues was another important issue. Third, the possibilities for longitudinal co-operation with the case organization (see Labro and Tuomela 2003: 418) and gaining and maintaining the commitment of the case company was attained through the TEKES project. The third point is also crucial in order for the research process to be successful (cf. e.g. Lukka 2000). The cases may be chosen to replicate previous cases or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types. While the cases may be chosen randomly, random selection is neither necessary, nor even preferable (Eisenhardt 1989: 537).

There have been various objectives and working methods of this case study as a subproject of the TEKES project. At first the researcher had to constitute a general view of the business and to study the potential development potential of the business. One working method was to study the present state of the company’s project management tool, called Own Tool (OWT), and report the development targets of the tool based on the persons interviewed. The possibilities for constructing a process for measuring the real time cost of quality data, and the possibilities for the exploitation of such data to reduce a risk of multiple failure costs in the future projects were depicted. The means to identify the causes of quality cost were also charted and the ways quality cost risks could be reduced, were sought.

6.2 Case B and its mother company

As Case B, a business unit of a subsidiary company of a big international company (the turnover of the company worldwide was 11.8 billion USD) was involved as a part of a TEKES funded project called “Testausalihankinnan tehostaminen”, the development of the rationalization of software testing subcontracting, it was possible to constitute a relationship long-term enough to study issues in another embedded software company (in addition to Case A). In addition to the development aspects, Case B offered a chance for the researcher to get feedback from the employees and managers of the idea of real time cost of quality accounting construction developed in Case A, and to study the
implement the possibilities of such a system in a completely different working environment.

The mother company of Case B specializes in permanent, temporary and contract recruitment, employee assessment, training, career transition, organizational consulting, and professional financial services. The mother company’s worldwide network of 4300 offices in 67 countries and territories enables the company to meet the needs of its 400,000 customers (per year), including small and medium size enterprises in all industry sectors, as well as the world’s largest multinational corporations. In Finland the company started up in 1997 and in 2005 it had 10 offices in Finland. In Finland the company provides services in the following areas: organizational consulting, recruitment, personnel renting, and providing business support services. Case B, which is an independent business unit of its mother company, provides quality assurance services like qualification Bluetooth devices, certification of OMA (open mobile alliance) features (MMS, DM, POC, etc), Java certification and verification for platforms, product lines, and products. It also provides test specialist services like MMS Test Specialists for managing and coordinating operations, Bluetooth Test Specialists, and Flash coordination services to its customers.

6.3 Description of the data

To clarify the objectives mentioned above in Chapter 6.1, semi-structured interviews (thematic interviews) were used. The people interviewed were the employees of Case Company B and its mother company and also a representative of the company’s main customer (see Appendix 3). The people interviewed were selected together with the company management to get a cross-section of the company’s main functions, managers and other personnel. All the interviews (total of 11), were tape recorded and transcribed. The original interviews lasted from half an hour to 1.5 hours. The transcribed data consisted over 100 pages of text files. Each text file consists of one transcribed interview. Tape recording the interviews eliminates the risk of misinterpretation of what has been said. The data can also be verified afterwards. One benefit of tape recording interviews is that the interviewees will take the interviews more seriously and they may think twice about what they are saying. Depending on the employee’s post, the themes mentioned below were discussed.

The Company B employees interviewed were the business unit manager Kai N., the testing engineer Jari T., group leader Lasse M., device responsible Ville T.,
group leader Sami S., sales manager Tarja P. and testing engineer Pasi V. The other interviewees were the Oulu site manager of Company B’s mother company Petteri J., sales manager of company B’s mother company Sauli O. from the Helsinki office who is responsible for the southern Finland sales area, the key account manager of company B’s mother company Riku M. from the Espoo office, and subcontracting manager Heikki S. who gave the views of Company B’s biggest customer. The interviews were carried out from June 2005 to September 2005. There were also several informal discussions with B’s business unit manager Kai N. These were not tape-recorded.

For the basis of the interviews, material on the project was sent to the interviewees beforehand, including the themes and questions which were to be discussed during the interviews. One interviewee answered the questions both via e-mail and in person in the interview, even though no written response was requested. Besides the interviews, the other working methods in this project were to get acquainted with the company by reading the documents received, to get acquainted to the technologies, processes, and working methods in the company, discussing with the employees, and transcribing the tapes recorded. The managerial result of the project for the company management was described in a project report (69 pages). The report was given to the manager of the company on October 31st 2005. This report consisted of the following parts: Introduction, the goals of the project, the themes of the interviews, a summary of every person’s interview, a summary of all the interviews collected by thematic areas, and also the researcher’s view and the recommendations of the development targets at the company.

All the tapes of the interviews were transcribed into colloquial raw data (Microsoft Word files), each interview saved in its own file. Some of the transcribing work was done by the researcher, and partly by the summer trainee of the Department and Accounting and Finance. However, all the transcribing work done by the trainee was checked by the researcher by listening to all the tapes and making the corrections needed because of misunderstanding some abbreviations or the technical jargon used by the interviewees. After that, the files were put together in one text file, and the colloquial expressions converted into standard Finnish language. Next, the text was classified by subject area. Some phrases were changed by the researcher because of the “unprintable” text, e.g. swearwords and accusations directed towards certain persons.

The interviews were in the form of face-to-face interviews in order to achieve a nice discussion atmosphere. Most of them were conducted on the premises of
Case Company B, in the company’s negotiation room to avoid any interruptions – McKinnon (1988: 44) talks about creating the conditions under which they will be allowed to the social relationships of the setting. The interview sessions often started with smalltalk on some daily issues totally outside the research topic, after that the researcher first explained something of himself and the research interests, and after that the nature and objectives of the research in question. This was done to create a relaxed atmosphere and arouse the interest of the interviewee. As McKinnon (1988: 44) points out: prior to having any real information, people in the setting will approach the researcher’s arrival with feelings ranging from genuine interest to annoyance, disinterest, and fear of exposure, or they may see the researcher as a means of promoting their own political agendas. Hence the researcher’s first concern on the research site should not be data collection; rather it should be preparing the ground for data collection. This point was taken into account by “walking around” in the company’s premises (also in the restricted R&D facilities with unpublished products), talking with almost all the employees and sitting in the coffee room with them to speak anything else but the research subject. The researcher also had his own desk on the company’s premises. I argue that these points were good in preparing the ground for data collection in the interviews; many interviewees were already acquainted with the researcher before the interviews. As Labro and Tuomela (2003: 424) point out, the interviewees are more likely to put more effort into the answers. As suggested by Atkinson and Shaffir (1998: 55), I also noticed that close interaction with company personnel improved our ability to understand their behaviour. When becoming deeply involved in an organization and in the trials and errors of company development practices the researcher him/herself participates in the experiential learning cycle (Kolb 1984) which should allow a more profound understanding of the case events.

