IQM-CMM:
Information Quality Management
Capability Maturity Model

by

Saša Baškarada

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Abstract

The awareness of the importance of information quality to effective decision making and successful business operations is growing world-wide. However, even though the majority of organisations are affected by information quality problems, only the minority of organisations have any information quality management programs in place. Furthermore, assessing, improving, and managing information quality has proven to be a notoriously difficult undertaking. There is thus a need for a holistic approach to the assessment and enhancement of information quality management practices. In view of that, this doctoral research thesis builds on contemporary information quality management theories as well as established total quality management theories to produce a capability maturity model for information quality management process assessment and improvement. Particular focus has been placed on the domain of engineering asset management – organisations primarily dealing with the management of engineering assets have been selected for the purpose of constructing and validating the model through the application of case study methodology. Given that this research explores an under-researched problem in information quality management and aims at building a deeper understanding of the information quality management capability maturity concept, the thesis adopts the interpretive research paradigm. Accordingly, several qualitative and quantitative research methodologies are employed. Six exploratory case studies and a four round Delphi study are employed to gain a better understanding of the research problem, identify the maturity indicators, and build the preliminary Information Quality Management Capability Maturity Model (IQM-CMM). The model is then applied in seven international case studies for further enhancement and external validation. This research makes a significant contribution to existing information quality management theory by identifying a large number of relevant maturity indicators and mapping them to a staged evolutionary capability maturity model. The final product is a set of evaluation tools and methodologies, which are intended to assist with the identification of problems in information management as well as information quality management practices. Thus, IQM-CMM may provide organisations with a measure of their maturity in information quality management, along with recommendations for increasing the level of maturity. This may result in enhanced information quality, organisational learning and decision making.

Declaration

I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text.

Saša Baškarada

08/08/08

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Even though I am considered as the sole author of this doctoral thesis, the truth is that many people have in various ways contributed to helping me reach this, at times, daunting goal of completing a PhD research project. Therefore, I would like to take a moment to acknowledge and thank those many people.

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Dedication

To my mother

Publications List

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"*Theories are nets cast to catch what we call 'the world': to rationalise, to explain, and to master it.*"

— Karl Popper

Table of Contents

Abstract ..... **iii**
Declaration ..... **iv**
Acknowledgments ..... **v**
Dedication ..... **vi**
Publications List ..... **vii**
Table of Contents ..... **ix**
List of Figures ..... **xiii**
List of Tables ..... **xv**
Chapter 1: Introduction **1**
1.1 Background to the Research 2
1.2 Research Problem and Research Questions 3
1.3 Justification for the Research 5
1.4 Aim of this Research 8
1.5 Methodology 8
1.6 The Scope and Key Assumptions 9
1.7 Findings 10
1.8 Outline of the Thesis 11
1.9 Conclusion 12
Chapter 2: Literature Review **13**
2.1 Introduction 14
2.2 Total Quality Management 15
2.2.1 Gurus *16*
2.2.2 Critical Success Factors for TQM *22*
2.2.3 Six Sigma *24*
2.2.4 Summary *25*
2.3 Quality Awards and Frameworks 25
2.3.1 The Deming Prize *26*
2.3.2 Japan Quality Award *27*
2.3.3 Singapore Quality Award *28*
2.3.4 Malcolm Baldrige National Quality Award *29*
2.3.5 Canadian Framework for Business Excellence *31*
2.3.6 Australian Business Excellence Framework *31*

2.3.7 European Foundation for Quality Management Excellence Model *33*
2.3.8 Summary *34*
2.4 Quality Standards and Best Practices 35
2.4.1 ISO 9000 ..... *35*
2.4.2 ISO/IEC 15504 ..... *37*
2.4.3. Capability Maturity Model *38*
2.4.4 Capability Maturity Model Integration *39*
2.4.5 Control Objectives for Information and Related Technology *40*
2.4.6 Information Technology Infrastructure Library *43*
2.4.7 ANSI/GEIA 859 ..... *44*
2.4.8 The Level of Adoption *47*
2.4.9 Summary *47*
2.5 Data and Information Quality 47
2.5.1 From Data to Information *48*
2.5.2 Definitions *49*
2.5.3 Implications *51*
2.5.4 Causes *52*
2.5.5 The Product Analogy *53*
2.5.6 Assessments *55*
2.5.7 Management *57*
2.5.8 Maturity Models *61*
2.5.9 Summary *66*
2.6 Engineering Asset Management 66
2.7 Conclusion 69
Chapter 3: Research Methodology 71
3.1 Introduction 72
3.2 Philosophy of Science 73
3.2.1 Defining Science *73*
3.2.2 Theories *74*
3.2.3 Causality *75*
3.2.4 Rationalism vs. Empiricism *76*
3.2.5 Inductivism *78*
3.2.6 Popper's Falsificationism *79*
3.2.7 Conventionalism *81*
3.2.8 Scientific Research Programmes *81*

3.2.9 Scientific Paradigms *82*
3.3 Justification for the Qualitative Interpretive Research Approach 89
3.4 Research Design 91
3.4.1 Stage 1: Exploratory Phase *91*
3.4.2 Stage 2: Theory Building Phase *96*
3.4.3 Stage 3: Theory Testing and Enhancing Phase *101*
3.5 Data Collection 103
3.5.1 Theoretical Sampling *103*
3.5.2 Interviewing *104*
3.6 Data Analysis 105
3.6.1 Constant Comparative Analysis *106*
3.6.2 Hermeneutics *107*
3.6.3 Pattern Matching *107*
3.6.4 Explanation Building *108*
3.6.5 Within-Case Analysis *108*
3.6.6 Cross-Case Analysis *108*
3.7 Criteria for Judging the Quality of Qualitative Interpretive Research 109
3.7.1 Construct Validity *111*
3.7.2 Internal Validity *112*
3.7.3 External Validity *112*
3.7.4 Reliability *113*
3.8 Ethical Considerations 113
3.9 Limitations 114
3.10 Conclusion 114
Chapter 4: Analysis of Data 115
4.1 Introduction 116
4.2 Exploratory Stage 117
4.2.1 Profiles of the Exploratory Case Study Organisations *117*
4.2.2 Candidate Maturity Indicators *118*
4.3 Theory Building Stage 120
4.3.1 Constructing the Staged Capability Maturity Model *120*
4.3.2 Constructing the IQM-CMM Diagnostic Tool *129*
4.4 Theory Testing and Enhancing Stage 131
4.4.1 Assessment Method *131*
4.4.2 Profiles of the Explanatory Case Study Organisations *135*

4.4.3 Capability Maturity Ratings of the Explanatory Case Study Organisations 135
4.4.4 Cross-Case Analysis 143
4.4.5 Theory Enhancements 179
4.4.6 Discussion 180
4.6 Conclusions 181
Chapter 5: Conclusions 183
5.1 Introduction 184
5.2 Conclusions about the Research Questions and Hypotheses 184
5.3 Implications for Theory 191
5.4 Implications for Practice 192
5.5 Limitations 193
5.6 Future Research 194
5.7 Conclusion 195
References 196
Appendix A: Glossary 215
Appendix B: Definitions 216
Appendix C: CobiT 4.0 Control Objectives Applicable to IQM 217
Appendix D: Definitions of Information Quality Dimensions 218
Appendix E: Research Information Sheet 220
Appendix F: Consent Form 221
Appendix G: Research Invitation Letter for Exploratory Case Studies 222
Appendix H: Candidate Maturity Indicators 223
Appendix I: Delphi Questionnaire (round 1) 227
Appendix J: Delphi Questionnaire (round 4) 229
Appendix K: Delphi Study Results 231
Appendix L: High-Level Interview Protocol 233
Appendix M: IQM-CMM Diagnostic Tool 234
Appendix N: Comparison of IQM-CMM with Related Maturity Models 243

List of Figures

Figure 1.1: The Impact of poor Information Quality 7
Figure 1.2: Research Methodology 9
Figure 1.3: High Level Description of IQM-CMM 10
Figure 2.1: Literature Review Stage of the Research Methodology 14
Figure 2.2: Japan Quality Award 28
Figure 2.3: Steps toward Mature Processes 30
Figure 2.4: The EFQM Excellence Model 33
Figure 2.5: History of CMMs 40
Figure 2.6: CobiT 4.0 Processes Addressed by CMMI 1.1 41
Figure 2.7: CobiT 4.0 Processes Addressed by ITIL 44
Figure 2.8: TDQM Methodology 57
Figure 2.9: The Key Steps in a Strategic Data Quality Methodology 59
Figure 2.10: Improvement Activities in Data Quality Maturity Levels 63
Figure 2.11: Enterprise Information Management Adoption Model 64
Figure 2.12: Elements of Comprehensive Asset Management 69
Figure 3.1: Representation of Knowledge 73
Figure 3.2: The Research Triangle 83
Figure 3.3: Methodologies and their Related Paradigms 87
Figure 3.4: A Framework for Positivist and Interpretive Research 87
Figure 3.5: Research Methodology 91
Figure 3.6: IQM Capability Maturity Framework 92
Figure 3.7: The Transition from Descriptive Theory to Normative Theory 96
Figure 3.8: The General Methodology of Design Research 100
Figure 3.9: The Hermeneutic Circle as Applied in this Research 107
Figure 3.10: Multiple Case Study Method 109
Figure 3.11: Information Systems Research Framework 110
Figure 4.1: Exploratory Stage of the Research Methodology 117
Figure 4.2: Information Lifecycle Model 118
Figure 4.3: The Theory Building Stage of the Research Methodology 120
Figure 4.4: Information Quality Management Capability Maturity Model (IQM-CMM) 123
Figure 4.5: Level 1 (CHAOTIC) 124
Figure 4.6: Level 2 (REACTIVE) 125

Figure 4.7: Level 3 (MEASURING).....126
Figure 4.8: Level 4 (MANAGED).....127
Figure 4.9: Level 5 (OPTIMISING).....128
Figure 4.10: The Hierarchical Structure of IQM-CMM.....129
Figure 4.11: Theory Testing and Enhancing Stage.....131
Figure 4.12: Case G IQM-CMM Appraisal Results.....136
Figure 4.13: Case H IQM-CMM Appraisal Results.....137
Figure 4.14: Case I IQM-CMM Appraisal Results.....138
Figure 4.15: Case J IQM-CMM Appraisal Results.....139
Figure 4.16: Case K IQM-CMM Appraisal Results.....140
Figure 4.17: Case L IQM-CMM Appraisal Results.....141
Figure 4.18: Case M IQM-CMM Appraisal Results.....142
Figure 4.19: Information Flow (Case G).....153
Figure 5.1: Information Quality Management Capability Maturity Model.....186
Figure 5.2: The Hierarchical Structure of IQM-CMM.....188

List of Tables

Table 2.1: Juran's Quality Trilogy 18
Table 2.2: Seven Tools of Quality 19
Table 2.3: Quality Management Maturity Grid 20
Table 2.4: Commonalities among the Quality Gurus 21
Table 2.5: Six Sigma DMAIC Process 25
Table 2.6: The Categories of the Deming Prize (100 total points) 27
Table 2.7: SQA Award Criteria Weightage (1000 total points) 28
Table 2.8: Baldrige Categories and Items 30
Table 2.9: Canadian Framework Road Map to Business Excellence 31
Table 2.10: Australian Business Excellence Framework 32
Table 2.11: The Learning Cycle 32
Table 2.12: Comparison of Quality Model Criteria 34
Table 2.13: Main Components of the ISO 9000:2000 Series 36
Table 2.14: CobiT Maturity Attribute Table 42
Table 2.15: ITIL's Service Management Process Maturity Framework 44
Table 2.16: Data Terminologies 48
Table 2.17: Data Quality Dimensions 50
Table 2.18: Product Manufacturing Analogy for IP Creation 53
Table 2.19: Approaches to Improving Data Quality 58
Table 2.20: CALDEA 61
Table 2.21: Meta Group's Information Maturity Model – DQ Perspective 62
Table 2.22: Data Management Practice Assessment Levels 63
Table 2.23: Gartner's Data Quality Maturity Model 64
Table 2.24: Gartner's EIM Maturity Model 65
Table 2.25: Engineering Asset Management Processes/Functions 67
Table 3.1: A Comparative Overview of the Major IS Research Paradigms 88
Table 3.2: Criteria for Selecting the Case Study Research Method 93
Table 3.3: Exploratory Case Study Organisations 95
Table 3.4: Exploratory Case Studies' Interview Details 95
Table 3.5: Explanatory Case Studies' Interview Details 102
Table 3.6: Explanatory Case Study Organisations 103
Table 4.1: Profiles of the Exploratory Case Study Organisations 117

Table 4.2: Partial Summary of the Delphi Study Results (rounds 1 and 2) 122
Table 4.3: Partial Summary of the Delphi Study Results (rounds 3 and 4) 122
Table 4.4: Mapping between IQM-CMM Maturity Indicators and CMMI PAs 130
Table 4.5: Quality Ratings 134
Table 4.6: Profiles of the Explanatory Case Study Organisations 135
Table 4.7: Case G IQM-CMM Appraisal Summary 136
Table 4.8: Case H IQM-CMM Appraisal Summary 137
Table 4.9: Case I IQM-CMM Appraisal Summary 138
Table 4.10: Case J IQM-CMM Appraisal Summary 139
Table 4.11: Case K IQM-CMM Appraisal Summary 140
Table 4.12: Case L IQM-CMM Appraisal Summary 141
Table 4.13: Case M IQM-CMM Appraisal Summary 142
Table C.1: CobiT 4.0 Control Objectives Applicable to IQM 217
Table D.1: Definitions of Information Quality Dimensions 218
Table H.1: Maturity Indicators Pertaining to Information Capture 223
Table H.2: Maturity Indicators Pertaining to Information Analysis 223
Table H.3: Maturity Indicators Pertaining to Information Access 223
Table H.4: Maturity Indicators Pertaining to Information Disposal 224
Table H.5: Maturity Indicators Pertaining to Information Storage/Update 224
Table H.6: Maturity Indicators Pertaining to the whole of Information Lifecycle 225
Table H.7: Maturity Indicators Pertaining to Information Quality Management 226

Chapter 1

Introduction

"*The beginning is the most important part of the work.*"

—Plato, *The Republic*

This chapter lays out the foundation for the rest of the thesis by presenting a brief overview of the research background, the research problem, the research questions, the justifications for the research, and the aims of the research. The research methodology is briefly explained and delimitations of scope and key assumptions are discussed. The chapter finally summarises the research findings and outlines the rest of the thesis.

1.1 Background to the Research

Information and Communication Technologies (ICTs) have been evolving at a very fast rate in the relatively recent times. Such a rapid progress has made the production, collection, and storage of information very easy and inexpensive. As a result, contemporary organisations are dealing with more information than ever before in history (Lyman & Varian 2003; McCue 2006; Nunno & Meehan 2007; Bell, Logan & Friedman 2008). However, these technological advances have among others led to a decrease in the quality of the available information. Information accuracy, completeness, timeliness, relevancy, and so on, have proven to be notoriously difficult to assess and manage. Furthermore, even though quality assurance methodologies have played a crucial part in the software engineering and manufacturing industries for decades (Paulk et al. 1993; Mahoney & Thor 1994; CMMI 2002; ISO 2005b), Information Quality Management (IQM) is only practiced in a minority of contemporary organisations (TDWI 2006). This is despite the fact that many such organisations clearly depend on quality information for every-day business operations, and even their very survival in today's competitive business environments (Redman 1998).

Quality management has been an integral component of software engineering and manufacturing industries for decades (Paulk et al. 1993; Mahoney & Thor 1994; CMMI 2002; ISO 2005b), and it has been described as being fundamental to organisational success and growth (Feigenbaum 1986; Zeithaml, Parasuraman & Berry 1990). The Total Quality Management (TQM) movement started with the development of the statistical control charts by Walter Shewhart in 1925 (Shewhart 1925). Since then, many researchers, whom we now call "quality gurus", including, Juran (1974), Crosby (1979), Deming (1982), and Ishikawa (1986) have contributed a great deal to quality management theories. Additionally many other researchers (Oliver 1988; Camp 1989; Saraph, Benson & Schroeder 1989; Bowen & Lawler 1992; Blackburn & Rosen 1993; Davenport 1993; Oakland 1993; Flynn, Schroeder & Sakakibara 1994; Motwani 2001b) have proposed a wide range of Critical Success Factors (CSFs) for TQM implementations. The Total Data

Quality Management (TDQM) program at MIT has been instrumental in the adaptation of TQM theories to the field of information quality management (Wang & Strong 1996; Strong, Lee & Wang 1997b; Wang 1998) by drawing an analogy between the manufacture of tangible products and Information Products (IPs).

Crosby (1979) was the first to propose the idea of quality management maturity. His ideas have since been adopted by IBM (Radice et al. 1985) and SEI (Paulk et al. 1993; CMMI 2002) to software engineering, and by several other researchers (Chambless & Parker 1998; English 1999; Caballero, Gómez & Piattini 2004; Ryu, Park & Park 2006; Aiken et al. 2007) to information management and information quality management.

This doctoral research project further adapts Crosby's ideas to the development of an Information Quality Management Capability Maturity Model – IQM-CMM. IQM-CMM is developed inductively, as opposed to some deductively proposed models found in the literature, and, as such, it is grounded in empirical data gatherer from a wide range of information quality experts and practitioners. As a result, the model does not represent a limited view of one researcher, but it aggregates a variety of different views.