6.3.1 Themes of the interviews

Semi-structured interviews means that the interviews were based on discussions between the researcher and the interviewee; the interviewer had a list of thematic areas which were gone through, but this list was not rigidly adhered to; rather the discussion was allowed to digress if needed. The purpose of the interviews for the researcher was to get a comprehensive view of the business which could be used in later phases of the case research. Quality issues especially were taken under closer review. The themes which were addressed in the interviews are presented
below. The questions on the current business concept of the company and the development opportunities of the concept (1. below) were asked to pursue a deep understanding of the issues researched (cf. Lukka 1999, 2000).

1. Questions about the current business concept of the company and the development opportunities of the concept. The strengths, weaknesses, opportunities and threats.

   - In your opinion, what are the strengths and weaknesses of the current business concept of software testing subcontracting?
   - What kind of opportunities and threats may occur in the future?
   - Analyse the present state and the development prospects of the following things:

     | The present state of the productized testing |
     | If you want, you can estimate the business areas separately |
     | (Communications group, Messaging Group) |
     | Pricing principles of producterized testing |
     | Delivery deadlines and how to keep it |
     | The adequacy and sufficiently of employee resources |
     | Testing facilities |
     | - Usability of testing facilities |
     | - Is the newest technology used or should it be used. Are there any problems? |
     | Is the testing process done using testing standards |
     | Customer/Supplier relationship |
     | Testing costs |
     | Possibilities to increase turnover of B company |
     | Other things to which the company should pay attention |

2. Questions on the new project management tool called Own Tool (OWT), recently developed inside the company. The present state of OWT and its further development needs.

   - Comment on the Own Tool, how do you see its usefulness supporting your work. What are the strengths and weaknesses of the tool? Is the documentation in order?

3. Questions about quality and quality risk minimization.
– What do you think the quality costs of B consist of? What causes quality costs?
– What kind of risks are there in quality of testing? Can testing find all the defects that the customer assumes it can find? How to prevent the defective product not going all the way to customer?

6.3.2 History and business concept of Case B.

B’s mother company’s sales manager Sauli O. from the Helsinki office, who is responsible for the southern Finland sales area describes the birth process of company B.

“The testing business had started from about five years ago. At first, one employee was at the main customer’s (used instead of the customer name) premises as a rented employee for a certain period of time, then two employees”. (Interview 15.8.2005.)

He adds:

“Then our main customer rented the whole team from us and then we had two testing teams doing the job. After that, they (main customer) needed team leaders, actually the activities had grown, and they chose two of our employees as team leaders. It meant that our organization was increased at the premises of our main customer. The strategy of the main customer has radically changed in that they are moving from employee renting to testing subcontracting. It means that B has to offer them ready-made solutions with B’s workforce or by subcontracting. Earlier, we had one case that we lost because we were not ready to make investments. We had about 20 to 40 employees working at the main customer (as rented employees) but we were not ready to work as a (testing) subcontractor at that time. The change of the business concept relates to B’s mother company’s European-level strategy change”. (Interview 15.8.2005.)

Company B started from personnel renting business. In 2004 the company hired a test manager and their own facilities were provided. Personnel subcontracting is a growing business area in B. A sales manager was also hired to seek new customers for B.
“Our line of business is going towards this (subcontracting). When we talk about personnel renting, our European-level strategy is actually our global strategy, but especially in Europe we are trying hard to develop our clientele in subcontracting. In Finland, our big customers (B’s mother company’s) are in that step that we can do it” says Sauli O. (Interview 15.8.2005.)

According to the sales director, there are strong expectations to raise the turnover of the company.

“We need to grow. This is still a start-up enterprise. [...] We know that the market is growing very fast in the testing business. We also need other customers (than our main customer) because we have to diversify this risk. We have been dependent on the one customer, on the customer’s one department. We also need other purchase orders to make our production more efficient [...] so that if our main customer has not orders to do so this guy (our employee) can do work for some other customer’s order”. (Interview 15.8.2005.)

6.3.3 Summary of the themes and main development objectives suggested by interviewees

In this chapter the thematic areas of the interviews are briefly discussed. Thus, the reader can get an overall picture of the situation in the company at the time when the interviews were conducted. All the views are based on opinions that came up in the interviews. At first, the questions of the strengths, weaknesses, opportunities and threats of the business concept were gone through (see the list of thematic areas in Chapter 6.3.1.). The main points of the preceding issues are briefly presented here so the reader can get a picture of the actual current topics at the company.

1. Questions about the current business concept of the company and the development opportunities of the concept. The strengths, weaknesses, opportunities and threats.

Quality of testing process was seen as strength. Quality has to be still ensured by developing processes further, e.g. by SW inspections. A fixed price testing subcontracting was seen as a strength because customers only pay for the work done. Testing the first few sets based on an hourly based charge was seen as strength to lower the risk. However, the amount of fixed price testing was desired
to be raised in the future. In new contracts, especially at the beginning of a new contract, resource renting was seen to be better than fixed price testing.

"Yes, in most of such of cases (considering a new customer) when we are going towards the subcontracting it means that in the beginning we make the 'training period' as a resource renting. And in that case it is just reasonable to do so". (Interview 7.10.2005, subcontracting manager Heikki S.)

The dependence of the main customer’s one department and the small number of other customers, as well as reporting, was seen as a weakness in Case B. Reporting problems, however, are going to diminish with the introduction of the company’s project management tool, named “Own Tool” (OWT)”. The tool was developed inside the company. Another weakness was seen to be the demand variability of the main customer. The releases of the customer software which are put in B’s test do not come steadily. This will hinder the planning of employee’s working schedules. In the future, this problem can be alleviated by negotiating a better order procedure at the customer’s site. This problem is illustrated as follows by group leader Sami S. and testing engineer Pasi V.:

"We don’t have access any more to certain things and e.g. to (customer’s) databases from which we could see if new (main customer’s) software has come up or not (to be put into test in B).[..]”. (Sami S. Interview 14.6.2005.)

“When working orders reach us from there (main customer) they may be cancelled and then comes another working order that should already have been done yesterday...[..]. There is a terrible rush but still the software is not working[...].apparently, there are managers and the people doing software, collaboration between them is not working”. (Pasi V. Interview 20.9.2005.)

The other biggest threats were seen to be that 80% of B’s turnover is still based on hourly based invoicing; problems at the moment are the narrow customer base and the current small facility space. The pricing of the fixed fee based testing was seen both as a threat and an opportunity. The pricing principles should be clarified so to take into account the urgency of the commission, the amount of workload, the devices needed in testing, and the amount of work in reporting and managerial activities. One big threat was seen to be dependence on key persons and keeping them on the payroll.

The main opportunities for the business were seen to be the possibility to develop the business towards subcontracting, e.g. invoicing based on a test case
or test set. Using flexible rented employees was also seen as an opportunity because those employees can be got via B’s mother company. Increasing the turnover was deemed possible; the growth could be acquired inside the main customer and also from other companies. If the growth is going to come from the main customer it means that B must find the right people inside the main customer who can market B’s services inside the main company using internal marketing inside a big customer company. A big threat was seen to be the possibility of the main customer outsources testing operations going elsewhere, but the same thing was also seen as an opportunity (to outsource more testing to B).