1.2 Research Problem and Research Questions

It has been argued that to ask the right question is to be well on the way to finding the right answer (Brown et al. 1997), and that the formulation of a research problem is the first and most important step of the research process (Kumar 1999). Thus, this section presents an overview of the research problem and details the research questions and hypotheses.

Quality management practices have routinely been employed in the manufacturing industries for over half a century and they have also been a standard component of the software engineering process for at least several decades. However, organisations have only relatively recently began to realise the importance of applying quality management principles to the domain of information management. Information quality, a strategic business issue (Friedman 2007b), has been defined as "fitness for use" (Wang & Strong 1996), comprising of a wide range of dimensions, including, accuracy, completeness, timeliness, relevancy, and the like. Furthermore, an analogy between traditional product manufacturing and the manufacture of information products has been drawn. As a result, processes – "logically related series of activities conducted toward a defined objective" (itSMF 2005, p. 28) – comprising an information system may have detrimental effects on the quality of the resulting information products. It has also been argued that "without

process maturity, it's difficult to make good judgments consistently" (Mingay & Bittinger 2005, p. 4). However, there has only been limited research on the concept of information quality management capability maturity.

As a result, this research aims to develop an Information Quality Management Capability Maturity Model – a set of information quality management maturity indicators shall be identified and organised into a staged evolutionary maturity model. It is expected that higher maturity levels would result in enhanced information quality. This research will not attempt to investigate any relationships between information quality management capability maturity and organisational performances.

The research presented in this thesis will specifically focus on information quality management issues in engineering asset management organisations, with an expectation that the research findings will largely be transferable to other types of organisations. Contemporary engineering asset management organisations are managing vast quantities of exceedingly diverse data in their information systems. Asset design data, maintenance procedures and records, condition/performance data, and so on, all need to be efficiently managed in order to obtain the lowest possible asset lifecycle cost. Consequently, managing asset information efficiently, and utilising information of high quality, is paramount to engineering asset management efforts.

The research problem has been summarised in the following research questions:

RQ1: How can information quality management capability maturity be assessed and enhanced in engineering asset management organisations?

RQ1.1: What are the information quality management maturity indicators?

RQ1.2: How can they be organised into staged evolutionary levels?

RQ1.3: What is their relative significance?

RQ1.4: How can they be assessed?

RQ2: How does the Information Quality Management Capability Maturity Model provide for better utilisation and management of information relating to engineering asset management?

Overall Hypotheses:

H_0: *Quality of engineering asset management information is not changed as the organisation moves to a higher information quality management capability maturity level.*

H_1: *Quality of engineering asset management information is enhanced as the organisation moves to a higher information quality management capability maturity level.*

1.3 Justification for the Research

There are many reasons why organisations may wish to assess and enhance their capability maturity in information quality management, including, minimising the costs associated with poor information quality and complying with government regulations and reporting requirements. In January 2002, 29-year-old Shiho Okamoto, a housewife, was walking with her two children when she was crushed to death by a wheel that rolled off a Mitsubishi truck. Her two boys were also left injured. Two ex-Mitsubishi members of staff, who were overseeing quality control, were subsequently found guilty of professional negligence over the death of the woman, and received 18-month prison sentences (BBC 2007). In April 2007, a data entry error by an air traffic controller led to a near-miss between two aircraft southwest of Sydney airport (NEWS 2007). In October 2006, three key Australian government departments failed a records audit conducted by the Australian National Audit Office (NEWS 2006). The audit found that the departments of Prime Minister and Cabinet, Attorney-General's, and the Australian Electoral Commission needed to substantially improve areas of record accessibility, access security, completeness, integrity, preservation and destruction. In 2002, The Data Warehouse

Institute (TDWI) interviewed 647 data quality experts across a wide range of US industries and they found that poor quality data cost US businesses more than US$600 billion per year (TDWI 2002). Examples abound where impact of poor quality information has caused significant financial losses and in some cases has lead to disastrous consequences.

Failure to continuously improve internal processes is a pervasive problem for many organisations (Milakovich 2004). Gartner Research, a leading information and technology research and advisory firm, has reported that "data quality must be considered integral to any IT environment", and that even though "virtually every organisation has data quality issues that must be addressed ... the vast majority of companies either have no concept of data quality at all or turn a blind eye to deficiencies" (Bitterer 2007, p. 2). Furthermore, according to Gartner, "only a handful of companies can be considered mature in how they manage information as a corporate asset". Gartner predicts that "through 2010, more than 75% of organisations will not get beyond Levels 1 and 2 in their data quality maturity" (Bitterer 2007, p. 2). Accordingly, they forecasted that through 2008, organisations that ignore Information Management (IM), will struggle to maintain their status in business environments (Logan & Newman 2006).

A Gartner survey, conducted in 2004, showed that many financial services providers were experiencing operational and decision support initiatives hampered by suboptimal quality information (Friedman, Nelson & Radcliffe 2004). A more recent survey was conducted among attendees of three Business Intelligence (BI) conferences in Chicago, Sydney, and London, from January through March 2007 (Friedman 2007b). The survey had 301 respondents in total – London (142), Chicago (136), and Sydney (23) – where about 75% of the respondents were from the IT department, followed by 7% of the respondents from the finance department. Several industries were represented, including, the financial sector, process manufacturing, discrete manufacturing, communications, insurance, healthcare, and the service sector. Gartner found that the interest in the discipline of data quality was growing, with 52% of survey respondents indicating they are investing in data quality tools. There was also an increased realisation that data quality is paramount for effective regulatory and legislative compliance. Survey respondents indicated various reasons for investing in data quality, including, to improve a general lack of trust in the data (52%); to support business intelligence and/or data warehouse initiatives (49%); to support Enterprise Information Management / Master Data Management efforts (33%); to support regulatory compliance efforts (25%); and to help reduce costs (21%) (Friedman 2007b).

Computer Sciences Corporation (CSC), a leading Information Technology and business services company, reported in its 2007 Annual Report on Technology Issues for Financial Executives that "improving data quality / information integrity, a new selection choice added to [the] survey, emerged as the most pervasive critical technology concern, with about 58 percent of respondents considering it to be a critical technology issue" (CSC 2007, p. 3). Furthermore, "most respondents indicated that the lack of information integrity is negatively impacting operations and performance, and about 70 percent plan initiatives in the next year to improve their information integrity" (p. 3).

Tom Redman, a leading data quality consultant (Redman 1998), identified a wide range of impacts that poor information quality may have on an organisation. He further mapped those impacts to the operational, tactical, and strategic business layers (Figure 1.1).



Figure 1.1: The Impact of poor Information Quality
Source: developed from (Redman 1998)

Studies have also identified a strong link between quality management approaches and superior financial performance in organisations (Porter & Tanner 2004). Existing research suggests that the adoption of quality improvement programmes results in a reduction of total costs, and increase in productivity and profitability (Wisner & Eakins 1994). Similarly, Redman (1992) argued that inaccurate and incomplete data may adversely affect the competitiveness of an organisation, since "operational design, planning, and policy decisions are based on collection, analysis, and interpretation of objective information" (Milakovich 2004, p. 86).

However, according to Gartner, most information quality projects are reactive in nature, addressing localised data quality issues as they occur (Friedman 2005). Many such initiatives only seek to apply technology, without addressing the underlying process issues.

As a result, most information quality initiatives deliver suboptimal benefits (Friedman 2005). Additionally, the number of errors in organisational databases as well as the impact of those errors has been on the increase (Klein 1998). Furthermore, at least 40 percent of companies undertaking a CRM strategy are unaware of information quality problems in their environment (Knox 2004), and even though many organisations recognise the existence of information quality problems, they do little about it because of a lack of perceived value (Friedman, Nelson & Radcliffe 2004).

1.4 Aim of this Research

The aim of this doctoral project has been to develop an Information Quality Management Capability Maturity Model, a set of evaluation tools, which are intended to assist in the identification of problems in the collection/storage/use of information and other information management practices. This tool may provide organisations with a measure of their capability maturity in information quality management, along with recommendations for increasing the level of maturity. It is expected that higher levels of process maturity may lead to enhancements in information quality.

The research findings shall contribute to the theory by identifying a wide range of information quality management maturity indicators and mapping them to a staged evolutionary capability maturity model. Contributions to practice involve helping organisations with assessing their existing information quality management practices, developing improvement strategies, and benchmarking against best practice approaches as well as other organisations.

1.5 Methodology

The correct choice of a research method is paramount for the validity of the results obtained in any research project. The research methodology for the development of the Information Quality Management Capability Maturity Model comprises of three stages (Figure 1.2). Stage one identifies a range of candidate information quality management maturity indicators, through six exploratory case studies, and a comprehensive literature review. Stage two involves a four round Delphi study (comprising of approximately 20 participants), which is used to validate and group the candidate maturity indicators into staged evolutionary levels. The final stage of the research methodology ensures further external validation and theory enhancement though the application of the model in seven explanatory international case studies. Following Walsham (1993), the research design has

been aimed at achieving a suitable combination of theory and practice, so that the research results can eventually be used by practitioners.

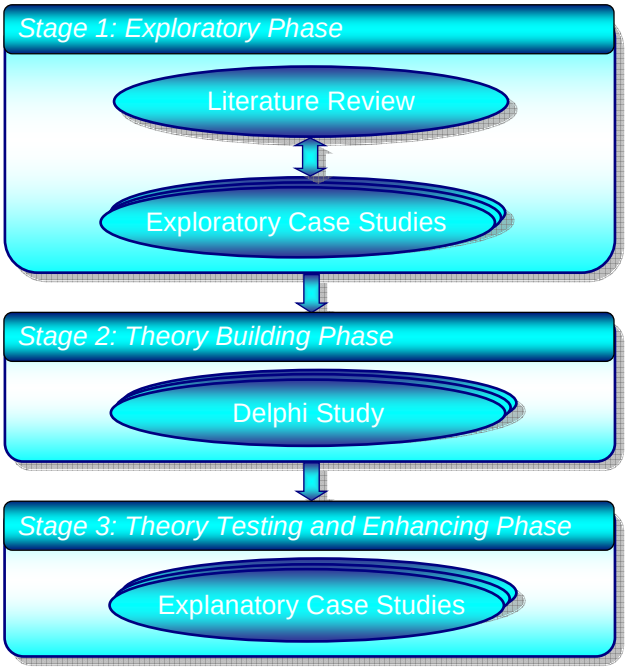


Figure 1.2: Research Methodology
Source: (developed by the author)

This research is mainly concerned with theory building and thus it can be classified as being qualitative and interpretive in nature. Interpretative research does not predefine dependent and independent variables, but focuses on the full complexity of human sense making as the situation emerges (Kaplan & Maxwell 1994). Additionally, when a subject area is not well understood, qualitative methods may be used to build theory and testable hypotheses; theory may then be tested using quantitative methods such as surveys and experiments. Thus, the model development can further be described as qualitative research since it is subjective, holistic, interpretative and inductive in nature.

1.6 The Scope and Key Assumptions

Given that information management processes may impact the quality of resulting information products, this research project shall focus on information management as well as information quality management maturity indicators and processes. Furthermore, the concept of information quality management capability maturity shall be investigated from three perspectives: technological, organisational, and social (Linstone 1981). The focus will be placed on engineering asset management organisations and all case studies shall be in this domain. Nevertheless, it is assumed that the finding shall be generic enough to be transferable to other types of organisations.

1.7 Findings

This doctoral research project has extended the information quality management theory by identifying a wide range of organisational, technical, and social information management as well information quality management maturity indicators, and mapping them to a staged evolutionary capability maturity model (Figure 1.3). It has identified close to 50 major factors, which, when not managed appropriately, may have detrimental effects on the quality of information used in contemporary organisations. The evolutionary model comprises of five levels, representing a 'best practice' maturity continuum for information quality management. Additionally, the diagnostic tool, developed in this research project, provides a unique and comprehensive method for assessing organisational information quality management maturity, specifying more than 200 specific appraisal criteria.

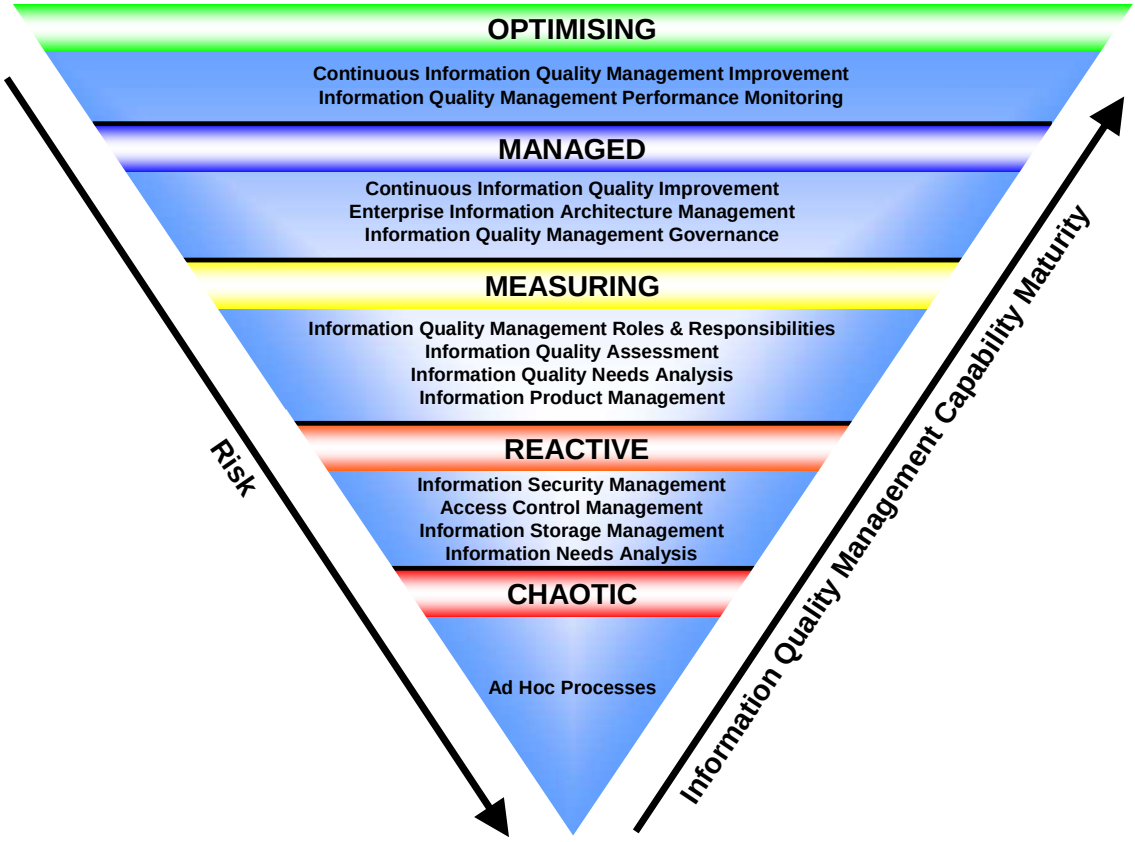


Figure 1.3: High Level Description of IQM-CMM
Source: (developed by the author)

1.8 Outline of the Thesis

This chapter laid out the groundwork for the rest of the thesis by presenting a brief overview of the research background, the research problem, the research questions, justifications for the research, and aims of the research. The research methodology was briefly summarised, delimitations of scope and key assumptions were discussed, and a brief summary of the research findings was presented. The chapter finally illustrates the outline of the rest of the thesis.

The second chapter critically reviews the literature relevant to the research problem. It explores existing approaches to quality management, discusses how traditional quality management theories have been adapted to the research on data and information quality, and briefly explores the specific industry domain this research problem is being investigated in – engineering asset management.

The third chapter outlines the research methodology employed in this doctoral research project and discusses the underlying philosophical research paradigms. It reviews the history of the philosophy of science, traditional approaches to acquiring new knowledge, different "logics of discovery", and scientific paradigms. The qualitative interpretive approach adopted in this research project is justified and the research design, comprising of three stages, is explained. Then, the chapter explains the data collection and analysis approaches. The chapter concludes with a discussion of the criteria used for judging the quality of qualitative interpretive research, ethical considerations, as well as the research limitations.

The fourth chapter presents the analyses of the data gathered in this research project. The chapter is aligned with the research methodology and as such it comprises of three main parts: exploratory stage, theory building stage, and theory testing and enhancing stage. The first part of the chapter identifies the candidate information quality management maturity indicators, which emerged from the exploratory case studies and the literature review. The second part of the chapter shows how the Delphi study has been used to construct the Information Quality Management Capability Maturity Model as well as build the associated diagnostic tool. The third part of the chapter details the application of the model in seven explanatory international case studies and discusses the implications.

The fifth chapter concludes this thesis by relating the findings to the research problem and the research questions. It further discusses the implications for theory and practice as well as the limitations of this research project. The fifth chapter concludes with a discussion on the direction of future research.

1.9 Conclusion

This chapter has set the scene for the rest of the thesis. Firstly, the background to the research, the research problem, and the research questions were introduced. The chapter then presented a range of justifications for conducting this research project, and illustrated the aims of the research. The methodology was briefly presented and delimitations of scope and key assumptions were discussed. The chapter finally summarised the key findings of this research project and explained the outline of the rest of the thesis.

Chapter 2

Literature Review

"*Employ your time in improving yourself by other men's writings, so that you shall gain easily what others have laboured hard for*."

—Socrates

2.1 Introduction

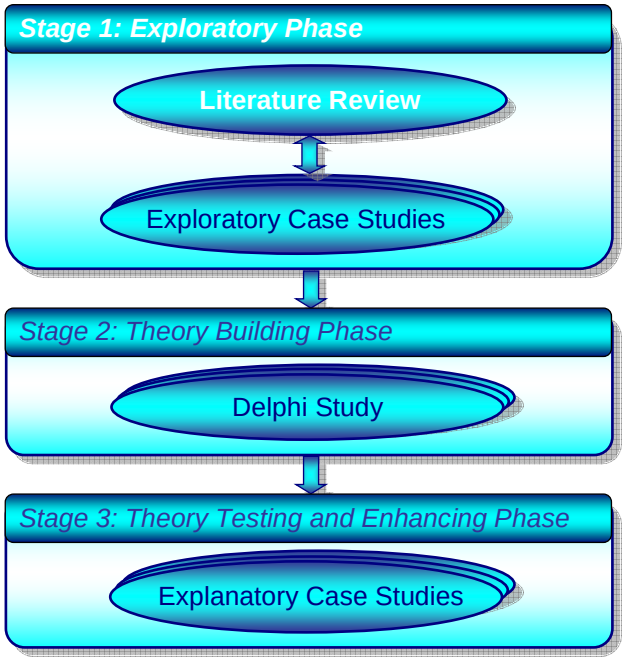


Figure 2.1: Literature Review Stage of the Research Methodology
Source: (developed by the author)

The aim in this chapter is to critically review the literature relevant to the research problem (Figure 2.1). The chapter explores the existing approaches to quality management, discusses how traditional quality management theories have been adapted to the research on data and information quality, and finally, briefly describes the specific industry domain this research problem is being investigated in – engineering asset management.

The origins of the quality management theories and specific contributions by quality gurus are identified in the first section of this chapter. Critical success factors for total quality management are presented and contemporary leading international quality awards and frameworks are discussed. Relevant quality management standards and best practice frameworks are also reviewed in detail. Next, the adaptations of quality management theories to the domain of data and information quality are reviewed, data and information quality definitions are presented, and several key frameworks are described. Finally, existing information management and information quality management maturity models are discussed and related to the research presented in this thesis. The research domain, engineering asset management, is also, briefly, discussed in this chapter. Even though the research presented in this thesis is generic and may be applied to organisations of any type, a specific focus has been placed on enterprises that manage engineering assets, and all case study organisations could be classified as such.

2.2 Total Quality Management

The literature related to Quality Control (QC), Quality Assurance (QA), and Total Quality Management (TQM) is reviewed in this section. The chief contributions by the quality gurus are highlighted, and the key Critical Success Factors (CSFs) for TQM are summarised. Finally, Six Sigma, a contemporary successor of TQM, is briefly discussed.

Many definitions of quality have been proposed in the literature (Hardie & Walsh 1994). One of them argued that quality "consists of the capacity to satisfy wants" (Edwards 1968, p. 37). Similarly, the American Society for Quality (ASQ) defines quality as “a subjective term for which each person or sector has its own definition” (ASQ 2002, p. 56). They go on to state that in technical usage, quality can have two meanings: 1) the characteristics of a product or service that bear on its ability to satisfy stated or implied needs, and 2) a product or service free of deficiencies. Shewhart (1931) and Crosby (1979) argued that quality is represented by a difference between two states (preferred and actual states), and thus mainly defined it as conformance to requirements. Feigenbaum (1986) and Juran (1974) defined quality in terms of customer satisfaction, where customer expectations can be seen as the preferred state and the concrete product or service received as the actual state. Garvin (1987) identified eight dimensions of product quality, including, performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Additionally, several further views of quality shall be presented in the subsequent sections of this chapter.

The Deming Prize Committee defines TQM as “a set of systematic activities carried out by the entire organisation to effectively and efficiently achieve company objectives so as to provide products and services with a level of quality that satisfies customers, at the appropriate time and price” (JUSE 2007a, p. 2). It has been argued that the philosophies of Deming, Juran and Crosby “provide fundamental principles on which total quality is based” (Motwani 2001a, p. 293). TQM is one of the most widely applied quality management approaches, and it focuses mainly on customer (user) satisfaction, participatory management, and a results-orientation (Milakovich 2004). Dean & Bowen (1994) identified customer focus and continuous improvement as the main principles of TQM, while others have also argued that based on Deming’s teachings (Deming 1982), process improvement is usually at the heart of any TQM initiative (Hackman & Wageman 1995).

Zeithaml, Parasuraman & Berry (1990) have argued that producing quality products and delivering quality services are considered fundamental for success and survival in the contemporary competitive business environment. It has also been shown that effective TQM initiatives can lead to competitive and strategic advantages (Anderson, Rungtusanatham & Schroeder 1994; Hendricks & Singhal 1997; Easton & Jarrell 1998). Furthermore, empirical evidence suggests that there are substantial benefits of TQM efforts to productivity and profitability (Hendricks & Singhal 1997; Reed, Lemak & Mero 2000; Allen & Kilmann 2001; Tena, Llusar & Puig 2001). In a study of US and Japanese air conditioner manufacturers, Garvin (1983) found that quality associated savings offset the quality control costs. Crosby (1979) argued that reduction of poor quality costs would lead to increased profitability, and Gale & Klavans (1985) showed that improvements in product quality lead to market share increases.

However, there have also been claims that TQM efforts are not very effective (Harari 1993; Eskildson 1994). For instance, Burrows (1992) showed that TQM initiatives can have a failure rate up to 95%. Nevertheless, many Western organisations realised in the early 1980s that quality was a strategic differentiator, which lead to a wide adoption of numerous quality systems (Porter & Tanner 2004). Thus, TQM was widely embraced by western organisations in the last decade (Lawler, Mohrman & Ledford 1995), and it "has been a popular business strategy in many leading organisations in the Australian manufacturing industry" (Sohal & Terziovski 2000, p. 158). Historically speaking, simple inspection activities have over the years evolved from quality control to quality assurance and eventually into TQM activities (Dale 1999). The following chapter section traces that evolutionary process from the quality gurus' perspectives.

2.2.1 Gurus

In this section, a comprehensive literature review on the main quality gurus (Bendell, Penson & Carr 1995) is presented, and their principal contributions to the TQM theory are highlighted (Table 2.4).

Walter Shewhart is considered by many to be the founder of the modern quality movement (Wilcox 2004; Sower & Fair 2005). He argued that quality has an objective and a subjective aspect, and that although the objective aspects of quality ("independent of the existence of man") are usually measured, the subjective aspects ("what we think, feel, or sense as a result of the objective reality") may be of greater importance (Shewhart 1931, p.

53). Thus, the objective aspect is analogous to "conformance to requirements" and the subjective aspect is analogous to "meeting customer needs". Shewhart also recognised that processes are subject to variation from two sources; chance causes that are inherent in the system, and assignable causes that could indicate a problem in the system (Shewhart 1925). As a result, he developed control charts that provide a statistical basis for differentiating between these two types of variation. He also developed the Shewhart cycle for continual improvement (Plan – Do – Check – Act), which was later widely popularised by Deming (1982).

W. Edwards Deming spent his early career in the USA further developing Shewhart's work (Bendell, Penson & Carr 1995), adapting the Shewhart cycle (Plan – Do – Check – Act) to what is now known as the Deming Cycle (Plan – Do – Study – Act). He later became widely known after he helped the Japanese manufacturing sector recover following the Second World War (Petersen 1999), by pushing senior management to become actively involved in the quality improvement initiatives (Bendell, Penson & Carr 1995). As a consequence, his teachings led to Japan's product quality being recognised as the highest in the world (JUSE 2007a). Deming (1982) defined quality as "a predictable degree of uniformity and dependability at a low cost with a quality suited to the market" (p. 176), arguing that quality improvements lead to improvements in productivity and competitive position. He identified the customer as "the most important part of the production line" (p. 174), and argued that top management is responsible for most quality problems in organisations by not providing employees with quality standards and an appropriate working environment. Accordingly, Deming identified top management's commitment to quality improvements as being critical to any TQM efforts. Even though, his philosophy was "based on improving products and services by reducing uncertainty and variability in the design and manufacturing processes" (Motwani 2001a, p. 293), and even though his early work was mainly focused on statistical quality control, he subsequently refocused on management issues (Bendell, Penson & Carr 1995), proposing his 14 points for TQM (Deming 1982). To support the implementation of the 14 points, he additionally proposed a seven-point action plan.

Anderson, Rungtusanatham & Schroeder (1994) proposed a theory of quality management based on Deming's principles. They developed the theory based on Deming's published writing and the results of a Delphi study, which included several participants who used to

personally work with Deming. They concluded that (Anderson, Rungtusanatham & Schroeder 1994, p. 473):

> *"The theoretical essence of the Deming management method concerns the creation of an organisational system that fosters cooperation and learning for facilitating the implementation of process management practices, which, in turn, leads to continuous improvement of processes, products, and services, and to employee fulfilment, both of which are critical to customer satisfaction, and, ultimately, to firm survival."*

Similarly to Deming, Juran also lectured in Japan (Bendell, Penson & Carr 1995), and argued that most quality problems are caused by the top management. He famously defined quality as "fitness for use" (Juran 1974, p. 2), thus emphasising the importance of identifying and satisfying customer needs. Juran also highlighted the costs incurred due to poor quality and used them to justify quality improvements (Bendell, Penson & Carr 1995), identifying four main aspects of quality related costs: *internal failure costs* – defects found prior to shipment, *external failure costs* – defects found after product shipment, *appraisal costs* – such as quality audits, and *prevention costs* – such as quality planning and training (Juran 1974). He also famously argued that "quality does not happen by accident, it must be planned" (Juran & Gryna 1988), thus developing his quality trilogy (Table 2.1) comprising of quality planning, quality control, and quality improvement (Juran 1988).

Table 2.1: Juran's Quality Trilogy

Quality Planning	**Quality Control**	**Quality Improvement**
• Establish quality goals. • Identify customers. • Discover customer needs. • Develop product features. • Develop process features. • Establish process controls, transfer to operations.	• Choose control subjects. • Choose units of measure. • Set goals. • Create a sensor. • Measure actual performance. • Interpret the difference. • Take action on the difference.	• Prove the need. • Identify projects. • Organise project teams. • Diagnose the causes. • Provide remedies, prove remedies are effective. • Deal with resistance to change. • Control to hold the gains.

Source: developed from (Juran & Gryna 1988)

Armand Feigenbaum has been described as the originator of total quality control (Bendell, Penson & Carr 1995). He argued that quality is the most important force in organisational success and growth and identified four main stages of total quality control: setting quality standards, appraising conformance to these standards, acting when standards are not met, and planning for improvement in these standards (Feigenbaum 1986). He argued that reductions in operating quality costs result from establishing a total quality system for two reasons: 1) the lack of existing, effective customer-oriented quality standards may mean that the current quality of products is not optimal, given their use, and 2) expenditure on

prevention costs can lead to a several fold reduction in internal and external failure costs (Bendell, Penson & Carr 1995, p. 46). Feigenbaum (1986) also identified ten benchmarks for total quality success.

Kaoru Ishikawa integrated and promoted the seven quality tools (Table 2.2) in the 1960's (Mach & Guaqueta 2001), also developing the cause and effect diagram (the Ishikawa diagram, or the fishbone diagram). He advanced the idea of company-wide quality control in Japan through the use of quality circles and various quality tools aimed at understanding the root causes of problems. According to Ishikawa (1986), "to practice quality control is to develop, design, produce and service a quality product which is most economical, most useful, and always satisfactory to the customer" (p. 44).

Table 2.2: Seven Tools of Quality

Ishikawa Diagram (Cause and Effect Diagram / Fishbone Diagram) Used to analyse potential causes of defects and sort ideas into useful categories.
Pareto Chart (Pareto Diagram / Pareto Analysis) A bar graph with longest bars on the left and the shortest to the right.
Check Sheet (Defect Concentration Diagram) A structured form for collecting and analysing data.
Control Chart (Statistical Process Control) Used to distinguish graphically between the two sources of variability.
Flowchart Graphical representation of steps in a process or activity.
Histogram Most commonly used to show frequency distributions.
Scatter Diagram (Scatter Plot / X–Y Graph) Used to investigate relationships between two variables.

Source: developed from (Tague 2004; ReVelle & Kemerling 2006)

Philip Crosby became widely known after the publication of his book "Quality is Free" (Crosby 1979). He defined quality as "conformance to requirements" (Crosby 1979, p. 15), and coined the phrases "zero defects" (p. 9), "right first time" (p. 15), and "quality is free" (p. 1). According to Motwani (2001a) "most authors endorse a 'zero defect' and a 'do it right the first time' attitude towards the quality program" (p. 295). Crosby (2005) proposed 14 steps to quality improvement and pioneered the idea of quality management maturity, proposing a quality management maturity grid (Table 2.3) in his 1979 book "Quality is Free" (Crosby 1979). The quality management maturity grid comprises of five levels and describes different aspects and stages of quality management maturity. This idea was subsequently adapted and further popularised by many organisations and researchers (Radice et al. 1985; Humphrey 1988; Paulk et al. 1993; CMU/SEI 2006).

Table 2.3: Quality Management Maturity Grid

Measurement Categories	Stage I: Uncertainty	Stage II: Awakening	Stage III: Enlightenment	Stage IV: Wisdom	Stage V: Certainty
Management understanding and attitude	No comprehension of quality as a management tool. Tend to blame quality department for "quality problems"	Recognising that quality management may be of value but not willing to provide money or time to make it happen.	While going through quality improvement program learn more about quality management; becoming supportive and helpful.	Participating. Understand absolutes of quality management. Recognise their personal role in continuing emphasis.	Consider quality management an essential part of company system.
Quality organisation status	Quality is hidden in manufacturing or engineering departments. Inspection probably not part of organisation. Emphasis on appraisal and sorting.	A stronger quality leader is appointed but main emphasis is still on appraisal and moving the product. Still part of manufacturing or other.	Quality Department reports to top management, all appraisals are incorporated and manager has role in management of company.	Quality manager is an officer of company; effective status reporting and preventative action. Involved with consumer affairs and special assignments.	Quality manager on board of directors. Prevention is main concern. Quality is a thought leader.
Problem handling	Problems are fought as they occur; no resolution; inadequate definition; lots of yelling and accusations	Teams are set up to attack major problems. Long-range solutions are not solicited.	Corrective action communication established. Problems are faced openly and resolved in an orderly way.	Problems are identified early in their development. All functions are open to suggestion and improvement.	Except in the most unusual cases, problems are prevented.
Cost of quality as % of sales	Reported: unknown Actual: 20%	Reported: 3% Actual: 18%	Reported: 8% Actual: 12%	Reported: 6.5% Actual: 8%	Reported: 2.5% Actual: 2.5%
Quality improvement actions	No organised activities. No understanding of such activities.	Trying obvious "motivational" short-range efforts.	Implementation of the 14-step program with thorough understanding and establishment of each step.	Continuing the 14-step program and starting Make Certain	Quality improvement is a normal and continued activity.
Summation of company quality posture	"We don't know why we have problems with quality"	"Is it absolutely necessary to always have problems with quality?"	"Through management commitment and quality improvement we are identifying and resolving our problems"	"Defect prevention is a routine part of our operation"	"We know why we do not have problems with quality"

Source: adopted from (Crosby 1979, pp. 32-33)

Commonalities among the Quality Gurus

Table 2.4: Commonalities among the Quality Gurus

	Crosby	**Deming**	**Feigenbaum**	**Ishikawa**	**Juran**
Customer Satisfaction	Maturity grid: from goodness and delighting the customer to satisfaction and conformance.	Customers define quality; consumers are the most important part of the production line.	Quality is what the customer says it is; customer focus is embedded in the management of quality.	Total quality control (TQC) means having a consumer orientation.	Customer satisfaction which drives market share and profits comes from product satisfaction.
Cost Reduction	The price of non-conformance means that quality is free.	Doing it right first time means less waste, less rework, and lower costs.	Controlling quality costs less than correcting mistakes.	TQC reduces cost over the long term, not the short term.	Costs of poor quality remain unknown, but they are very high.
Leadership & Top Management Commitment	Leadership by example – commitment is demonstrated by participation and attitude.	Management's job is leadership (to show constancy of purpose in their focus on quality).	Requires complete support of top management, who realise that it is not a temporary cost reduction project.	Top management commitment should be shown by adopting the lead role in implementation.	Top management's job is motivation, which includes participation in quality program.
Training & Education	Use training in quality, from the CEO down, to internalise concepts; training and education should be continuous.	Vigorous, continuous program for (re) training employees in new knowledge and skills; statistical methods to check training efficacy.	Training (on-the job, classroom, problem solving) and education are fundamental to achieving full commitment to quality.	TQC is a revolution in thinking, so training and education must be continuous for all employees (from CEO down).	To make quality happen, training should include the entire hierarchy, starting at the top: purpose of training is to create or update skills.
Teams	Use management team for quality for internal communication, quality council for internal / external communication	Cross-functional teams can create improvement in product, service, and quality and reduce costs.	Quality control committees should have representatives from all functional areas.	Cross-functional management. Committees facilitate the responsible development of quality assurance.	Major quality improvement projects are multi-functional in nature, thus requiring multifunctional teams.
Culture	Quality commitment – genuine belief by employees in importance of good quality, workmanship, good designs and service.	A new philosophy is required: drive out fear (of quotas, questioning accepted methods, etc.), and instil pride in quality	Quality control is a "spirit of Quality mindedness", from CEO to the shop floor; it is a Communication channel and means of participation.	TQC requires organisation wide participation; where there are no voluntary quality circle activities, there is no quality control.	Changing to a company-wide quality system means changing existing cultural patterns; there may well be cultural resistance.