2. Questions on the new project management tool called Own Tool (OWT), recently developed inside the company. The present state of OWT and its further development needs.

Before describing the employee’s opinions on the OWT system the application is first described in this chapter. The Own Tool application serves as a resource management tool in the company. It is used for project management purposes and as an equipment of work time controlling. OWT is used for example for creating new projects, editing projects, carrying out cases and marking up work times. The application is controlled via a browser and every user updates the same database over the network. Subsequently, all the concepts belonging to the first version of system will be described. All the definitions for concepts, operations or other data including all the demands are also listed. All the possible development targets are also included, thus the system environment stays in control despite of changes.

The OWT application is created in the company to manage resources and follow up the projects. Using it new projects can be started and employees resourced to them. It is also possible to manage all kinds of reporting through the system, because all the necessary information about working hours, project statuses and other evaluated data will be saved in the application’s database.

OWT system sorts users into different privilege groups. Operator status is given in the PrivilegeID-column in the user table for each user. All the Operators are the users of the system. The system user can be an Administrator (admin), Leader, User, Report or Device. A user with “Admin” status means that (s)he can modify the whole system, make changes to functions and manage the system totally, e.g. delete the stored data. However, that privilege is used only for maintenance needs. The Leader has normal rights to use all operations integrated to the system. A Leader can set new orders to the database and select the
resources for projects on the basis of orders. User has rights for normal operational use – marking case results, using working hour management and to-do-tasks, but no rights for reports nor for project or order management. A Report status is set for an opportunity to retrieve different reports from the system. The Device status is used in a centralized workstation for device use signing only. Every order is placed by a customer, whose contact info needs to be saved in the database. All the information generated during projects will be saved in this system.

The application is used on a network so that all users update the same database. It makes real time situations on the project possible, meaning that cases already accomplished will be shown as such for every user. A project with several cases can also be completed by several users. The end users of the system are all the employees of Company B who have advanced experience in computing.

Table 9 shows all the concepts used in the system with their descriptions.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>One part of the project which forms one whole specific task</td>
</tr>
<tr>
<td>Case list</td>
<td>Details of one case, what is supposed to be done on the case</td>
</tr>
<tr>
<td>Customer</td>
<td>Person/Organization who places customer order</td>
</tr>
<tr>
<td>Device</td>
<td>Equipment/component etc. used in cases or in other tasks</td>
</tr>
<tr>
<td>Off-time</td>
<td>Work time that is used for other than working</td>
</tr>
<tr>
<td>Order</td>
<td>An order for a new project to be done, placed by customer</td>
</tr>
<tr>
<td>Project</td>
<td>An assignment created on the basis of an order. May include some files which are created during completion or within the creation of the project. Can also be another project created by the user and not based on any order.</td>
</tr>
<tr>
<td>Resource</td>
<td>Users who have been assigned as employees of certain project(s)</td>
</tr>
<tr>
<td>Session case list</td>
<td>Shows the status, project and composer (User) of the case</td>
</tr>
<tr>
<td>Status</td>
<td>States where the case or project is going at the time.</td>
</tr>
<tr>
<td>Todo time</td>
<td>Time spent by one user to complete the cases of the project</td>
</tr>
<tr>
<td>User</td>
<td>User of OWT. Also an employee of B company (refers to employee)</td>
</tr>
<tr>
<td>Work area</td>
<td>Describes what tasks s/he will do for the project at present</td>
</tr>
<tr>
<td>Work hour</td>
<td>The time that the employee is on duty. May differ each working day</td>
</tr>
</tbody>
</table>

The OWT-application consists of PHP-forms (PHP form is the advanced web form builder that makes it possible to create web forms fast and with minimum effort). Web forms are easily integrated into websites, databases and different parts of hardware needed like workstations and servers. All the data is set to on the server on network and is directed via Apache web server which supports PHP.
All operations are divided by operation features into PHP-forms so that every form includes the operations of specific feature. Forms divide applications into the following sections: Log in, Main page, Create new order, Create new project, Manage resources, Work calendar, Device register, View/Search orders, View/Search projects, Reports, My todo, Calendar, Change password and Log out. Every section includes functions which could be related to the operation area e.g. “Create new project”-form includes functions to set the details of a new project and for adding cases to project. On the Main page work time counting and break-handling are operated. User interface is created on a CSS (Cascading Style Sheet) file which sets all the settings for layout. Layout is made to imitate all other layouts of company B. Interface is created to look a like the web interface so that all commands are driven on links and there are no special menus for operations.

The OWT system consists of a server, a web server, a network and workstations connected to the network. All the system data is stored in the server which includes the web server, database and PHP-forms on the own OWT-section. The workstations can be used via a browser for entrance to the system. Mozilla Firefox browser is installed in the workstations (as a default browser), but other browsers can also be used. The workstations have no special needs for system usage. The operating systems vary from Windows 2000 to Windows XP. The Web server needs to support PHP. For device register use, there are a few barcode readers attached to the system. A special label printer is used for labelling devices with the needed barcodes. Table 10 below describes the operators of the OWT-system.

<table>
<thead>
<tr>
<th>Role</th>
<th>Rights on the system usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admin</td>
<td>Rights to edit the system according to the rights of a leader (for maintenance)</td>
</tr>
<tr>
<td>Leader</td>
<td>Rights to edit projects and list new orders in the system according to the rights of a user</td>
</tr>
<tr>
<td>User</td>
<td>Rights to edit status of cases, make new other projects</td>
</tr>
<tr>
<td>Report</td>
<td>Rights to browse reports and copy them</td>
</tr>
<tr>
<td>Device</td>
<td>Used only in device register for device signing</td>
</tr>
</tbody>
</table>

The OWT system operates using the user’s commands. The first operation in every use case is logging into the system. After logging into the system it can be used for project maintenance, order placing, working hours-counting, resourcing or to reporting purposes. These operations are divided by the above mentioned
privileges so that not all operations are available to every user. Operations for privilege status Report are report viewing and report saving. Operations for privilege status User are Work time counting, My todo -controlling, Case status setting, Break setting, Calendar usage, Work calendar usage, and Password changing. The Operations for privilege status Leader are Project maintenance, Order maintenance, Resourcing, Device register management, Work time counting, My todo -controlling, Case status setting, Break setting, Calendar usage, Work calendar usage, and Password changing. Operations for privilege status Admin are System maintenance and all of the operations for maintenance reasons. Operations for privilege status Device are the Device register management.

The impact of the Tool was analysed to assess what kind of implications it has in the company. The interviewees were asked to comment the present state of OWT development, the good and weak points of it, and its further development needs.

“Even though I find it (OWT) very positive, there is still one weak point. It is that it is still not in the same domain as the (main) customer’s databases. But it will be changed into the same domain just in the coming weeks and then we can get all the projects to the same domain and we can create all the projects there, we can make the distribution of work through it, and also to get various weekly reports, monthly reports and also the invoicing in a much more handy way. It will help a lot. The reports are going to be improved all the time. It is a very good thing. [...] and we can plan beforehand what work comes to us and what kind of a resource load we have. And that is the thing that I have already wanted for a one year”. (Interview 14.6.2005, team leader Sami S.)