Source: adopted from (Reed, Lemak & Mero 2000, p. 8)

2.2.2 Critical Success Factors for TQM

Numerous researchers have, over the years, proposed a wide range of critical success factors for TQM (Oliver 1988; Camp 1989; Bowen & Lawler 1992; Blackburn & Rosen 1993; Davenport 1993; Oakland 1993; Lawler 1994; Mann & Kehoe 1994; Anderson et al. 1995). Motwani (2001b) conducted a comparative analysis of six empirical studies on CSF for TQM (Saraph, Benson & Schroeder 1989; Flynn, Schroeder & Sakakibara 1994; Powell 1995; Ahire, Golhar & Waller 1996; Black & Porter 1996; Zeitz, Johannesson & Ritchie 1997), whereby he grouped similar constructs to arrive at seven factors.

Existing research shows that management commitment is vital to the success of total quality initiatives (Deming 1982; Juran & Gryna 1988; Daraph, Bensen & Schroeder 1989; Dean & Bowen 1994; Anderson et al. 1995; Flynn, Schroeder & Sakakibara 1995; Black & Porter 1996; Reed, Lemak & Mero 2000; Antony et al. 2002). What's more, Brown, Hichcock & Willard (1994) identified lack of top management commitment as one of the main reasons for the failure of TQM efforts. Hence, it has been argued that "managers at all levels… must have a positive attitude towards quality" (Sohal & Terziovski 2000, p. 166), and that top management is required to define and communicate a long-range vision, implement an action plan, and inspire and motivate the entire organisation (Anderson, Rungtusanatham & Schroeder 1994). Moreover, they should lead by example and empower and train employees to assess quality and improve processes (Deming 1982; Tenner & DeToro 1992). Thus, "it is essential that, prior to TQM implementations, all members of the board support the proposed approach" (Mann & Kehoe 1993, p. 20). Juran & Gryna (1988) identified several key top management's responsibilities, including: establishing quality policies, establishing and deploying quality goals, providing resources, training, and motivating quality improvements. Motwani (2001a) identified four areas where management's support is vital to TQM efforts: allocating budgets and resources, control through visibility, monitoring progress, and planning for change. Several authors have also argued about the importance of top management commitment to the success of software process improvement efforts (Debou & Kuntzmann-Combelles 2000; Dyba 2002; Rainer & Hall 2003), including that top management commitment is one of the most critical success factors for CMM (Paulk et al. 1993) and ISO 9000 (ISO 2005b) implementations (Stelzer & Mellis 1998).

Quality assessments allow organisations to gain insights into the current levels of quality, identify potential problem areas, and provide a basis for any potential quality

improvements (Juran & Gryna 1988). According to Motwani (2001a), “quality programs should measure the percentage or the number of parts that deviate from the acceptable in order to prevent the recurrence of a defect” (p. 295). Additional examples of performance measures could include the percentage of products needing rework, and the unit cost (Motwani 2001a). Furthermore, internal and external benchmarking can be used to compare quality within an organisation, or against the world-leaders in the field (Slack et al. 1995).

According to Gartner “worldwide IT organisations are going process mad" (Mingay & Bittinger 2005, p. 1). Process management has been defined as “a set of practices that combine methodological approaches with human resource management, [which] are implemented in order to manage and improve processes that produce products and services” (Anderson, Rungtusanatham & Schroeder 1994, p. 486). Given that organisations are “sets of interlinked processes, … improvement of these processes is the foundation of performance improvement” (Dean & Bowen 1994, p. 407). Moreover, according to Motwani (2001a), process management “emphasises adding value to processes, increasing quality levels, and raising productivity per employee” (p. 296). Deming (1982) also supported this approach, arguing against mass inspections and promoting the idea of identifying and fixing root causes of quality problems. The PDCA cycle, along with the seven quality management tools are seen as being fundamental to continuous process improvement (Deming 1982; Dale 1999).

The design stage of the system lifecycle also provides an opportunity to ensure “fitness for use”. What’s more, it has been argued that “design practices provide an ideal starting point for the study of quality performance” (Motwani 2001a, p. 298), and that product design, which is strongly rooted in customer requirements, is paramount to quality improvements (Juran & Gryna 1988). Several tools and supporting techniques for design quality assurance have also been proposed (Franceschini & Rossetto 1999).

Employee empowerment, which is comparable to the Theory Y (McGregor 1960), assumes that employees are inherently motivated and capable of performing quality work (Dean & Bowen 1994). Thus, “employees must be oriented to a company's philosophy of commitment to never-ending improvement, be informed of company goals, and be made to feel a part of the team” (Motwani 2001a, p. 298). In addition, “managers… must receive appropriate education and training” (Sohal & Terziovski 2000, p. 166). It has also been

shown that employee involvement and empowerment is critical to the quality improvement of software engineering processes (Paulk et al. 1995; Stelzer & Mellis 1998; Dyba 2002).

According to Motwani (2001a), “partnerships with suppliers have the greatest appeal to most companies due to the shared risks associated with the development of new products” (p. 298). Hackman & Wageman (1995) also argued that the development of long-term supplier partnerships is one of the main TQM implementation practices. Feigenbaum (1986), Deming (1982), Juran & Gryna (1988) stressed that choosing the right supplier is vital to TQM efforts, and Deming (1982) and Ishikawa (1986) argued that suppliers should be chosen based on quality and not on the price, since the lowest bidders may supply low quality products or services that would eventually result in greater costs. Therefore, according to Juran & Gryna (1988), various quality related costs should be added to any purchasing price.

Deming (1982) argued that the customer is the most important part of the production line. Consequently, customer focus is one of the central principles of TQM (Dean & Bowen 1994). Quality should be customer oriented, which means that it should be valued by customers and should always be directed towards their needs and expectations (Deming 1982; Tenner & DeToro 1992; Bergman & Klefsjo 1994). Internal and external customers should be treated equally in this context, since satisfying internal customers is a prerequisite to satisfying external customers (Oakland 1993; Bergman & Klefsjo 1994). Therefore, “customer service should be addressed from two main areas: internal customer service and external customer assurance” (Motwani 2001a, p. 298).

2.2.3 Six Sigma

Six Sigma, the contemporary successor of TQM, is a methodology for process improvement, based on rigorous data gathering and analysis (Porter & Tanner 2004), with an objective to create stable and manageable processes (Zarnekov, Brenner & Pilgram 2006). It was initially developed by Motorola and subsequently adopted by companies like GE, Honeywell, and Texas Instruments (ReVelle & Kemerling 2006). Six Sigma is used to identify and eliminate costs that do not add value to customers, while retaining or improving value to the customer (Porter & Tanner 2004). It has been successfully used in manufacturing as well as service companies, and it could also be applied to information management processes (Zarnekov, Brenner & Pilgram 2006). This is the case since IT production processes exhibit some of the characteristics of industrial manufacturing

processes – they are highly standardised and repeatable. The goal of Six Sigma is achieving 3.4 defects per million opportunities (Porter & Tanner 2004), which should be achieved by reducing variability. The end goal is, however, to align the processes of a company to its customers' requirements (Zarnekov, Brenner & Pilgram 2006). According to Pyzdek (2003), most organisations operate at around four sigma, or approximately 6,000 defects per million. Six Sigma uses the DMAIC methodology for process improvement, which is based on Deming's PDCA cycle (Table 2.5).

Table 2.5: Six Sigma DMAIC Process

Define	*Define the key attributes of the product or process under review.* Identify the business needs met by the process, scope the process, and identify the Critical to Quality (CTQ) characteristics of the process output and tolerance limits.
Measure	*Determine how the key attributes will be measured.* Obtain quality process data and begin analysis. Measure quality, based on the customer requirements.
Analyse	*Identify sources of variation and/or key parameters to improve the outputs.* Identify the root causes of process problems and key factors in a process.
Improve	*Remove the sources of variation and/or set key process parameters for minimum variation.* Develop appropriate process and/or product improvements while considering business needs.
Control	*Install controls to keep the process as defined and to indicate that the process has shifted.* If implemented incorrectly, could result in having to repeat the entire process.

Source: developed from (ReVelle & Kemerling 2006)

2.2.4 Summary

Total quality management has been an ongoing research subject matter for more than 50 years; however, most previous efforts have focused on product and service quality, with few references to data and information quality. Nevertheless, it is expected that most of the TQM CSFs may be relevant to the research problem explored in this thesis.

2.3 Quality Awards and Frameworks

This section provides an overview of the most widely used quality awards and frameworks. Given that this doctoral research project aims at developing an information quality management maturity model, along with the relevant assessment tools, it is considered as essential to review the content and the structure of other well-established quality models and frameworks.

Quality awards go back to 1950s, when the Union of Japanese Scientists and Engineers (JUSE) established the Deming Prize (Porter & Tanner 2004). They are all founded on TQM concepts and, today, there are several international quality awards, which specify explicit quality management criteria. What's more, over 50 countries have established

national quality awards (Milakovich 2004), and according to Calingo (2002), "there are at least 77 quality and business excellence awards being implemented in at least 69 countries and economies worldwide" (p. 4). However, according to Dutta (2007), most widely used models include Japan's Deming Application Prize, the Malcolm Baldrige National Quality Award, and the European Quality Award, where for most organisations it takes an average of three years to achieve such a performance excellence award (ReVelle & Sabelhaus 2006). In the case of the Deming Prize, the preparation period may take five years or longer (ReVelle & Sabelhaus 2006). However, many organisations are using these frameworks for self-assessment and improvement purposes (Khoo & Tan 2003; Porter & Tanner 2004), since the frameworks identify key processes which affect total quality and link these with one another, as well as the outputs and the outcomes attained (Ghobadian & Woo 1994). The quality awards generally aim to increase awareness of the importance of TQM, encourage systematic self-assessment against established criteria, prompt co-operation between organisations, stimulate sharing and dissemination of information on TQM strategies and on benefits, promote understanding of the requirements for the attainment of quality excellence and successful deployment of quality management, and encourage organisations to introduce TQM improvement process (Ghobadian & Woo 1994, p. 11).

2.3.1 The Deming Prize

Ironically, even though Deming advocated against quality awards (Porter & Tanner 2004), the Deming Prize is today one of the highest awards on TQM in the world (JUSE 2007a). It was established by the Board of Directors of the Japanese Union of Scientists and Engineers in 1951 (Deming 1982; Ghobadian & Woo 1994; Mahoney & Thor 1994; Porter & Tanner 2004), and it does not follow a set model, but encourages customised TQM implementations, assessing applicants on a case-by-case basis (JUSE 2007a). Accordingly, the Deming Prize does not specify what issues the applicants must address, but expects the applicants to identify any such issues (JUSE 2007a). It is not even generally known in the West, how assessors are trained (Porter & Tanner 2004); however, evaluation criteria are based on basic activities, unique activities, and the roles of top management (JUSE 2007b). The Deming Prize has three categories (JUSE 2007a): The Deming Prize for Individuals (for individuals or groups), The Deming Application Prize (for organisations or divisions of organisations that manage their business autonomously), and The Quality Control Award for Operations Business Units (for operations business units of an organisation). The Deming Application Prize has been awarded to nearly 200 companies since 1951, and

although the competition is open to any nation, most of the recipients have been Japanese organisations (ReVelle & Sabelhaus 2006). Many of Japan's leading manufacturers, including, Bridgestone, Hitachi, Fuji Photo, Mitsubishi Electric, Nissan, and Toyota have received Deming Prizes (Milakovich 2004). Kano, Tanaka & Yamaga (1983) compared the financial performances of Deming Prize award winning companies against the industry averages, and found that the Deming Prize award winning companies performed consistently better in every measure used in the study.

Table 2.6: The Categories of the Deming Prize (100 total points)

Management Policies and their Deployment	***20 points***
Policies and Strategies	*10 points*
Deployment of Policies	*10 points*
New Product Development and Work Process Innovation	***20 points***
Enthusiasm	*10 points*
Results	*10 points*
Maintenance and Improvement	***20 points***
Daily Management	*10 points*
Continual Improvement	*10 points*
Management Systems	***10 points***
Information Analysis and Utilisation of IT	***15 points***
Human Resources Development	***15 points***

Source: adapted from (JUSE 2007b)

Table 2.6 shows the categories of the criteria used in the Deming Prize. It can be seen that it considers Information Analysis and Utilisation of IT as a key category. Most importantly, The Guide for The Deming Application Prize makes a specific reference to information quality, requiring that "the company collects quality information from the market and within its organisation in an organised manner and utilises it effectively" (JUSE 2007b, p. 35). Each criterion is evaluated against four different perspectives, assessing effectiveness, consistency, continuity, and thoroughness (JUSE 2007b).

2.3.2 Japan Quality Award

The Japan Quality Award (JQA), which is based on the Malcolm Baldrige Model, was set up by the Japan Productivity Centre for Socio-Economic Development (JPC-SED) in 1995. It is administered by the Japan Quality Award Council, which comprises of more than 300 corporate members and 800 individual members (APO 2002). The award is customer focused, employee oriented, focusing on individual capability and social responsibility (APO 2002). It is underpinned by 11 core values, which are similar to the Baldrige Award's core values (APO 2002). JQA also specifically addresses information management and analysis in the overall framework (Figure 2.2). The assessment, which is maturity model based, specifies six levels and is based on the approach, the deployment, and the results (APO 2002).

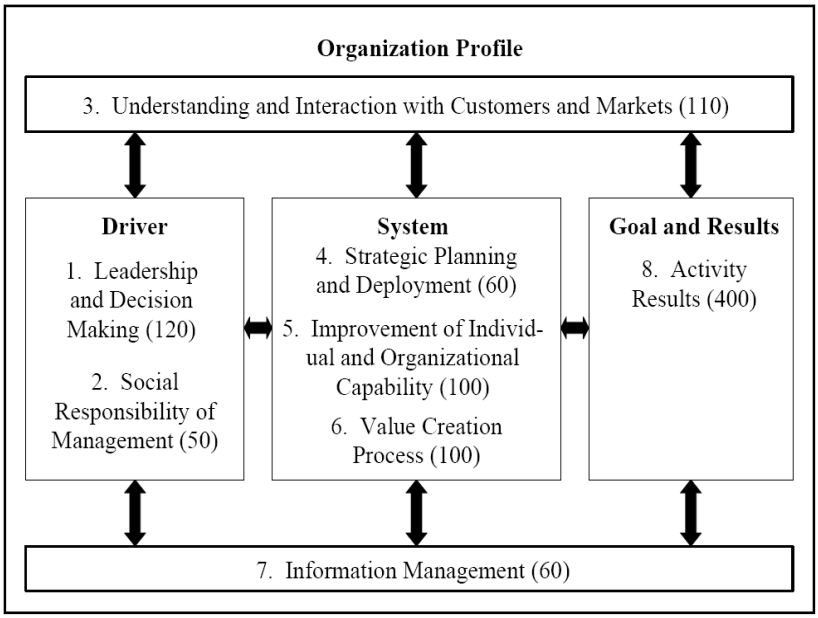


Figure 2.2: Japan Quality Award
Source: adopted from (APO 2002, p. 86)

2.3.3 Singapore Quality Award

The Singapore Quality Award (SQA) was introduced in 1994 (Porter & Tanner 2004). The framework itself is heavily based on the Malcolm Baldrige National Quality Award, the European Quality Award, and the Australian Business Excellence Award. Table 2.7 shows that SQA award criteria address information management along with the relevant comparisons and benchmarking.

Table 2.7: SQA Award Criteria Weightage (1000 total points)

Leadership	Senior Executive Leadership	*50 points*
(120 points)	Organisational Culture	*50 points*
	Responsibility to Community and the Environment	*20 points*
Planning	Strategy Development and Deployment	*80 points*
(80 points)		
Information	Management of Information	*55 points*
(80 points)	Comparison and Benchmarking	*25 points*
People	Human Resource Planning	*20 points*
(110 points)	Employee Involvement and Commitment	*20 points*
	Employee Education, Training and Development	*30 points*
	Employee Health and Satisfaction	*20 points*
	Employee Performance and Recognition	*20 points*
Processes	Innovation Process	*40 points*
(100 points)	Process Management and Improvement	*40 points*
	Supplier and Partnering Process	*20 points*
Customers	Customer Requirements	*40 points*
(110 points)	Customer Relationship	*40 points*
	Customer Satisfaction	*30 points*
Results	Customer Results	*140 points*
(400 points)	Financial and Market Results	*90 points*
	People Results	*80 points*
	Operational Results	*90 points*

Source: adopted from (SPRING 2007)

2.3.4 Malcolm Baldrige National Quality Award

The award was launched in 1987, after the US Congress passed the Malcolm Baldrige National Quality Improvement Act (Ghobadian & Woo 1994). The award, which is perhaps the best-known and most widely used quality model, focuses on continually delivering improved value to customers and shareholders, improving overall organisational effectiveness and capabilities, and organisational and personal learning (Porter & Tanner 2004; BNQP 2007). Hackman & Wageman (1995) argued that Baldrige Award winners have actually implemented the full TQM package. However, others have argued that TQM is a never ending process. MBNQA is one of the most widely used self assessment quality management frameworks (Porter & Tanner 2004), and it has inspired the creation of forty-five state sponsored "mini Baldrige" programs in the USA (Milakovich 2004). A maximum of two MBNQA, in each of five categories (manufacturing, healthcare, education, service, and small business) are awarded every year (Milakovich 2004), and winners are required to publicly share their quality management strategies, so that other organisation can learn from best practices (Milakovich 2004; BNQP 2007). 'The Quest for Excellence', the annual conference of the Malcolm Baldrige National Quality Award provides an opportunity for award recipients to share their practices with other organisations (BNQP 2007). Furthermore, each award applicant receives a feedback report at the conclusion of the review process (BNQP 2007).

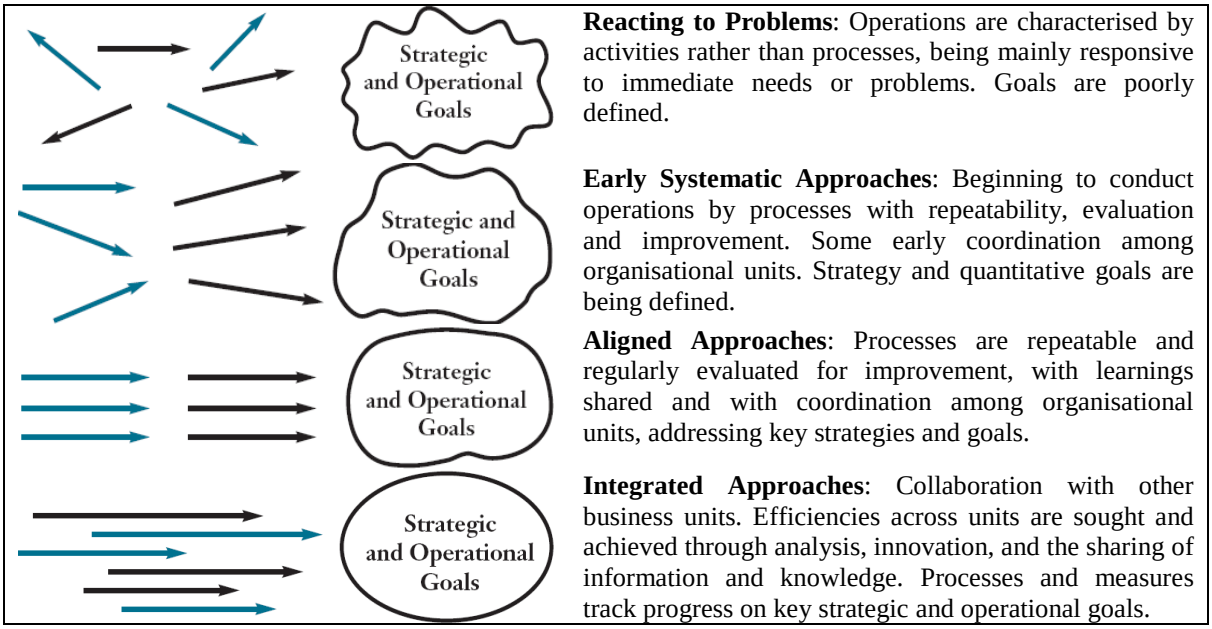
The American General Accounting Office conducted a comprehensive study on the benefits of the practices addressed in the Baldrige Award (GAO 1991). They reviewed twenty highest scoring Baldrige Award applicants from 1988 and 1989, concluding that "companies that adopted quality management practices experienced an overall improvement in corporate performance, … achieved better employee relations, higher productivity, greater customer satisfaction, increased market share, and improved profitability" (GAO 1991, p. 5). Wisner & Eakins (1994) analysed the financial and competitive performances of 17 organisations that won the Baldrige Award between 1987 and 1994. They found that "the Baldrige Award winners provide examples that investments in quality programmes can result in cost savings, market share improvement, and impressive improvements in manufacturing and service performance" (Wisner & Eakins 1994, p. 9). However, in a recent study, Przasnyski & Tai (2002) analysed the impact of the MBNQA on the stock performance of its recipients from 1988 1998, and found that Baldrige winners under-performed by 17% compared to non-winning organisation of similar type and risk.

Table 2.8: Baldrige Categories and Items

Leadership	Senior Leadership	*70 points*
(120 points)	Governance and Social Responsibilities	*50 points*
Strategic Planning	Strategy Development	*40 points*
(85 points)	Strategy Deployment	*45 points*
Customer and Market Focus	Customer and Market Knowledge	*40 points*
(85 points)	Customer Relations and Satisfaction	*45 points*
Measurement, Analysis and Knowledge Management	Measurement, Analysis and Improvement of Organisational Performance	*45 points*
(90 points)	Management of Information, Information Technology and Knowledge	*45 points*
Workforce Focus	Workforce Engagement	*45 points*
(85 points)	Workforce Environment	*40 points*
Process Management	Work Systems Design	*35 points*
(85 points)	Work Process Management Improvement	*50 points*
Results	Product and Service Outcomes	*100 points*
(450 points)	Customer-Focused Outcomes	*70 points*
	Financial and Market Outcomes	*70 points*
	Workforce-Focused Outcomes	*70 points*
	Process Effectiveness Outcomes	*70 points*
	Leadership Outcomes	*70 points*

Source: developed from (BNQP 2007)

The 'Management of Information, Information Technology and Knowledge' section (Table 2.8) specifically deals with the issue of information quality, addressing accuracy, integrity, reliability, timeliness, security and confidentiality (BNQP 2007). Furthermore, all of the criteria are evaluated against two dimensions: *processes* (approach, deployment, learning, and integration), and *results* (outputs and outcomes). The award also specifies four steps toward mature processes (Figure 2.3).



Reacting to Problems: Operations are characterised by activities rather than processes, being mainly responsive to immediate needs or problems. Goals are poorly defined.

Early Systematic Approaches: Beginning to conduct operations by processes with repeatability, evaluation and improvement. Some early coordination among organisational units. Strategy and quantitative goals are being defined.

Aligned Approaches: Processes are repeatable and regularly evaluated for improvement, with learnings shared and with coordination among organisational units, addressing key strategies and goals.

Integrated Approaches: Collaboration with other business units. Efficiencies across units are sought and achieved through analysis, innovation, and the sharing of information and knowledge. Processes and measures track progress on key strategic and operational goals.

Figure 2.3: Steps toward Mature Processes
Source: developed from (BNQP 2007, p. 54)

2.3.5 Canadian Framework for Business Excellence

The Canada Awards for Excellence were introduced in 1984. The framework was revised in 1989 to reflect the Baldrige Model (Porter & Tanner 2004), which has led to the development of the Canadian Framework for Business Excellence (NQI 2007). The framework is supported by a ten step 'Roadmap to Excellence' (Table 2.9).

Table 2.9: Canadian Framework Road Map to Business Excellence

1	**Support the Principles.** Review the principles and discuss within organisation how they should be implemented.
2	**Understand & Review the Framework.** Set up a small team, review and study the Canadian framework. The organisation should familiarise itself with the contents and the scope.
3	**Take the NQI Assessment.** Conduct a check-up, using the NQI assessment and reach consensus on how existing practices are currently working. Identify any gaps.
4	**Develop the Improvement Plan.** Communicate with customers and partners about their needs. Gain consensus about the priority areas for improvement. Plan improvement actions.
5	**Spread the Message.** Communicate the principles, framework, and the commitment to continuous improvement.
6	**Put the Improvement Plan into Action.** Put the plan, developed in step 4, into action. Be very clear about the goals, and train staff in the use of quality improvement tools and methods.
7	**Monitor the Improvement Plan.** Monitor and evaluate the progress made towards meeting the goals of the improvement plan.
8	**Take the NQI Assessment.** Conduct another NQI assessment, to measure progress since the previous assessment.
9	**Maintain the Gains:** Apply quality assurance approaches to every aspect of the organisation.
10	**Focus on Continuous Improvement.** Maintain the commitment to continuous improvement and make the Canadian framework part of the organisation's culture.

Source: adopted from (Porter & Tanner 2004)

2.3.6 Australian Business Excellence Framework

The Australian Business Excellence Awards were introduced in 1987 by the Australian Quality Council (AQC) (Porter & Tanner 2004; SAI_GLOBAL 2007), which were acquired by Standards Australia International (SAI) in 2002. The framework is compatible with the Baldrige and EFQM models and contains all requirements of the ISO 9004:2000 system (SAI_GLOBAL 2007). The 2004 framework (SAI_GLOBAL 2004) was extensively updated in 2007 (SAI_GLOBAL 2007), and the number of 'principles' has been reduced, from 12 to eight. According to SAI Global, the aim of the Australian Business Excellence Framework is to create an environment for continuous improvement (SAI_GLOBAL 2007). It is applicable to all organisations (small, large, public, and private), without any distinction between private and public organisations (Vogel 2002). The Australian Business Excellence Framework (Table 2.10) is based on eight principles, which are interpreted using seven categories and 17 sub-categories (SAI_GLOBAL 2007). The categories form a structure that organisations can use to review and analyse their leadership and management system.

Table 2.10: Australian Business Excellence Framework

Principles	**Leadership** Leading by example, providing clear direction, building organisational alignment, and focusing on sustainable achievement of goals.		
	Customers Driving strategy based on the understanding of market's and customers' current and future requirements.		
	Systems Thinking Viewing the organisation as a system. Continuously improving the system.		
	People Developing and valuing peoples' capabilities, skills, and creativity.		
	Continuous Improvement Agility, adaptability, and responsiveness, based on a culture of continuous improvement, innovation and learning.		
	Information and Knowledge Improving organisational performance through the use of data, information, and knowledge.		
	Corporate and Social Responsibility Behaving in an ethically, socially, and environmentally responsible manner.		
	Sustainable Results Focusing on sustainable results, value and outcomes.		
Categories	**Leadership** *(180 points)*	Leadership throughout the organisation Leading the organisational culture Society, community & environment responsibility	*60 points* *60 points* *60 points*
	Strategy & Planning *(100 points)*	Strategic direction The planning process	*50 points* *50 points*
	Information & Knowledge *(100 points)*	Generating, collecting and analysing the right data to inform decision-making Creating value through applying knowledge	*50 points* *50 points*
	People *(160 points)*	A great place to work Building organisational capability through people	*80 points* *80 points*
	Customer & Market Focus *(150 points)*	Gaining and using knowledge of customers and markets Effective management of customer relationships Customer perception of value	*60 points* *50 points* *40 point*
	Process Management, Improvement & Innovation *(160 points)*	Identification and management of processes Process improvement and innovation Process outputs	*50 points* *60 points* *50 points*
	Success and Sustainability *(150 points)*	Measuring and communicating organisational performance Achieving sustainability	*100 points* *50 points*

Source: developed from (SAI_GLOBAL 2007)

The assessment is based on four dimensions: approach, deployment, results, and improvement (Vogel 2002; Porter & Tanner 2004; SAI_GLOBAL 2007), which appear to be analogous to Shewhart's PDCA cycle (Table 2.11).

Table 2.11: The Learning Cycle

Approach	*Thinking and Planning* What is the intent? What goals have been established? What strategies and KPIs have been developed?
Deployment	*Implementing and Doing* How have the strategies been implemented? What is the scope of the implementation?
Results	*Monitoring and Evaluating* How are the KPIs performing?
Improvement	*Learning and Adapting* What has been learned?

Source: developed from (SAI_GLOBAL 2007)

2.3.7 European Foundation for Quality Management Excellence Model

The European Foundation for Quality Management (EFQM), which was originally set up in 1988 by 14 large European companies, today has more than 600 European organisations as its members (itSMF 2005). As a result, over 1000 people were involved in the development of the EFQM Excellence Model and the award process (Porter & Tanner 2004). The objective of the EFQM is to "promote Total Quality Management, aimed at excelling in customer satisfaction, employee satisfaction, appreciation by society, and performance results" (itSMF 2005, p.19). Even though, the European model adopted many aspects of the Deming Prize and the Baldrige Award, it is more 'business focused' (Porter & Tanner 2004), allocating 500 points to both enablers and results (Figure 2.4). Enablers deal with the organisation's approach to running the business, and results refer to the achievements or outcomes. The Model comprises of nine criteria, comprising of 32 parts, which contain around 300 further guidance points. The European Foundation for Quality Management Excellence Award, Europe's most prestigious Award for Business Excellence (EFQM 2007), was launched in 1991 (Ghobadian & Woo 1994). The award process provides a detailed feedback report to all award applicants (Porter & Tanner 2004). The CII-EXIM Bank Award for Business Excellence, which is perceived in India as the most prestigious award for Indian companies (Dutta 2007), as well as the Iberoamerican and the UK Business Excellence Award are based on the EFQM (Porter & Tanner 2004; FUNDIBEQ 2007).

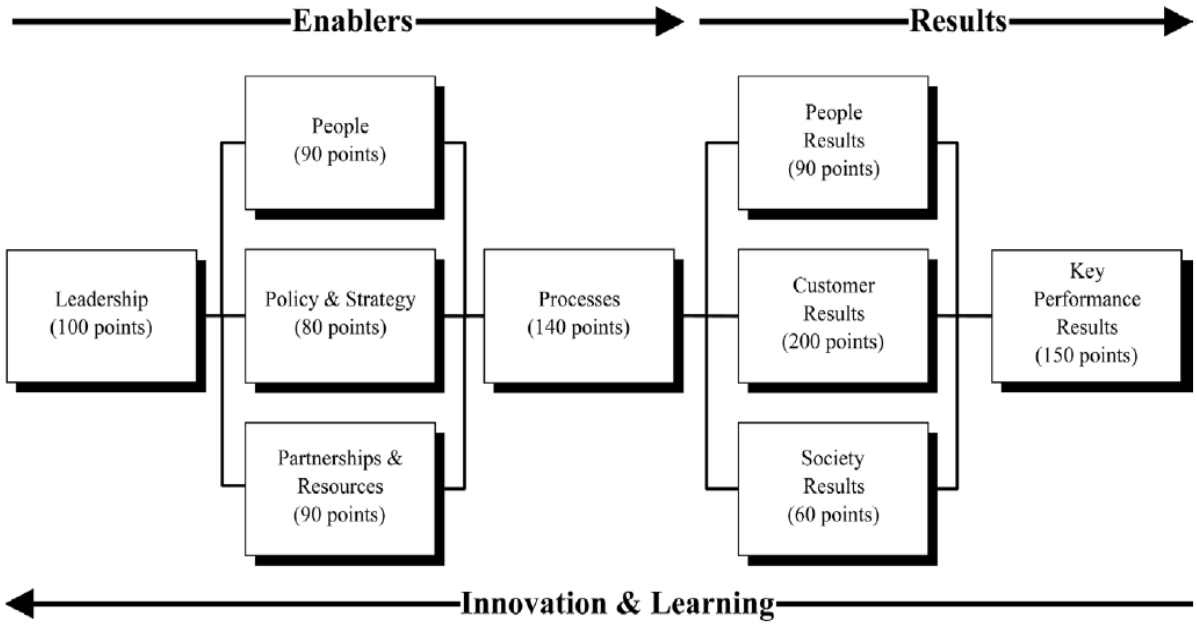


Figure 2.4: The EFQM Excellence Model
Source: adopted from (Eskildsen, Kristensen & Juhl 2001, p. 784)

2.3.8 Summary

Table 2.12 compares the criteria from each of the quality models presented in the previous sections.

Table 2.12: Comparison of Quality Model Criteria

Deming Prize	JQA	SQA	MBNQA	CQA	ABEA	EQA
• Management Policies and Deployment • Product Development and Work Process Innovation • Maintenance and Improvement • Management Systems • Information Analysis and Utilisation of IT • Human Resources	• Leadership • Social Responsibility • Customer and Market Understanding • Strategic Planning and Deployment • Capability Improvement • Value Creation • Information Management • Activity Results	• Leadership • Planning • Information • People • Process • Customers • Results	• Leadership • Strategic Planning • Customer and Market Focus • Measurement, Analysis and Knowledge Management • Human Resource Focus • Process Management • Business Results	• Leadership • Planning • Customer Focus • People Focus • Process Management • Partnership • Business Performance	• Leadership and Innovation • Strategy and Planning Processes • Data, Information and Knowledge • People • Customer and Market Focus • Processes Products and Services • Organisational Results	• Leadership • Policy and Strategy • People • Partnerships and Resources • Processes • Customer Results • People Results • Society Results • Key Performance Results

Source: devloped from (Eskildsen, Kristensen & Juhl 2001; APO 2002; Porter & Tanner 2004; BNQP 2007; JUSE 2007a; JUSE 2007b; NQI 2007; SAI_GLOBAL 2007; SPRING 2007)

Most of the quality models reviewed in this section placed a focus on similar themes, including, customer focus, process management, and quality measurements/improvements. Most importantly, they were not only directed toward product or service quality, but also considered organisational, technological, and social factors. Therefore, the research effort conducted in this doctoral project shall also focus on a wide range of factors that may be relevant to information quality management, as opposed to focusing only on the technological issues.

2.4 Quality Standards and Best Practices

This section presents a comprehensive literature review of relevant quality management standards and best practice frameworks, including, ISO 9000, ISO 15504, CMM, CMMI, CobiT, ITIL, and ANSI/GEIA 859. These best practice frameworks provide detailed measurement and benchmarking guidelines, and are thus very relevant for this doctoral research project.