Another team leader also saw the tool in a positive way:

“In my opinion in the longer run it (OWT) is fundamental to our business because we cannot keep this kind of working hours bookkeeping and other things with Excel-sheets if we are going to make this (testing subcontracting business) a real business. Our main thing here is to test products by using our IT skills, not to wrest (make) the reports, hourly reports. And then, we should get the reports done because I’m the man who mainly makes these Excel-sheets every week and I welcome this kind of automatized option”. (Interview 13.6.2005, team leader Lasse M.)
The Key Account manager adds

“...of course the problem is that we make huge amount of test cases all the time. Everybody is doing something all the time, so how to stay on the map, is the work cost effective or not? For that purpose it (OWT) is just an excellent tool, plus it leaves marks who has done something and what has been done. Yes, it is an excellent tool”. (Interview 13.6.2005, key account manager Riku M.)

Only a few interviewees saw the using of OWT neutral, and nobody saw it in a negative light.

“Difficult to say because it has not been fully launched yet. I can’t say with certainly very exactly yet”. (Interview 13.6.2005, test engineer Jari T.)

3. Questions of quality and quality risk minimization. The interviewees were asked about the quality of the testing process, how to prevent defective products reaching the customers. The interviewees’ opinions of the consistency of quality costs and the things which could cause quality costs were also asked in the interviews. Subsequently, the questions on testing process quality were gone through, and after that came the questions about quality costing.

The quality of testing was seen to be good without any bigger risks because ultimately B’s customer(s) takes the business risk of the possibly defective software in its products to go into the market. It is enough for B to find and report the errors. Quality risk has been taken into account in the contracts; the maximum payment of damages is specified and insurances have been taken. Not all the test plans are done at B, the responsibility of B is restricted to the success of the testing process to locate the defects.

In the future, the interviewees believed B could take bigger business risks.

“It depends very much on the customer, how much it trusts us and surely, first of all, how much responsibility it gives to us”. (Interview 13.6.2005, key account manager Riku M.)

“Well, we have a real threat, it means that the customer always takes a risk what to test, when to test and if some error is found, how well we do the re-tests. Everyone of us is doing our job as well as possible but not all the errors are ever found. It is because the test specifications do not define exactly
enough what to test and we can have a situation that we make certification
tests, e.g. bluetooth for various profiles. It means that we do tests for hands-
free profile, by-transfer profile etc.; it means that we have to make them (the
tests) for various softwares and as the software changes, it means that the
customer is responsible for the software which is put in (certain) device to be
sold. If there is some boob in the integration it means that non-marketable
software can reach the market.”

Considering the responsibilities for the faultlessness of the software tested, it was
seen that the customer carried the final responsibility.

“Yes. The customer always takes the risk even if we find an error at the last
moment before the product goes to market; the customer can make the
decision that this is such a business risk that we take it. It means that there
can be a lot of bugs in the product but it will be put on the market and a so-
called bug fix will be initiated. After a few months, or in case a critical fix,
after a few weeks updating software can reach the operators and customers.
But honestly, this is actually our main customer’s decision that we test what
has been asked and often we also tell such errors that we notice even it would
not include the test. We give extra information to the customer that we have
found this kind of a problem.” (Interview 14.6.2005, team leader Sami S.)

In the interviews, the need to construct and measure various key ratios
considering to the quality of testing came out. B’s mother company’s sales
manager adds:

“..we have to have our own indicator, we are changing our operations
towards ISO standards. It is Kaituu’s task to construct the indicators and
actually they have to be created together with the customer[..]. Probably, we
have to tailor the quality job together with the customer; what to meter, how
to meter and why to meter”. (Interview Sauli O., 15.8.2005.)

The company’s project management tool called Own Tool (OWT) was seen to
have very much potential in improving the various processes in company B. It
allowed the company to gather much more data to be used in project management
and quality measurement. In the next chapter, the possibility of implementing real
time cost of quality accounting in B is discussed.
6.3.4 The possibility of implementing real time cost of quality accounting (RQC) in Case Company B

It would be technically possible to construct a quality cost measurement system via OWT. However, during this project it was not done because of the project targets and timetables. It was also noticed that there was no acute need to measure quality costs at B. OWT includes the follow-up of every employee’s working hours and how this time is broke up to projects. This information can also be used for quality costing purposes. However, it is the company management’s decision whether quality cost measurement project will be launched or not in the future. However, it would be possible to trace e.g. the following quality cost items which are collected via OWT:

- **Inspection** (appraisal cost): Inspection hours and hours used to make inspection reports
- **Retesting** (internal failure cost): Time used to retesting. The error has been noticed before the product (test case) has been given to the customer. All the working time which is used to design, implement and report the retesting.
- **Retesting** (external failure cost): Time used to retesting. The error has been noticed after the product (test case) has been given to the customer and the customer has returned the product because of dissatisfaction. All the working time which is used to design, implement and report the retesting. Also the time used into treatment of customer reclamations; e.g. meetings, negotiations.

The foregoing quality cost items can be traced e.g. by projects by constructing a system into OWT which follows the working time usage e.g. by demanding to enter the working hours used as normal working hours (e.g. testing), as inspection hours, or as retesting working hours. By doing this way a “normal” employee of the company do not need to know much of quality cost accounting but the software calculates the quality cost working hours. Later on, these costs can be multiplied by each persons salary costs if the actual cost information is needed (as done in Case Company A).

In the project at Case Company B, a new quality cost measurement system was not built within the project timetables. It is important that all employees are committed to use OWT. The commitment can be increased by good leadership and by employee training. Shields (1995) argues that when a new management accounting construct is implemented and taken into use, it means that a
management accounting change is taking place. In order to cope with the challenges of change, researchers need to be alert not only to the technical issues but to the behavioural and organizational variables that are likely to play a paramount role when successful implementations are pursued. In addition to addressing and taking advantage of the basic advancing forces of change, i.e. motivators, catalysts and facilitators of change (Innes and Mitchell 1990), the role of leaders and the need for a momentum for change should be acknowledged (Cobb et al. 1995). Moreover, a profound analysis of potential barriers to change, i.e. confusers, frustrators and delayers of change, is useful when implementing a construct (Kasurinen 2002).

A leading principle when constructing a quality cost system based on the OWT is that it is not necessary to try to collect all quality cost items but to concentrate on following up the most important ones. By following up the most important quality cost items it is possible to access the problems which cause the highest quality costs. Thus the company’s main process, testing, can be improved. The above mentioned quality costs (testing, retesting and retesting) can be collected by OWT.

Since constructive research relies on pragmatism of truth, the implementation phase is an elementary part of the research (Lukka 2000). Moreover, the phase of trying out the construct is critical, since even a failed implementation test may turn out to be theoretically interesting (Lukka and Tuomela 1998). It should be borne in mind that the implementation test has a twofold purpose: a successful implementation means both that the research process has been successful, at least with regard to the most critical factors, and that the construct has been technically feasible (Lukka 2000, 2002).