According to ReVelle & Sabelhaus (2006), certifying quality systems to an industry or international standard has become the norm throughout the world. Certifications may be performed by an external and independent third-party, which may then issue a certificate and list the organisation in a register of certified companies. The term *certification* is mainly used in Europe and Australia, while USA mainly uses the term *registration* (ReVelle & Sabelhaus 2006). Drivers for the use of IT best practices include better returns from IT investments, need to better control an ever increasing IT expenditure, need to meet regulatory requirements (e.g. Sarbanes-Oxley Act and Basel II), increasing IT risks, IT governance issues, and the like, while some benefits of the use of best practices include improving quality, enhanced standardisation, cost and risk reduction, and improved management (ITGI 2003). According to Mingay & Bittinger (2005), the goal of process improvement should not be to implement a framework (such as ITIL, CobIT, CMMI, or ISO 9000), but to tangibly increase the quality, efficiency and effectiveness. However, some organisations may become "overly focused on doing the minimum required to get the certification at the expense of the broader, but more important issue of driving improved performance" (Mingay & Bittinger 2005, p. 3). Nevertheless, according to Gartner, "the alignment of IT operations, processes and controls with these standards and frameworks is bringing some organisations added business benefits in quality, reduced rework and reliability" (Caldwell et al. 2007, p. 4).

2.4.1 ISO 9000

The International Organisation for Standardisation is the world's largest developer of technical standards (ReVelle & Sabelhaus 2006, p. 618). It has 148 member countries, with one representative per country, and has a Central Secretariat in Geneva, Switzerland to coordinate its activities (ReVelle & Sabelhaus 2006). ISO 9000 is one of the most widely used and fastest growing quality frameworks in the world (Milakovich 2004; Porter & Tanner 2004), and because any acronym for the organisation would be different in the different languages (ReVelle & Sabelhaus 2006), ISO is not an acronym, but the shortened

Greek word for equal (Milakovich 2004). ISO initially published the standards in 1987, revised them in 1994, and then republished an updated version in 2000 (Cater-Steel, Tan & Toleman 2006, p.16; ReVelle & Sabelhaus 2006). The 1994 version mainly focused on the documentation of the quality requirements, with little focus on the resulting product quality, while the 2000 version presented quality management in a systems approach, addressing processes with inputs and outputs that interact with other processes (ReVelle & Sabelhaus 2006). The new version also placed an increased emphasis on customer focus and thus product quality (ReVelle & Sabelhaus 2006). ISO 9000 comprises of three quality standards (Table 2.13): ISO 9000:2000, ISO 9001:2000, and ISO 9004:2000. ISO 9001:2000 documents requirements for a quality management system, focusing on the effectiveness of the quality management system in meeting customer requirements (SAI 2001), while ISO 9000:2000 and ISO 9004:2000 present guidelines. ISO 9004 gives guidance on a wide range of objectives of a quality management system, including, continual improvement of performance, efficiency, and effectiveness (SAI 2001). According to ISO (2001), "the adoption of a quality management system should be a strategic decision of an organisation" (p. 10), since an ISO 9001 registration typically takes 12 to 18 months to complete (ReVelle & Sabelhaus 2006). Furthermore, it has been reported that up to the end of 2005, at least 777,608 ISO 9001:2000 certificates had been issued in 161 countries (ISO 2006b). This represented an increase of more than 18% compared to 660,132 ISO 9001:2000 certifications in 154 countries in 2004.

Table 2.13: Main Components of the ISO 9000:2000 Series

ISO 9000:2000	*Fundamentals and Vocabulary:* Describes the fundamentals of quality management systems and specifies the relevant terminology.
ISO 9001:2000	*Quality Management System Requirements:* Specifies the requirements for a quality management system.
ISO 9004:2000	*Guidelines for Performance Improvements:* Provides guidelines that consider both the effectiveness and efficiency of a quality management system.
ISO 19011:2000	*Guidelines for Auditing:* Provides guidance on auditing quality and environmental management systems.

Source: adopted from (Porter & Tanner 2004)

The new ISO 9000 2000 standards are based on eight quality management principles (ISO 2006a), which are closely related to the Baldrige core values (ReVelle & Sabelhaus 2006). ISO 9001 requires organisations to develop their quality management systems according to a set of specific requirements (SAI 2001), where all the requirements are generic and are intended to be applicable to all organisations. The ISO 9000 process based quality management system (SAI 2001) illustrates that customers play a significant role by providing the requirements. The system also subsequently monitors customer satisfaction.

Furthermore, a quality system that complies with the ISO 9000 standard ensures that the supplier has taken measures to be able to provide the quality agreed with the customers; that the management regularly assesses the operation of the quality system, and uses the results for further enhancements; that the procedures are documented and communicated; that customer complaints are recorded, addresses promptly, and used to improve the service; and that the supplier controls the production processes and can improve them (itSMF 2005). ISO 9001, among others, can also be used to specify requirements for the control of documents, including procedures to: approve documents for adequacy prior to use, review and update as necessary and re-approve documents, ensure that changes and the current revision status of documents are identified, ensure that relevant versions of applicable documents are available at points of use, ensure that documents remain legible and readily identifiable, ensure that documents of external origin are identified and their distribution controlled, and prevent the unintended use of obsolete documents and to apply suitable identification to them if they are retained for any purpose (SAI 2001).

2.4.2 ISO/IEC 15504

The Software Process Improvement and Capability dEtermination (SPICE) initiative was created to support the development of an international standard for software process assessment (Dorling 1993). This effort eventually led to the empirically validated (ElEmam & Birk 2000) ISO/IEC 15504 standard, which has been adapted to become a generic process assessment standard. The Software Engineering specific process dimension has been moved to the ISO 12207 Process Reference Model, which defines the Software Life Cycle Processes (ISO/IEC 1995). ISO TR 15504 was first published in 1998, and the full publication of ISO/IEC 15504 was in 2004. The standard comprises of five documents. ISO/IEC 15504-1 (2005a) provides an introduction and a glossary for the assessment related terms. ISO/IEC 15504-2 (2004a) defines a measurement framework and specifies the minimum requirements for performing an assessment. ISO/IEC 15504-3 (2004b) provides guidance for interpreting the requirements for performing an assessment. ISO/IEC 15504-4 (2005b) provides guidance on use for process improvement and process capability determination. And ISO/IEC 15504-5 (2006) contains an exemplar process assessment model based upon ISO 12207. The standard is aimed at process capability determination, which may provide drivers for prioritising process improvements (ISO/IEC 2005a). An assessment process normally gets initiated by an assessment sponsor. Then, the assessment input is compiled, defining the purpose, scope, constraints, roles and responsibilities, and the like. The assessment is then performed by evaluating processes

against the assessment model, which has to be compatible with the requirements specified in ISO/IEC 15504-2. The subsequent assessment output includes a set of process profiles and capability level ratings. The two dimensional Process Assessment Model comprises of a Process Reference Model (a set of processes, defined in terms of their purpose and outcomes), and a Measurement Framework (containing process attributes, which apply across all processes and are grouped into capability levels).

2.4.3. Capability Maturity Model

Crosby's Quality Management Maturity ideas (Crosby 1979) were first adapted to the software engineering discipline by IBM under the leadership of Watts Humphrey in 1985 (Radice et al. 1985). The US Department of Defence (DoD) formed the Software Engineering Institute (SEI) at Carnegie Mellon University (CMU) in 1984 "to establish standards of excellence for software engineering and to accelerate the transition of advanced technology and methods into practice" (Humphrey 1988, p. 73). Watts S. Humphrey, the founder of the Software Process Program of the SEI, then adapted the quality management maturity ideas to the domain of software engineering. He identified 'predictability' as one of the main characteristics of an ideal software process (Humphrey 1988), so that the cost and the schedule estimates can be met with reasonable consistency, and that the quality of the resulting products generally meets user needs. Humphrey (1988) proposed five levels of software engineering process maturity (p. 74):

- Initial – until the process is under statistical control, no orderly progress in process improvement is possible;
- Repeatable – a stable process with a repeatable level of statistical control;
- Defined – the organisation has defined the process, to ensure consistent implementation and provide a basis for better understanding;
- Managed – comprehensive process measurements, beyond those of cost and schedule performance; and
- Optimising – the organisation now has a foundation for continued improvement and optimisation of the process.

The original Capability Maturity Models (CMM) was developed by the SEI, beginning in 1986. CMM has been extensively used by the US DOD to evaluate its software and system developers and the current CMM release (which has now been retired), version 1.1, was made available in February 1993. It is a methodology used to develop and refine an organisation's software development process, by establishing a framework for continuous

process improvement and defining the means to be employed to that end. CMM describes five maturity levels, which represent an evolutionary path of increasingly structured and methodically more mature processes.

However, several authors, including (Brodman & Johnson 1994; Herbsleb & Goldenson 1996; Fitzgerald & O'Kane 1999) have criticised CMM as being incomplete, not universally applicable, or producing excessive bureaucracy. On the other hand, other authors have shown that the implementation of CMM can lead to benefits, including, cost reduction, productivity improvements, and increased quality (Basili & Green 1994; Lawlis, Flowe & Thordahl 1995; McGibbon 1999; Pitterman 2000). Brodman & Johnson (1997) identified a number of problems experienced by over 200 small organisations/projects in the US with their software process improvement initiatives based on the CMM. The problems included documentation overload, unrelated management structure, inapplicable scope of reviews, high resource requirements, high training costs, lack of need guidance, and unrelated practices. Other researchers have questioned the suitability of large-scale methodologies to smaller software development groups, arguing that “smaller groups need some of the software methodologies developed for large-scale projects, but they don’t need all of them” (Fayad, Laitinen & Ward 2000, p. 116). Jung & Goldenson (2002) evaluated the internal consistency (reliability) of CMM key process areas, by examining the dimensions underlying the maturity construct. The analysis was based on 676 CMM-Based Appraisal for Internal Process Improvement (CBA IPI) assessments conducted from 2000 to 2002. They found that the SW-CMM maturity is a three dimensional construct, where level 2 Key Process Areas (KPAs) were closely correlated and thus can be treated as a single dimension. Level 3 KPAs had the same result, but level 4 and 5 KPA were combines under a single dimension. Countless other maturity models, for various disciplines, have followed CMM, including, the E-Business Resilience Maturity Model (Duffy 2001), Testing Maturity Model (Burnstein et al. 1998), Verification and Validation Maturity Model (Jacobs & Trienekens 2002), Requirements Engineering Maturity Model (Niazi 2005), Software System Documentation Maturity Model (Visconti & Cook 1993; Visconti & Cook 1998), and the like.

2.4.4 Capability Maturity Model Integration

The Capability Maturity Model Integration (CMMI) is the successor of the Capability Maturity Model (CMM). It was initially created through the merger of several Capability Maturity Models (Figure 2.5), including, the Software CMM, Systems Engineering CMM,

and Integrated Product Development CMM. Currently, there are two versions: CMMI for Development (CMU/SEI 2006), and CMMI for Acquisition (CMU/SEI 2007). The CMMI for Development addresses product and service development processes, while the CMMI for Acquisition addresses acquisition and outsourcing processes.

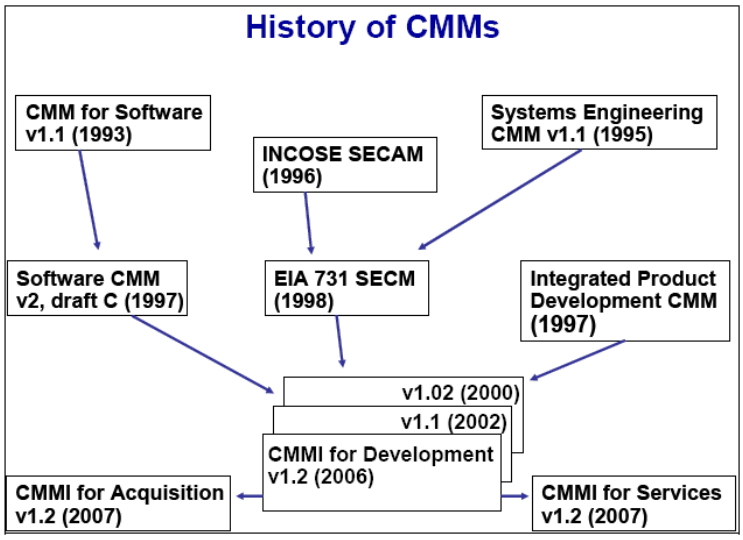


Figure 2.5: History of CMMs
Source: adopted from (CMU/SEI 2006, p. 7)

The CMMIs for Development and Acquisition each comprise of 22 process areas (CMU/SEI 2006). Each process area has specific goals, which only apply to that process area, as well as generic goals, which apply across process areas. Goals are made up of practices and sub-practices, thus creating a hierarchical structure.

2.4.5 Control Objectives for Information and Related Technology

The first version of Control Objectives for Information and Related Technology (CobiT) was developed by the International Systems Audit and Control Foundation (ISACF) in 1996 (ITGI 2006a). ISACF changed its name to Information Technology Governance Institute (ITGI) in 2003 (Cater-Steel, Tan & Toleman 2006). CobiT is aimed at all types of organisations, including, public and private companies (ITGI 2006a), and it is "frequently used as part of compliance (particularly Sarbanes-Oxley), governance, or quality improvement programs" (Caldwell et al. 2007, p. 30). The ITGI defines IT governance in the following manner (ITGI 2006a, p. 11):

> *"IT governance is the responsibility of the board of directors and executive management. It is an integral part of enterprise governance and consists of the leadership and organisational structures and processes that ensure that the organisation's IT sustains and extends the organisation's strategies and objectives."*

According to Gartner, “the third edition of CobiT became a de facto standard IT control framework” (Mingay 2005, p. 7), and it is widely used in industry (Cater-Steel, Tan & Toleman 2006), even though the academic literature on it has been somewhat sparse (Liu & Ridley 2005). It specifically addresses the following information quality criteria: effectiveness, efficiency, confidentiality, integrity, and availability (ITGI 2006a, p. 14). COSO, a related internal control framework, deals with the following information quality dimensions: *appropriateness* – is it the right information?, *timeliness* – is it available when required and reported in the right period of time?, *currency* – is it the latest available?, *accuracy* – are the data correct?, and *accessibility* – can authorised individuals gain access to it as necessary? (ITGI 2006b, p. 25). CobiT covers operational, tactical, and strategic processes, detailing 34 high-level control objectives, one for each of the IT processes, grouped into four domains: Plan and Organise, Acquire and Implement, Deliver and Support, and Monitor and Evaluate (ITGI 2006a). It also provides a generic multidimensional maturity model (Table 2.14), which may help organisations with “benchmarking and identification of necessary capability improvements” (ITGI 2007, p. 17), thus providing them with a relative measure of where the enterprise is, a manner to efficiently decide where to go, and a tool for measuring progress against the goal. However, there is some overlap between CobiT and CMMI. The CobiT processes highlighted in dark blue in Figure 2.6 are also addressed by CMMI.

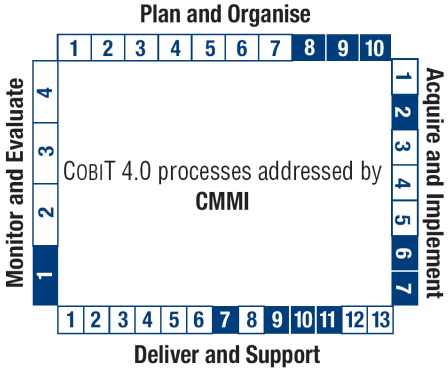


Figure 2.6: CobiT 4.0 Processes Addressed by CMMI 1.1
Source: adopted from (ITGI 2006a, p. 57)

A large number of CobiT control objectives are applicable to information quality management. The relevant CobiT 4.0 control objectives have been summarised in Appendix C.