In Case Company B, the old Excel-based model used for project management purposes was substituted for a new Own Tool (OWT) system. Company B’s Own Tool application will serve as a resource management tool in the company. It will be used for project management purposes and as device for work time control. The OWT application was created in the company to manage resources and follow up the projects. Using it new projects can be started and employees allocated to them. It is also possible to manage all kinds of reporting through the system, because all the necessary information about working hours, project statuses and other evaluated data will be saved to application’s database. As such, OWT would be an excellent instrument for quality cost measurement by doing minor improvements. Quality costs collection could be done real time via the Tool using the RQC-idea developed in Case Company A. The working hours can be
changed to monetary units (euros) using the same procedure as in Case Company A (by multiplying working hours by each employee’s salary costs). The modifications to the OWT system could be made by measuring the quality cost elements mentioned above (inspection and retesting). It would be possible to gather quality costs by projects by using OWT, which follows working time used e.g. by the demand to enter the working hours used as normal working hours (e.g. testing), or inspection-, or retesting working hours. As in Case Company A, prevention costs could also be excluded. By doing this an employee of the company do not need to know much about quality cost accounting (theory) but the software calculates quality costs automatically for the project management purposes for the managers (by using OWT privilege “Report”).

The question of including prevention costs (or not), is discussed e.g. by Moen (1998), Porter and Rayner (1992), and Sörqvist (1998). According to Sörqvist (1998), prevention costs are not a cost for poor quality but are rather an investment in good quality. It is, of course, possible to measure these costs parallel to failure costs. However, this would appear unnecessary since decisions have actually been made to incur these investment costs and they are therefore not unknown costs that we wish to study as a means of identifying problems and selecting appropriate improvement measures. It is difficult to determine what a prevention cost really is since costs incurred in the business which are not quality costs result in good quality. It could, in an extreme case, be claimed that the prevention costs comprise the costs of all activities in the business except quality costs. According to this argument, the result is arbitrary and Sörqvist (1998) argues that there is therefore little point in measuring prevention costs.
7  Conclusions

This chapter presents the main findings of the thesis, discusses the potential insights, and provides a basis for assessing the contribution of the study. The contributions, reliability and validity of the research are considered, and limitations of the research as well as avenues for future research are also presented below.

7.1 Contributions

This study elaborate the theory by linking the concepts of real time measurement, quality costing, and software quality issues. We have pursued a strong practical relevance and accounting theory development instead of implementing some general theory taken from social sciences.

Successfully implementing a method for measuring quality costs on a real time basis is not an easy task. Practitioners so far receive no support from the management accounting research community. The purpose of this study was to develop a model for measuring quality costs on a real time basis in software development. This was achieved by seeking answers to the research questions on how to measure quality costs on a real time basis in the software industry, how the characteristics of the software business impact on the accounting of quality costs and how to use quality cost measurement as a top management tool in modern software business environment. The answers to the above questions were sought through the development of a theoretical framework and the analysis of the key concepts of the study. The thesis extended the current literature in three main respects.

First, the study presented the idea of measuring quality costs on a real time basis. The thesis was a first attempt at systematically identifying the possibility for the implementation of real time quality cost measurement. The study provides some evidence that real time quality cost measurement is feasible. Despite advances in quality management and systems, most managers still find it difficult to link quality development projects with expected economic returns (Ittner and Larcker 1996). Ittner (1999) considers the primary reason for this to be the lack of adequate methods for determining the financial consequences of poor quality. The previous literature on real time quality cost accounting was limited or even non-existent. In this thesis, the idea was demonstrated and tested by developing a model for measuring the cost of quality on a real time basis in a Case Company A
(a constructive case study (in Chapter 5) and searching consolidation of the weak market test (in Chapter 6) to study the applicability how to construct such a system in a totally different working environment. The results show that the construction built in Case A could be constructed irrespective of the cost accounting environment or the software used in another embedded software company.

According to Lukka (2000), there are two primary ways of contributing to theory in constructive studies. First, it is possible that the construct itself is of such novelty that it introduces an awareness of a completely new means to achieve certain ends. This is the fundamental purpose of applied science (Mattessich 1995). Second, a constructive case study can serve the purpose of developing, illustrating, refining or testing a theory or theories (Keating 1995). Through the pragmatic implementation test, the underlying positive relationships are also tested. In this way, both successful and failed implementations may turn out to be interesting and lead to the refinement, maybe even the discarding, of theories and proposals of new theories (Lukka 2000, 2002). In Case A of the thesis, the emphasis was mainly on the first type of contribution in Lukka’s (2000) classification.

Dale and Plunkett (1991: 54–55) argue that a most striking feature of quality costing is the preoccupation with the prevention-appraisal-failure categorization, even though arrangements into the categories tends to be a post-collection exercise carried out to accord with convention. The main contribution of this study is to construct and test the real time cost of quality measurement model. I argue that the contribution arises from the fact that the construct is a novelty that leads to a new means of quality cost accounting in software business. These features differentiate the construct from the existing quality costing literature. Before this study, quality costing has so far been modeled only by using ex-post calculation methods. I also argue that real time measurement will produce more up to date quality cost data compared to conventional ex-post calculation methods. The real time model will also improve the accuracy and accountability of COQ measurement. Dale and Plunkett (1991: 36–51) give lot of guidance of quality cost collection, including objectives and scope, approaches, sources of data, ease of collection, level of detail, accuracy of data, and people involved. I argue that this thesis also contributes to the Dale and Plunkett (1991) by presenting guidance of quality cost collection especially from the viewpoints of ease of collection, level of detail, and accuracy of data.
Second, a contribution was made by answering the research question how the characteristics of software business impact on accounting of quality costs by presenting the nature and distinction of software business as well as its implications to software quality and applying quality cost measurement to software business. Malmi et al. (2004) argue that the COQ literature typically deals with manufacturing or service organizations in continuous or repetitive business processes in which identical or similar activities and work phases are repeated in the same sequence or order, after batch or customer after customer. Many modern businesses, however, are outright project based, or operate like a string of semi-independent projects characterized by unique resources, customized activity or work sequence order, and a predefined start and finish. In this study, the COQ literature has been used in such a context in an embedded software business which fulfills the description by Malmi et al. (2004) as outright project based, etc. In this study, the developed COQ framework was applied to an embedded SW segment, which also makes a contribution as such. The results show that COQ measurement can also be applied to organizations which have not traditionally been targets of cost of quality researchers. The finding brought out one essential issue; on the one hand, the characteristics of the software business make real time quality cost accounting easier because of the big proportion of labour costs (of total costs), on the other hand in the software business the amount of time spent on firefighting seemed to be quite big because of the amount of defect fixing work.

Goulden and Rawlins (1995: 36) argue that the process model is advocated as a preferred method for quality costing within total quality management as it presents a more integrated approach to quality than the PAF-model. They argue that within the TQM culture, all business activity is related to processes and therefore the cost model should reflect the total costs of each process rather than an arbitrarily defined cost of quality. But they also argue that the high level of complexity of these (process) models when applied to their case company, presented a barrier to understanding, did not create a sense of ownership and did not allow an integrated view of divisional activities. My study combines the traditional PAF model with the software development process environment.