Table 2.14: CobiT Maturity Attribute Table

	Awareness and Communication	Policies, Plans and Procedures	Tools and Automation	Skills and Expertise	Responsibility and Accountability	Goal Setting and Measurement
Level 1	Recognition of the need for the process is emerging. Sporadic communication of issues.	Ad hoc approaches to processes and practices. The process and policies are undefined.	Usage based on standard desktop tools. No planned approach to the tool usage.	Skills required for the process are not identified. No training plan and no formal training.	No accountability and responsibility. Ownership of issues based on own initiative on a reactive basis.	Goals are not clear and no measurement takes place.
Level 2	Awareness of the need to act. Management communicates the overall issues.	Some aspects of the process are repeatable. Some documentation and informal understanding of policy and procedures may exist.	Solutions developed by key individuals. Vendor tools are probably not applied correctly.	Minimum skill requirements are identified for critical areas. Training is provided in response to needs. Informal training on the job.	There is confusion about responsibility when problems occur. A culture of blame tends to exist.	Some goal setting. Some financial measures established but are known only by senior management. Inconsistent / isolated monitoring.
Level 3	Understanding of the need to act. Management is more formal and structured in its communication.	Usage of good practices emerges. The process, policies and procedures are defined and documented for all key activities.	Tools are being used for their basic purposes, but may not all be in accordance with the plan, and may not be integrated.	Skill requirements are defined and documented for all areas. A formal training plan has been developed, but formal training is still based on individual initiatives.	Process responsibility and accountability are defined and process owners have been identified. The process owner is unlikely to have the full authority to exercise the responsibilities.	Some goals and measures are set, but are not communicated, and there is a clear link to business goals. IT balanced scorecard and root cause analysis ideas are being adopted.
Level 4	Understanding of the full requirements. Mature communication techniques are applied and standard communication tools are in use.	The process is sound and complete. All aspects of the process are documented and repeatable. Policies have been approved and signed off on by management. Standards for developing and maintaining the processes and procedures are adopted and followed.	Tools are implemented according to a standardised plan, and some have been integrated with other related tools. Tools are being used in main areas to automate management of the process and monitor critical activities and controls.	Skill requirements routinely updated, proficiency is ensured, and certification is encouraged. Mature training techniques are applied, and knowledge sharing is encouraged. All internal domain experts are involved, and the effectiveness of the training plan is assessed.	Process responsibility and accountability are accepted and working in a way that enables a process owner to fully discharge his/her responsibilities. A reward culture is in place that motivates positive action.	Efficiency and effectiveness are measured, communicated and linked to business goals and the IT strategic plan. The IT balanced scorecard is implemented in some areas. Root cause analysis is being standardised. Continuous improvement is emerging.
Level 5	Advanced, forward-looking understanding of requirements. Proactive communication of issues. Mature communication techniques are applied, and integrated communication tools are in use.	External best practices and standards are applied. Process documentation is evolved to automated workflows. Processes, policies and procedures are standardised and integrated to enable end-to-end management and improvement.	Standardised tool sets are used across the enterprise. Tools are fully integrated with other related tools to enable end-to-end support of the processes. Tools are being used to support improvement of the process and automatically detect control exceptions.	Continuous improvement of skills, based on clearly defined goals. Training and education support external best practices and use of leading-edge concepts and techniques. Knowledge sharing is an enterprise culture, and. External experts and industry leaders are used for guidance.	Process owners are empowered to make decisions and to take action. The acceptance of responsibility has been cascaded down throughout the organisation in a consistent fashion.	There is an integrated performance measurement system linking IT performance to business goals by the global application of the IT balanced scorecard. Exceptions are globally and consistently noted by management and root cause analysis is applied. Continuous improvement is a way if life.

Source: adapted from (ITGI 2007, p. 21)

2.4.6 Information Technology Infrastructure Library

Information Technology Infrastructure Library (ITIL) is a framework of best practices that addresses a wide range procedures for IT service management (itSMF 2005). It was developed by the Office for Government Commerce (OGC) in England and it originated as a collection of 31 books (in version 1). ITIL addresses service support and delivery, and it provides comprehensive checklists, tasks, procedures and responsibilities that can be customised based on the need of the organisation. It is "a well-established framework that's been around for almost 20 years" (Caldwell et al. 2007, p. 25), and it is being used by "many organisations to improve important IT services and the governance of IT operations" (Caldwell et al. 2007, p. 4).

> *"The quality of a service refers to the extent to which the service fulfils the requirements and expectations of the customer. To be able to provide quality, the supplier should continuously assess how the service is experienced and what the customer expects in the future… The results of the assessment can be used to determine if the service should be modified." (itSMF 2005, p.16).*

ITIL may help align IT services with business goals, by providing non-proprietary, vendor/technology neutral guidance, based on best practices. Furthermore, several other IT service management frameworks have been based on ITIL, including, Hewlett-Packard's HP-ITSM Reference Model, IBM's IT Process Model, and Microsoft's MOF (itSMF 2005). ITIL is process oriented, defining process inputs and outputs, even though the v2 processes were mainly operational and tactical, with little support for strategic direction. Gartner research found that "enterprises that use ITIL are less likely to underfund their infrastructure" (Mingay 2006, p. 2), and although the academic literature on ITIL has been somewhat sparse, there is a growing awareness and adoption of ITIL in industry (Hochstein, Tamm & Brenner 2005; Potgieter, Botha & Lew 2005; Cater-Steel, Tan & Toleman 2006). ITIL v2 covered eight ICT management areas. However, ITIL v2 lacked a specific measurement system for process improvement (Potgieter, Botha & Lew 2005). On the other hand, ITIL version 3 focuses more on the alignment of IT with the business and it comprises of five volumes. Service Strategy (OGC 2007d) provides guidance on aligning business and IT. Service Design (OGC 2007b) provides guidance on the production and maintenance of IT policies, architectures, and documents. Service Transition (OGC 2007e) provides guidance for the transition of services in the operational business environment. Service Operation (OGC 2007c) illustrates delivery and control activities to achieve operational excellence. And, Continual Service Improvement (OGC 2007a) provides guidance on identifying and implementing service management improvements and service

retirement. ITIL version 3 also defines a Service Management Process Maturity Framework (OGC 2007b, pp. 261-267), comprising of five levels (Table 2.15).

Table 2.15: ITIL's Service Management Process Maturity Framework

Level 1: Initial	– The process has been recognised but there is little or no process management activity. It is allocated no importance, resources or focus within the organisation. The level can be described as 'ad hoc' or occasionally even 'chaotic'.
Level 2: Repeatable	– The process has been recognised, but is allocated little importance, resources or focus within the operation. Generally, activities related to the process are uncoordinated, irregular, without direction, and are directed towards process effectiveness.
Level 3: Defined	– The process has been recognised and is documented, but there is no formal agreement, acceptance and recognition of the role within the IT operation as a whole. However, the process has an owner, formal objectives and targets with allocated resources, and is focused on the efficiency as well as the effectiveness of the process. Reports and results are stored for future reference.
Level 4: Managed	– The process has now been fully recognised and accepted throughout IT. It is service focused and has objectives and targets that are based on business objectives and goals. The process is fully defined, managed, and has become proactive, with documented, established interfaces and dependencies with other processes.
Level 5: Optimised	– The process has now been fully recognised and has strategic objectives and goals aligned with the overall strategic business and IT goals. These have now become 'institutionalised' as part of the everyday activity for everyone involved in the process. A self contained process of improvement is established as part of the process, which is now developing a pre-emptive capability.

Source: developed from (OGC 2007b, pp. 261-267)

ISO 20000, a standard for IT service management, which is based on the British Standard BS 15000 (Dugmore 2006), is broader and somewhat less prescriptive than ITIL. However, any organisation wishing to implement it would still have to heavily rely on ITIL for guidance (Iijima 2007). There is also some overlap between ITIL and CobiT. The CobiT processes highlighted in dark blue in Figure 2.7 are also addressed by ITIL.

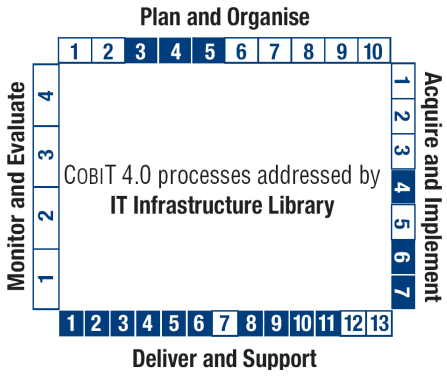


Figure 2.7: CobiT 4.0 Processes Addressed by ITIL
Source: adopted from (ITGI 2006a, p. 21)

2.4.7 ANSI/GEIA 859

The Government Electronics & Information Technology Association (GEIA) developed a data management standard GEIA-859, and published it in September 2004 (ANSI/GEIA 2004). The Implementation Guide for Data Management (ANSI/GEIA 2006), also published by GEIA, provides detailed guidance for the implementation of the standard.

However, the standard has found little adoption in industry to date, and academic research on it has been somewhat sparse. It addresses nine fundamental data management principles, where each principle includes further detailed enablers (ANSI/GEIA 2004):

1. **Define the Enterprise Relevant Scope of Data Management.**

   This principle explains that contemporary data management requires a broad spectrum of skills, and that every organisation will have its own specific requirements for those skills. Four high-level data management tasks are defined:

   - DM strategy and architecture development;
   - DM process and infrastructure design;
   - DM execution; and
   - DM process and infrastructure maintenance.

2. **Plan for, Acquire, and Provide Data Responsive to Customer Requirements.**

   General data requirements define the data mission, specifying what needs to be done for whom, how, and why. They are then used for the development of a data strategy, which creates the potential for data-related decisions to contribute to enterprise goals by aligning data management with the organisational context. Next, the enterprise determines specific data requirements and performs risk analysis. The data requirements also have to be authenticated. Contract award is the final enabler for this principle.

3. **Develop Data Management Processes to Fit the Context and Business Environment in which they be Performed.**

   This principle addresses four major components of a successful DM solution:

   - Deriving the complete set of DM requirements.
   - Determining the shape of the preferred DM solution.
   - Comparing the proposed best solution to existing and planned enterprise process infrastructure.
   - Making needed adjustments that fulfil the total set of DM solution requirements by resolving gaps and conflicts.

4. **Identify Data Products and Views so their Requirements and Attributes can be Controlled.**

The purpose of this principle is to ensure that metadata is selected to enable effective identification, storage, and retrieval of data, so that the creation and retention of data can be properly managed. The enterprise should develop consistent methods for describing data.

5. **Control Data, Data Products, Data Views, and Metadata using Approved Change Control Processes.**

   This principle provides guidance that will ensure the integrity and timeliness of data, data elements, data structures, and data views, by applying the principles of configuration management.

6. **Establish and Maintain a Management Process for Intellectual Property, Proprietary Information, and Competition-Sensitive Data.**

   Internal and external Intellectual Property (IP) needs to be identified and tracked for protection based on data rights. Enterprise policies for IP management provide a standardised way to type, mark, and identify the information; control and track ownership; manage rights; control access; and the like.

7. **Retain Data Commensurate with Value.**

   The purpose of this principle is to delineate methods for ensuring adequate retention and preservation of data assets that are of value to the enterprise, and effectively disposing of data assets that are no longer of value.

8. **Continually Improve Data Management.**

   This principle provides a basis for implementing a process for data quality improvement. Data management metrics should be defined, monitored and regularly reported. Monitoring the data quality through the use of metrics ensures that changes in initial input quality are identified. The enterprise should develop and implement a process improvement plan, with resources planned and allocated, to improve process performance and capability.

9. **Effectively Integrate Data Management and Knowledge Management.**

   This principle describes the interdependent relationship between Data Management (DM) and Knowledge Management (KM). Because DM and KM are naturally interdependent, the objective of this principle is to distinguish the roles of each so that, in practice, DM and KM efforts are complementary.

2.4.8 The Level of Adoption

Gartner Research conducted a survey of CIOs, IT operations heads, and data centre managers in 2005, finding that investment in process models was increasing in popularity (Curtis et al. 2005). They found that ITIL was the favoured approach, although it was often used in conjunction with other models, including, CobiT, CMM, ISO 9000, and Six Sigma. IT organisations in the manufacturing industry were mainly opting for Six Sigma because of their existing familiarity with it. However, Gartner also found that ITIL lacks a measurement capability (as opposed to Six Sigma for instance), and thus it was difficult to assess maturity and to use it for continuous improvement. They also found that little guidance was available on where and how to start with ITIL, and that some organisations were using it as a defence against corporate compliance audits like the SOX Act. Gartner also surveyed 350 midsize and large businesses in 2005, about their approaches to ITIL, CMMI, CobiT and Six Sigma frameworks (Mingay 2006). They found that enterprises using the frameworks have a lower propensity to underfund their infrastructure, and that one in five organisations was using Six Sigma or was planning to use it by the end of 2006. However, Gartner's 2007 Hype Cycle for Regulations and Related Standards (Caldwell et al. 2007) forecasted that ITIL and CobiT have 5 to 10 years to mainstream adoption. It also placed them in the Through of Disillusionment phase, which states that "because the technology does not live up to its over inflated expectations, it rapidly becomes unfashionable, media interest wanes, except for a few cautionary tales" (Caldwell et al. 2007, p. 36).

2.4.9 Summary

The quality standards and best practices reviewed in this section placed a strong focus on process orientation, ensuring the quality of processes employed in producing products or delivering services. Furthermore, CMMI has been found to be very relevant to the research problem explored in this thesis and, as such, its structure shall be adapted to the development of an information quality management capability maturity model.

2.5 Data and Information Quality

This section aims to critically review the existing literature on data and information quality, identify relevant works, and discover gaps in the existing research. This section firstly presents a discussion on the terms 'data' and 'information', followed by definitions of 'data/information quality' and a discussion on implications of poor information quality. Relevant causes of quality problems are identified and the information product analogy is

explained. Finally, the literature on information quality assessment/improvement frameworks as well as relevant maturity models is also reviewed.

2.5.1 From Data to Information

There has been a lot of confusion about the exact meanings of the terms 'data' and 'information'. Information has been defined as "anything that can be digitised" (Shapiro & Varian 1999, p. 3); however, according to Information Theory, which was largely developed at Bell Labs in the 1940s, information serves to reduce uncertainty (Shannon 1948; McEliece 2002; Avery 2003). Accordingly, Handscombe & Patterson (2004) describe the quantity of information as "the ratio of the number of possible answers before and after receiving information" (p. 28). On the other hand, Tuomi (1999) argued that information can only be created with the existence of some knowledge. More specifically, "the generally accepted view sees data as simple facts that become information as they are combined into meaningful structures, which subsequently become knowledge as meaningful information is put into a context" (Tuomi 1999 p. 103). Thus, information can be seen as data in context (Wiig 1993; Davenport 1997; Lillrank 2003). In that view, data itself is "useless until some thought has been applied to its meaning" (Wolstenholme, Henderson & Gavine 1993 p. 2). However, it has also been argued that "data is information" (ANSI/GEIA 2004), and terms 'data quality' and 'information quality' are often used interchangeably in literature. As a consequence many researchers utilise the terms synonymously (Huang, Lee & Wang 1999; Kahn, Pierce & Melkas 2004). The typical model of data organisation has data stored in multiple sources, where each source is composed of multiple relations, and where each relation is made up of multiple tuples, which are further composed of a predefined number of attributes (Oliveira, Rodrigues & Henriques 2005). This model results in a hierarchy of four levels of data granularity: multiple data sources, multiple relations, single relation, and attribute/tuple. The multiple data sources may also be combined in a Data Warehouse for analytics and reporting purposes.

Table 2.16: Data Terminologies

Data. A representation of an object.
Information. The aggregation of data into something that has meaning (semantics) through interpretation by human or automated process.
Knowledge. That which is derived and inferred from assimilating information against perceived context, experience or business rules.
Decision. A process for arriving at a solution to a problem, using knowledge to assess and judge information.
Awareness. The assessment of information into decisions and actions, guided by knowledge of the contextual domain.

Source: adopted from (Miller et al. 2001, p. 365)

2.5.2 Definitions

In order to be able to proceed with this section, it is paramount to clearly define the main concepts. Early IQ research focused mainly on the accuracy dimension, classifying records as 'correct' or 'erroneous' (Paradice & Fuerst 1991). However, IQ is a relative rather than an absolute term (Ballou & Pazer 1985), and thus the IQ research community later adopted Juran's definition of quality "fitness for use" (Ballou & Tayi 1989; Wang & Strong 1996; Strong, Lee & Wang 1997b; Redman 1998). Numerous researchers have over the years attempted to define data quality and to characterise its dimensions (Feltham 1968; Gallagher 1974; Halloran et al. 1978; Kriebel 1979; Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Ballou & Pazer 1985; Wang & Kon 1993; Wang, Kon & Madnick 1993; Fox, Levitin & Redman 1994; Wang, Reddy & Kon 1995; Wang, Storey & Firth 1995; Wand & Wang 1996; Wang & Strong 1996; Shanks & Darke 1998; Kahn, Strong & Wang 2002); yet, the quality of data considered appropriate for one use may not be of sufficient quality for another use, since different data consumers may have different quality requirements (Tayi & Ballou 1998; Giannoccaro, Shanks & Darke 1999a). Furthermore, improving one data quality dimension may impair another; for instance, it may be possible to improve the timeliness of data at the expense of accuracy (Ballou & Pazer 1995). A large number of definitions of information quality dimensions have been summarised in Appendix D.

Wand & Wang (1996) argued that there was no consensus on data quality dimensions and definitions. Hence, they suggest defining data quality dimensions using ontological concepts, where an information system is seen as a representation of a real-world system. According to Wand & Wang, data deficiencies transpire when there is a difference between user's view of the real-world as inferred from the information system and user's view of the real world through direct observation. They argued that every lawful state of the real-world system should be mapped to at least one lawful state of the information system. Furthermore, it should be possible to map an information system state back to the corresponding real-world state. Next, they proceed to define five types of data deficiencies. Incompleteness can occur if there are lawful states of the real-world system that cannot be represented by the information system. Ambiguous representation can occur if two states from the real-world are mapped into the same state of the information system. Hence, it would be impossible to infer which state in the real-world is represented. For instance, "a system design may allow only for one telephone number, without indicating whether it is the office or home telephone" (Wand & Wang 1996, p. 91). Meaningless states can occur

if there are lawful states in the IS that can not be mapped back to a state in the real-world. Such system may still properly represent a real-world system even though it would contain meaningless data. A real-world state may also get mapped to a meaningless IS state or to a meaningful, but incorrect IS state. They called this garbling. On the other hand, Kim et al. (2003) took a different approach to developing a taxonomy of dirty data by looking at missing data, not missing but wrong data, and not missing and not wrong but unusable data. The taxonomy they developed consisted of 33 primitive, dirty data types, which they claimed to be about 95% comprehensive. Dirty data types included the use of wrong data type, outdated temporal data, entry into wrong fields, misspellings, and so on.