A Contribution was also made by confirming the argument by Porter and Rayner (1992) who argue that perhaps the greatest waste of resource in any organization is the amount of management time that is spent on “firefighting” – performing a task which only exists because somebody did not do the original job right the first time. Moreover, they also argue that the cost of such waste to the
organization is almost incalculable. I argue that by using the model presented in the thesis quality cost elements are no longer incalculable.

Third, the study answered the question how to use quality cost measurement as a management accounting tool in a modern software business environment.

In their journal article, Malmi et al. (2004) follow the constructive approach suggested by Kasanen et al. (1993), considering the practice-relevant problem of managers having to justify investments in quality improvement (Ittner and Larcker 1996, Ittner 1999, cf. Kasanen et al. 1993). The construct by Malmi et al. – a collaborative approach for managing the project costs of poor quality – developed provides some indication of expected cost savings or expected reductions in resource consumption given that certain poor quality cost elements can be removed or the required proactive actions are successful (Malmi et al. 2004: 314). In this thesis, this point was be elaborated further by providing an indication of the real time cost of quality information classified by software product versions, calendar time, quality cost categories, or by defect type. This classification broadens the applicability of quality cost accounting from the “traditional” ex-post perspective to a proactive perspective of using quality cost accounting as a management accounting tool.

The results indicate that it is possible to measure quality costs on a real time basis by integrating the software debugging database, software inspection database, working hours database, and software testing databases. By completing the construction suggested in this study, real time cost of quality information e.g. by software product versions, by calendar time, by defect type, and by customer can be brought out. It is also possible to monitor the defect fixing status in the software projects by using the change control board procedure developed on this project. By using such information, the study provided managerial implications how to gain a more profound understanding of quality cost structures and quality cost behaviour in the software business. This will help managers to analyze the software projects and to see what has caused the highest quality costs. The experience gained from the projects can also be tapped in future projects.

The real time cost of quality measurement also provides data which can be used in daily project management and also in comparing the success of the projects. By using the RQC model as a management accounting tool the manager can see the real time cost of quality information as (s)he wants; e.g. by software product versions, by calendar time (detected defects, defects assigned to defect debugging, fixed defects), by customer, by quality cost categories: (appraisal cost, internal failure cost, external failure cost), and by defect type (e.g. parameter
defect, coding defect, unknown defect, BIOS defect, hardware defect, design defect). It is also possible for the managers to monitor the defect fixing procedure of every defect by using the “change control board” procedure in the RQC-model. The manager can review the defect statuses of the software products (requested, submitted, assigned, opened, resolved, closed, or postponed). The managers can also follow the defect fixing status of their projects and thus make better estimates of the accomplishment of their projects. In the case of approaching a busy project deadline, the managers can move personnel from their other projects to most urgent project.

There has been quite a lot of research considering quality costing in management accounting and quality journals in the past two decades. This study summarized the conceptual framework for understanding the work being done on the subject. There has also been some research on the cost of software quality. In this study I have studied the measurement of quality costs as a management accounting tool in the software business environment. This thesis combined the elements conceptualized in previous studies and presented the reader with the framework of quality in software business, the new concepts of cost of quality measurement and how this information can be used by improving the software processes.

The thesis explained how quality costs can be measured in a company, especially in a company producing embedded software. In order to achieve this purpose, factors of importance were examined and discussed. Before starting to measure quality costs in a software business environment it is important to understand the characteristics of the software business and software quality, especially the various quality standards and the the way in which the software process differs from a normal manufacturing company’s production processes. These topics were clarified in Chapter 2 of the thesis.

While most COQ measurement methods are activity/process oriented, traditional cost accounting establishes cost accounts by the categories of expenses, instead of activities. Thus, many COQ elements should be estimated or collected by other methods. These methods were demonstrated in Chapter 3 of the thesis. This chapter presented the cost of quality measurement in various cost accounting environments; in traditional cost accounting and in an activity based accounting environment. Methods of measuring cost of quality in an integrated cost of quality and activity-based costing framework were presented. The cost and nonfinancial information gained from the integrated COQ-ABC system can be used to identify the magnitude of quality improvement opportunities, to identify
where the quality improvement opportunities exist, to control quality costs, and to meet management’s various information needs regarding quality improvement programs.

Chapter 4 of the thesis showed the potential benefits of using the cost of software quality concept and gave the reader some facts about the results obtained in case companies using the concept. The results from the case companies show the managers and researchers the usefulness of cost of quality tool. Quality costing is a proven way to show the level of software quality.

The first four chapters of the study presented a theoretical framework for quality cost measurement in the software business, and presented some results gained from companies. Chapter 5 investigated whether it is possible to measure quality costs on a real time basis in the software industry. Quality cost measuring and reporting are traditionally based on ex post calculations. In Case Company A, an idea for real time quality cost measurement was developed and tested. This part of the thesis contributed to the existing literature by presenting a real time quality cost model. The literature on real time quality cost accounting was limited or even non-existent. What makes Case A interesting from the point of view of management accounting research? The case study was a constructive case study. The company was ready to call into question the old working methods and procedures. The company had several development targets and the researcher was able to participate in the development projects. The researcher was also able to utilize the company’s database expertise in the development projects. Because of this, it was possible to test the functionality of accounting systems authentically, not only “on paper”. An important fact during the research process was that all information the researcher needed was given to the researcher in both companies and the researcher was aware of no restrictions on mobility and access to certain documents, places (e.g. restricted R&D facilities with unpublished products, etc.), events, or people. Without this kind of trust from the companies, a real time quality cost model (RQC model) could not have been constructed.

Chapter 6 demonstrated the applicability of the construct. As Case B, a business unit of a subsidiary company of a major international company, was involved as a part of a TEKES funded project called “Testausalihankinnan tehostaminen”, the development of the rationalization of subcontracting of software testing, it was possible to constitute a relationship long-term enough to study issues in another embedded software company (in addition to Case A). In addition to the developing aspects, Case B offered the researcher an opportunity to get feedback from the employees and managers of the idea of real time cost of
quality accounting construction developed in Case A, and to study the implementation possibilities of such a system in a completely different working environment. The results show that the construction built in Case A could be built irrespective of the cost accounting environment or the software used.

7.2 Evaluation of the study – reliability and validity

A scientific study has to be evaluated as an overall research process, in terms of its research design and in the way the researcher has obtained the results presented. This means that scientific methods have been used appropriately.

This study uses case research methodology which means that a small number of research objects are studied in their real-life, temporal, and spatial contexts. According to Lukka and Kasanen (1995) the aim of qualitative management accounting research is not to produce generalizations of a statistical nature, or to make inferences to a broader population. A single case study (or two case studies as in this case) is not statistical study with a sample of one, and it is a mistake to seek this kind of “universal” generalization in it. Qualitative studies can, however, arrive at a different kind of generalization – theoretical generalizations. They can bring theories into contact with empirical reality, thus exposing their strengths and weaknesses and modifying or even refuting them.

The interventionist approach used in this thesis subscribes to the idea of pragmatic truth theory even more distinctly than the other research avenues (cf. Malmi and Granlund 2006: 30) although here also to varying degrees (Kasanen et al. 1993). Overall, this implies that we should always first consider the relevance and then truth, rather than vice versa. An underlying assumption then is that in problem solving, researchers can and should be prescriptive and the validity of the results is tested through implementation: what works in practice is true. The fundamental question then is: how to relax the dominant view embedded in most conventions of management accounting research that avoids intervention and sticks strictly to the very traditional criteria of science, like statistical generalizability only and objectivity. Regarding the former, Lukka & Kasanen (1995) argue – while demonstrating problems with statistical generalizations and uncertainty embedded in all inductive reasoning – that we can also pursue other

43 Particularly in the constructive research approach testing the functionality of the created construct in the spirit of pragmatism plays an important role in the research process. For the different market test levels for constructs, see Labro & Tuomela (2003; cf. Kasanen et al., 1993).
forms of generalizability and suggest contextual (mainly in case studies) and constructive (in constructive research approach) rhetoric of generalizability to be applied alongside statistical means. Regarding objectivity, Malmi and Granlund (2006) follow Mattessich (e.g. 1995b: 279), who suggests that the major criterion of objectivity in an applied discipline is the clear revelation of its value judgements (or objectives/objective functions) and extensive empirical testing of its prescriptions. They argue that an important thing to realize is that, when succeeding in producing a construct to solve a practical problem that is of theoretical interest (i.e. it is novel), and if the construct is shown to be working, we have built a management accounting theory (see e.g. Malmi et al. 2004). This has been done in Case A of the thesis. Thus there is no need for any other kind of theory building. The functionality of the theory should then, of course, be tested in other similar types of organizations and further under very different circumstances. This was done in Case B of the study. The scope and applicability of the new theory would thus be examined.

In case research, the researcher has direct and in-depth contact with the target(s) of the empirical examination over a considerable period of time, and s/he is a major research instrument him/herself. The researcher typically collects empirical material in multiple ways, which are mutually supportive: observation, interview, and analysis of archival data (cf. Yin 1984, Scapens 1990, Otley & Berry 1994, Chua 1996, Berry & Otley 2004, Scapens 2004).

In general, Reliability is concerned with the question of whether the researcher is obtaining data on which she or he can rely, or in other words, how well another researcher is able to obtain results with the same data. This means that reliability refers to the extent to which measurements are repeatable. According to Yin, (1984) the objective of testing reliability is to ensure that, if a later researcher followed exactly the same procedures as those of an earlier researcher and conducted the same study all over again, he or she would arrive at the same findings and conclusions. According to Ahrens and Chapman (2006: 833), the question of reliability takes on a different significance in qualitative field studies that are not characterized by the use of research instruments (even though they may use them) but are instead propelled by a mix of structured and unstructured data. In this study, the research and the research environment were unique in nature and it is extremely difficult, if not impossible, to conduct the same research; the business environment is everchanging, old technologies are replaced by new ones, and people with their tacit knowledge move from one position to another. By following the same data collection process, involving long
periods in the field, another researcher could also gain *deep understanding* (cf. Lukka 1999) of the issues researched in case companies A and B by observing, interviewing (see Appendix 1 and 3), discussing with the workers, reading accounting data, and studying archival material (see Appendix 2). However, it is unlikely that the research process would have produced a similar construction. While it would be possible to discuss any research approach exclusively in terms of reliability and different dimensions of validity or purely in terms of theoretical linkages and empirical procedures, it is useful to take the research process as the starting point for analysis (see e.g. Labro and Tuomela 2003). In this way, we can address different methodological aspects, such as theoretical connections, while keeping a practical focus on doing constructive research (see Ahrens and Dent (1998) for a similar approach).

Ahrens and Chapman (2006: 833) argue that the question of reliability of research is not easily separated from validity. Reliability has been introduced to social research through the use of research instruments such as questionnaires, in positivistic studies. *Valid measures are always reliable but not vice versa.* The notions of validity that were developed to evaluate positivistic studies of objective reality are unsuitable for qualitative field studies, which assume that “social reality is emergent, subjectively created, and objectifies through human interaction” (Chua 1986: 615). Objectifications and social reality are context specific. Ahrens and Chapman (2006: 833) emphasize that actors in the field can, and do, strive to undo their history and invent new concepts, images, and ways in which they went to infuse action. Valid and reliable accounts of the role of accounting in social reality cannot pretend to study this reality without relevance to the agency of actors in the field and independency of the researcher’s theoretical interest. This means that the question of *replication* studies in qualitative field research is inappropriate since

> “we should not expect identical results when two observers study the same organization from different points of view, or when they study different substructures within a large organization. What we have right to expect is that the two descriptions be compatible, that the conclusions of study do not implicitly or explicitly contradict those of the other”. (Becker 1970: 20.)

Patterns and causality are of interest to both qualitative and positivistic researchers. Ahrens and Chapman (2006: 834) argue that qualitatively oriented research by contrast conceives of social reality studied in ways that are not easily captured by key variables. According to Hammersley and Atkinson (1983: 20) the
theory of a qualitative field study must include reference to mechanisms or processes by which the relationship among the variables identified is generated. The qualitative researcher works on the assumption that organizational activity is meaningful in practice (Hastrup 1997). (S)he has done well when (s)he has developed a convincing account of the ways in which meanings and purposes relate to patterns of activity.

Defined broadly, Validity is concerned with the question of whether the researcher is studying the phenomenon she or he pursues to be studying (McKinnon 1988: 36). Cronbach (1982: 108) states that validity is subjective rather than objective: the plausibility of the conclusion is what counts. And plausibility, to twist a cliché, lies in the ear of the beholder. In this section I briefly consider the three key issues of external, internal and construct validity (cf. Modell 2006: 234). The issue of external validity has traditionally been conceived of as the extent to which the findings of a particular study can be generalized across populations, contexts and time (Birnberg et al. 1990). This study was done in two case companies. One can assume that the main results of the idea of real time cost of quality measurement can be generalized to other software companies. Naturally, modifications have to be made to the construction because every cost accounting environment is unique. Labro and Tuomela (2003: 415) emphasize that the seven steps are a powerful means of bringing forward the key points in studies made by a constructive research approach. They argue that the sixth step (to examine the scope of the solution’s applicability) explicitly brings forward the need to deal with external validity.

The internal validity of a specific study refers to the credibility of causal relationships between independent and dependent variables inferred from the data. Case study as well as survey methods have typically been considered inferior to controlled laboratory experiments in this respect (Modell 2006: 236). Labro and Tuomela (2003: 415) argue that steps 3, 4 and 5, for example, are related most of all to ensuring internal validity. Most steps are partly overlapping with the previous and following phases of the research process. The third step – obtaining a profound understanding of the topic – continues throughout the entire research process. In addition, developing a theoretical understanding is likely to have started well before the actual constructive research process. The earlier versions of the research topic were presented at the 24th Annual EAA Congress in Athens (2001), at the 26th Annual EAA Congress in Seville (2003), at the MCA and ENROAC research conference on the changing roles of management accounting as a control system in Antwerp (2005), and at the 8th Manufacturing
Accounting Research congress – Cost and Performance Management in Services and Operations in Trento (2007). This research has been commented by many professors and researchers with whom the research findings have been discussed. The internal validity has therefore been respected.

Construct validity refers to whether theoretical concepts are adequately reflected by the operational definitions and measures of empirical phenomena (Modell 2006: 237). In this study, data were collected using various ways to ensure construct validity. In the case companies, research reports were written and the personnel in both companies had an opportunity to read the reports and give feedback during the research process.

Lukka and Kasanen (1995) questioned the generalizing rhetoric often invoked in quantitative research, typically manifested in heavy emphasis on statistical significance tests, arguing that such rhetoric can never substitute for thorough theoretical knowledge and framing the research issues at hand. The research problem of this study was viewed from different perspectives and each perspective was reflected through existing theories. Research papers were also written on the subject. The research environment was unique, but the thesis showed how to use real time quality cost accounting in practice in the case company. With regard to empirical work, Lukka (1999) argues that this phase resembled other case study methodologies in which deep understanding of the issues researched is pursued through observing, interviewing, studying archival material, etc.

A popular question in this context has been whether qualitative field studies can achieve validity if their data are ‘triangulated’? (Yin 1984). According to Ahrens and Chapman (2006: 834) triangulation works if you are out on a boat trip trying to get a fix on your position: Measure the direction of three lines of sight to three different fixed objects on land, draw three lines on a map, and the (hopefully very small) triangle on the map will tell you where you are on the water. With reference to qualitative field studies what methodologists like Yin (1984) call triangulation could not be further from this process of determining a position. Ahrens and Chapman (2006 834) argue that triangulation of Yin’s terms is a metaphor for the corroboration of evidence for certain assumptions about the object of the study. What data the researcher needs to make an argument about an organization depends on the argument. Further data can support or undermine the argument. According to them it is, however, misleading to call such support triangulation because it suggests that some certainty has been gained in the capture of an objective reality. Covalevski et al. (1998) argue that triangulation is
a problematic concept for the conduct and assessment of qualitative studies. We need to make our studies “plausible” or, to use a term frequently referred to qualitative field studies, “trustworthy”. However, Ahrens and Chapman (2006: 835) argue that the plausibility of Covaleski et al. (1998) is a complex effect that does not rely on observing the correct antidotes of threats to validity such as “(1) observer-caused effects; (2) observer bias; (3) data access limitations; and (4) complexities and limitations of the human mind” (McKinnon 1988: 37). McKinnon recommended that it is possible to counter these threats to the validity of field studies through three strategies: spending more time in the field, using multiple methods and observations, and controlling one’s behaviour as a field researcher (Ahrens & Chapman 2006: 835).

7.3 Limitations of the research and avenues for future research

All scientific research has limitations that can be pointed out, criticized, and raised for discussion. This study includes, as also discussed above, a number of limitations. During the research process, many choices and limitations of scope had to be made to avoid the research becoming too fragmented. These limits have left many interesting areas open for further research. In this section, these limitations will be discussed. After that, avenues for future research are considered.

The construct developed and tested in Case A was not completed in Case B, mainly because the final “tuning” of the construct would also have required more financial investments in software and it was not, during the empirical work in B, the main interest of the company management at that time. In addition, regarding to case A, the testing manager in the company using most of his time for programming the construction, was transferred to another time-critical customer project. The managers of A were satisfied with the newly developed defects detection, clarification, testing and fixing process based on the construction based on Rational ClearQuest software; as such there was no longer any need to see the monetary value in real time. However, the whole construction passed the weak market test. The research was based on two case companies. Application of the method to other companies may further corroborate the conclusions in the future.

Another limitation of the construct is that it only covers the quality costs of software development. Of course, it would have been interesting to achieve full coverage of the company’s quality costs. Because of the time and resource limitations, the measurement of quality costs of the hardware development
process and other parts of the company were left outside the scope of this project. However, this construction fits an embedded software company.

In further studies, the idea of real time cost of quality measurement could also be tested in other environments outside software development. This study was bounded by the context of the Finnish information technology industry; more closely to ‘software products and services’; and even more closely to embedded software in the Hoch et al. (1999) classification. Today the main product category in which embedded SW is used is what is known as ‘intelligent products’. This segment includes embedded SW development services and the production of packaged SW used in embedded products, such as operating systems. The products of both case companies in this study can be classified as part of the embedded SW segment. Thus, the results cannot be generalized to other contexts without reservations.

These limitations, however, offer opportunities for further research. Future studies could investigate e.g. developing real time quality cost measurement in companies belonging to other categories in Hoch’s (1999) classification. The nature of software is a fertile ground for this kind of cost accounting innovations. As Brodman (1998: 4) states, for some reason, we have come to accept mountains of rework (e.g. fix time) as part of our everyday activities. Thus, there is room for this kind of innovations in the software industry.

Besides applying the real time cost of quality accounting in industries that are very closely related to software, it would be interesting to further develop the model in some other, more traditional industry. Also in other industries there are processes which are very much work intensive and both the calculation of working time and project cost calculation are in use. In such environments it would be interesting to test the possibility to construct RQC accounting and see how it could be used as a management accounting tool.
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### Appendix 1 Sources of empirical qualitative material in Case A

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<tr>
<th>Time</th>
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<th>Subject</th>
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Appendix 2 List of data for Case A

Field notes:

Quality costs in company A. Introduction to quality cost project. 13 pages. 18.10.2001.
Support material given to interviewees. 4 pages. 22.10.2001.
Interview form. 4 pages. 22.10.2001.
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Transcribed interview report Riku N. 7.11.2001. 2 pages.
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Material for the project group meeting 10.1.2002. 20 pages.
Outlooks of the CQ software. 1.2.2002. 9 pages.
Description of quality cost reporting. 3 pages. 18.4.2002.
Memorandum, description of QC reporting. 2 pages. 8.5.2002.
Memorandum of 3 meetings with the controller, quality manager, and testing manager. 2 pages. 23.5.2002.
Timetable of the interviews. 2 pages. 13.11.2002.
Memorandum, meeting with the controller. 1 page. 21.8.2003.
Archival material:

Description of a customer SW “BP Dm.” 20.11.2001. 3 pages.
Description of a customer SW “BP MHC.” 14.2.2002. 4 pages.
Description of a customer SW “PB Tc.” 14.2.2002. 7 pages.
Description of a customer SW “PB SWs.” 14.2.2002. 8 pages.
Description of the inspection process at QC –software. 19.2.2002. 7 slides.
Description of the company’s testing process. 19.2.2002. 12 slides.
Display modes of a main customer software. 22.2.2002. 24 pages.
PBM SW Architecture. 22.2.2002. 20 slides.
Appendix 3 Sources of empirical qualitative material in Case B (semi-structured thema interviews, tape recorded and transcribed)

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