Orr (1998) argued along similar lines as Wand & Wang and defined data quality as "the measure of the agreement between the data views presented by an information system and that same data in the real world" (p. 67). He argued that no serious information system can have 100% data quality, mainly because of the dynamic nature of the real world. Therefore, data views from the system have to be constantly compared with data from the real world, so that any deviations can be corrected. Orr (1998) also deduced six general data quality rules including: unused data cannot remain correct for very long; data quality in an information system is a function of its use, not its collection; data quality will, ultimately, be no better than its most stringent use; data quality problems tend to become worse as the system ages; the less likely some data attribute is to change, the more traumatic it will be when it finally does change; and laws of data quality apply equally to data and metadata (p. 68).

Wang & Strong (1996) defined DQ dimensions from user's perspective. Using a two stage survey as well as a two stage sorting procedure, they developed a framework comprising of four categories and 15 DQ dimensions (Table 2.17).

Table 2.17: Data Quality Dimensions

IQ Category	IQ Dimension
Intrinsic	Accuracy, Objectivity, Believability, Reputation
Representational	Interpretability, Ease of Understanding, Concise/Consistent Representation
Contextual	Relevancy, Value-added, Timeliness, Completeness, Amount of Information
Accessibility	Accessibility, Access Security

Source: adopted from (Wang & Strong 1996, p. 20)

Shanks & Darke (1998) took a different approach and modelled DQ requirements for a data warehouse using semiotic theory (Stamper 1992). Using semiotics, the study of symbols (Liu 2000), they structured data quality into four categories: syntactic, semantic,

pragmatic, and social. Syntactic category deals with the form of data, semantic category deals with the meaning of data, pragmatic category deals with the usage of data, and social category deals with the shared understanding of the meaning (Shanks & Darke 1998). However, since not all dimensions apply equally to all stakeholders, in all circumstances, Giannoccaro, Shanks & Darke (1999b) explored the relationships between data quality dimensions and stakeholder groups in a data warehouse environment, finding a complex pattern of associations.

2.5.3 Implications

It is generally accepted that effective information management is critical to the success of executive information systems (Koh & Watson 1998). Accordingly, organisations are now starting to view quality information as one of their most important assets (Wang & Strong 1996; Agarwal & Venkatesh 2002). Also, given the fact that decision quality is a function of information quality, organisational decision making may be impacted by the quality of information employed to make those decisions (Stephenson 1985; Strong, Lee & Wang 1992). Raghunathan (1999) investigated the impact of information quality and decision-maker quality on actual decision quality using a theoretical and a simulation model. He used accuracy as the measure of quality and found that depending on the decision-maker quality, decision quality may improve or degrade when information quality improves. Raghunathan argued that the decision quality improved with higher information quality for a decision-maker that had knowledge about the relationships among problem variables. However, he argued that the decision quality of a decision-maker that doesn't know these relationships may degrade with higher information quality. Simultaneous improvement in information quality and decision-maker quality resulted in higher decision quality. However, IQ problems are not a new phenomenon. Markus' (1983) classic case study on power and politics illustrated a situation she encountered in her research:

> *"If it turned out that an account we needed had not already been defined to Financial Information System, rather than wait for the special account creation run, we might change the plant code, just to get the data in. After all, we knew what the numbers really were!" (p. 435)*

A preliminary assessment carried out by the Office of Technology Assessment (U.S. Congress) in 1978 found that existing state and federal Computerised Criminal History (CCH) systems contained high levels of inaccurate, ambiguous, and incomplete information (OTA 1978). Furthermore, Laudon (1986) carried out research from 1979 to 1984, where he examined the computerised criminal-record system of the United States for

data quality issues, and subsequently found that in excess of 14,000 persons were at risk of being falsely detained or arrested, because of invalid warrants. Nevertheless, those records were increasingly being used for screening employees in both the public and private sector. Space shuttle Challenger exploded moments after lift-off killing seven astronauts on the 28th of January 1986, and US Navy Cruiser USS Vincennes fired two missiles at an Iranian Passenger Airbus (Iran Flight 655) killing 290 people on the 3rd of July 1988. What those two disasters have in common, is the fact that IQ problems (including issues with accuracy, completeness, consistency, relevance, fitness for use, and timeliness) have been identified as one of the main causes (Fisher & Kingma 2001). Information quality may also have impacts on computer user satisfaction and information system success. Bailey & Pearson (1983) developed a tool for measuring and analysing computer user satisfaction, by reviewing 22 relevant studies, and conducting 32 interviews with middle managers in eight organisations. They identified 39 factors affecting user satisfaction, nine of which were characteristics of information quality, including, accuracy, precision, currency, timeliness, reliability, completeness, conciseness, format, and relevance. DeLone & McLean (1992) reviewed 180 research articles and consequently developed a model for IS success. They identified IQ as a key factor to the success of information systems and summarised a large number of IQ dimensions, including, format, content, timeliness, relevance, and so on. Rainer & Watson (1995) also identified information quality (accurate, timely, concise, convenient, and relevant information) as key factor to executive information system success.

2.5.4 Causes

There are many potential causes of poor information quality. In the past, researchers were focusing more on the technological shortcomings leading to poor information quality (Guynes & Vanecek 1996). For instance, Brodie (1980) focused on system states and transitions, identifying various issues with programming languages and database constraints. More recently, Strong, Lee & Wang (1997a) conducted 42 mini-case studies of IQ improvement projects in three organisations (an airline, a hospital, and a health maintenance organisation – HMO), and analysed those cases using content and pattern analysis techniques. They ultimately identified 10 key causes of IQ problems:

1. Multiple sources of the same information.
2. Information produced using subjective judgements.
3. Systemic errors in information production.
4. Information overload.

5. Distributed heterogeneous systems.
6. Nonnumeric information may de difficult to index.
7. Automated content analysis across information collections.
8. As consumers' tasks and business processes change, so does the information.
9. Easy access to information may conflict with requirements for security and privacy.
10. Lack of sufficient computing.

Maydanchik (2007) identified 13 processes, which may have a negative effect on information quality, including, initial data conversion, system consolidations, manual data entry, batch feeds, real-time interfaces, changes not captured, system upgrades, new data users, loss of expertise, process automation, as well as data processing/cleansing/purging.

2.5.5 The Product Analogy

Wang, Storey & Firth (1995) analysed 105 data quality related research papers published prior to 1995. By drawing an analogy between product manufacturing and information manufacturing, they developed a framework that they used to analyse and organise the data quality literature. The framework consisted of seven categories: management responsibilities, operation and assurance costs, research and development, production, distribution, personnel management, and legal function. The main findings were that most data quality literature published prior to 1995 focused on research and development issues; that it was necessary to develop policies and systems that facilitate delivery of quality data products; that there was a need to evaluate costs of external data failures along with the corresponding costs of data quality assurance; that there was a need to study the link between poor data quality and procedures to detect and eliminate problems; and that there were fundamental technical needs for an overall data quality metric and for a way to specify quality requirements for data products. Wang (1998) later drew an analogy between traditional manufacturing of tangible products and the manufacturing of Information Products (IPs) (Table 2.18). Therefore, he argued that the quality of IPs may be directly affected by the quality of processes employed in the Information System (IS), a view also held by Ballou & Pazer (1985).

Table 2.18: Product Manufacturing Analogy for IP Creation

	Product Manufacturing	**Information Manufacturing**
Input	Raw Materials	Raw Data
Process	Assembly Line	Information System
Output	Physical Products	Information Product

Source: adopted from (Wang 1998, p. 59)

Consequently, data may become corrupted during: *gathering* – manual entry, no uniform standards for content and formats, and parallel data entry causing duplicates; *delivery* – inappropriate aggregation, nulls converted to default values, buffer overflows, and transmission problems; *storage* – poor metadata, inappropriate data models, and hardware/software constraints; *integration* – no common key, different field formats, different definitions, time synchronisation; *retrieval* – source data not properly understood, need for derived data not understood, and computational constraints; and *mining/analysis* – attachment to models, insufficient domain expertise, and causal empiricism (Dasu & Johnson 2003).

Wang et al. (1998) proposed four principles for treating information as a product: understand consumers' information needs; manage information as the product of a well-defined process; manage information as a product with a life cycle; and appoint an information product manager to manage the information process and resulting product. Furthermore, Pierce (2005) argued that organisations interested in treating information as a product should develop an information product inventory. Pierce (2005) proposed five steps for the creation and management of an IP inventory: catalogue IPs used by the organisation; identify those IPs critical to the health of the organisation; establish DQ specifications for critical IPs; document the processes that produce the critical IPs and then assess if changes are needed to bring the quality of the IP up to required levels; and review periodically the contents of the IP inventory to see if any changes to the IPs have taken place (p. 101).

There are however some fundamental differences between information products and physical products (Ballou et al. 1998). Moreover, ensuring the quality of information is much more difficult than is the case with manufactured products (Tayi & Ballou 1998). For instance, it is very difficult to measure information and its quality, given that information has no physical properties to measure (Redman 1995; Ballou et al. 1998). Additionally, information can be consumed indefinitely, without being depleted (Paradice & Fuerst 1991; Wang 1998). Furthermore, many IQ dimensions would not make sense if applied to physical products (Wang 1998). According to Redman (1995), most useful information is novel or unique, which agrees with the argument that information is used to reduce uncertainty (Shannon 1948). Thus, the uses of such novel information may only be partially known (Tayi & Ballou 1998).

2.5.6 Assessments

Maffei (1958) argued approximately 50 years ago that there was a need to quantitatively assess the impacts of poor quality information; however, he also noted the difficulty of measuring information quality (Maffei 1958). A mechanism for tagging data, which was initially proposed by (Codd 1979), was later adapted by (Wang, Kon & Madnick 1993; Wang, Reddy & Kon 1995), who suggested tagging data at the cell level with quality indicators. Paradice & Fuerst (1991) proposed a formula for computing a stored error rate; and Naumann & Rolker (2000) developed an assessment-oriented classification for IQ-criteria. They identified three IQ criterion classes (subject, object, and process criteria), each with different general assessment possibilities, and provided detailed assessment methods for each criterion, including, user experience, user sampling, continuous user assessment, parsing, expert input, and cleansing techniques. Furthermore, several information quality metrics have been proposed by other researchers.

$Accuracy = 1 - \frac{Number\ of\ incorrect\ data\ items}{Total\ number\ of\ data\ items}$	adopted from (Redman 1997)
$Appropriate\ Amount\ of\ Data = \min\left(D_p / D_r, D_r / D_p\right)$ D_p – *the number of data items provided* D_r – *the number of necessary data items*	adopted from (Pipino, Lee & Wang 2002)
$Completeness = 1 - \frac{number\ of\ absent\ data\ items}{total\ number\ of\ data\ items}$	adopted from (Wang & Strong 1996)
$Timeliness = \max\left(0, 1 - \frac{currency}{volatility}\right)^S$ S – *parameter used to control the sensitivity of the timeliness to the currency / volatility ratio*	adopted from (Ballou et al. 1998)
$Accessibility = \max\left(0, 1 - \frac{\Delta t1}{\Delta t2}\right)$	adopted from (Strong, Lee & Wang 1997b)

Lee et al. (2002) proposed the Information Quality Assessment (IQA) measurement instrument, which they used to subjectively measure stakeholder perception of each IQ dimension (Wang & Strong 1996). That instrument was then used by Kahn, Strong & Wang (2002) to extend previous research on managing information as product, and to incorporate the service characteristics of information delivery. Thus, they developed a conceptual model that describes IP quality as well as the quality of IP service delivery to consumers. Furthermore, the Product and Service Performance Model for Information Quality (PSP/IQ) model addresses two aspects of quality, conformance to specification,

and meeting or exceeding consumer expectations. They also proposed PSP/IQ as a benchmarking methodology. Moreover, they conducted a survey with 45 professionals to determine how existing IQ dimensions should be grouped into the PSP/IQ model. They also validated the model by conducting three case studies in large healthcare organisations. Their findings were that those organisations mainly focused on the 'Sound Information' quadrant; that is to say, they were treating information as a product and assuring conformance to specifications.

Pipino, Lee & Wang (2002) proposed combining subjective and objective quality assessments, and described three functional forms for developing objective data quality metrics (simple ratio, min or max operation, and weighted average). Pipino et al. (2005) later developed formal definitions for completeness, correctness, system currency, storage time, and volatility, showing how each one of them can be measured with a ratio scale.

Pierce (2004a) proposed the information product control matrix as a tool for evaluating the reliability of information products, and Pierce & Thomas (2007) demonstrated how prediction markets (speculative markets similar to stock exchanges) can be applied to the assessment of information quality.

Gebauer, Caspers & Weigel (2005) showed how data quality can be measured in a reproducible and understandable way, on the basis of defined business rules, through the use of a data quality tool, and Gebauer & Mielke (2008) developed a generic checklist for data quality audits in projects.

Klein, Goodhue & Gordon (1997) conducted a series of tests and found that users of information systems seem to be able to detect data errors under certain circumstances. They further argued that explicit error detection goals, managerial directives, training and incentives can enhance error detection performance. However, Dasu & Johnson (2003) have argued that some dimensions, such as accuracy and completeness, are very difficult, perhaps impossible to measure. Furthermore, Strong, Lee & Wang (1997b) examined DQ projects from three organisations and identified common patterns of quality problems. They found that IQ problems from one category may have an impact on IQ dimensions in another category. For instance, they argued that a believability problem (intrinsic IQ) may lead to a perception of low added-value (contextual IQ).

2.5.7 Management

Wang (1998) also adapted Deming's PDCA cycle to form the TDQM methodology (Figure 2.8). The *Define* stage identifies IQ requirements; the *Measure* stage produces IQ metrics; the *Analyse* stage identifies the root causes of IQ problems and determines the impact of poor IQ; and the *Improve* stage provides techniques for improving IQ.

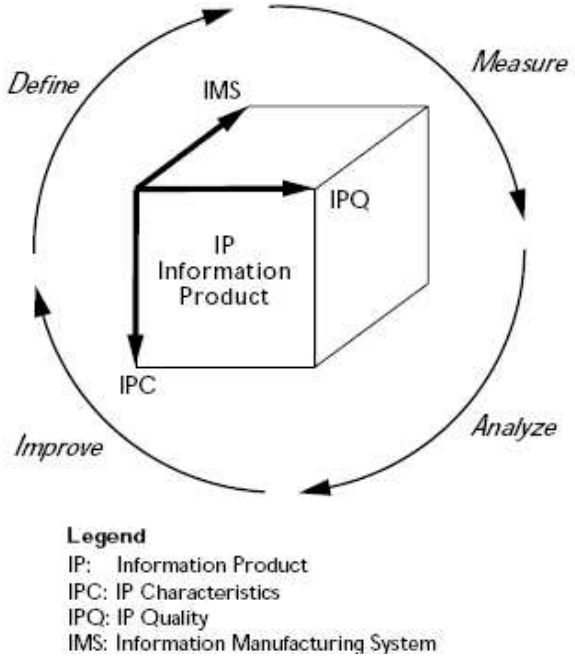


Figure 2.8: TDQM Methodology
Source: adopted from (Wang 1998, p. 60)

Wang (1998) also identified four stakeholders in the information manufacturing system: *Information Suppliers* – who create or collect data; *Information Manufacturers* – who design, develop, or maintain the data and systems infrastructure; *Information Consumers* – who use the Information Products; and *Information Product Managers* – who manage the entire IP production process throughout the IP lifecycle. Redman (1994) contrasted two approaches to IQ improvements – process management and data cleansing (Table 2.19). He found that the process management approach provided far better results and is a great deal less expensive in the long run. Similarly, Abate, Diegert & Allen (1998) argued that data quality is a multi-dimensional and hierarchical concept. They also argued that data quality cannot be improved independently of the process that produced the data, or the context in which the data is to be used. Hence, pure technological solutions are not sufficient to provide sustained data quality improvements. To ensure long term data quality improvements, they argued, research efforts should be directed at processes and systems.

Table 2.19: Approaches to Improving Data Quality

	Feature	Cleanup Approach	Process Approach
Short Term	Cost	High	Low
	Improvement to Data	High	Low
	Improvement to Process	None	Medium
Long Term	Cost	High	Low
	Improvement to Data	Low	High
	Improvement to Process	None	High

Source: adopted from (Redman 1994, p. 312)

Given the fact that many traditional, product quality control, theories can be applied to the information quality management domain, Ballou et al. (1998) developed an information manufacturing model to determine the timeliness, quality, cost, and value of information products. Their data production maps included five building blocks. Data vendor blocks represent sources of raw data, which can be internal or external to the organisation. Processing blocks represent information system processes and can be used to represent any manipulations involving raw or component data. Storage blocks are used to represent storage files or databases. Quality blocks represent points at which data quality checks are performed on the specified component data items. Consumer blocks are used to represent the consumers of the information products. Their approach may provide for easier visualisation of the whole information manufacturing process, and thus may also help with the identification of critical stages, and ultimately aid in any process improvement efforts. Ballou et al. (1998) work was further extended by Shankaranarayanan, Wang & Ziad (2000), who called it IP-MAP. Shankaranarayanan, Wang & Ziad (2000) added three additional block types: decision blocks, organisational boundary blocks, and information system boundary blocks. They also incorporated data quality dimensions in each block, and added metadata specifications. Pierce (2002) demonstrated how IP-MAPs can be rearranged into a family of diagrams based on the event-driven process chain methodology.

Pipino, Lee & Wang (2002) proposed a high-level three step approach to information quality improvements, including, performing subjective and objective data quality assessments; comparing the results of the assessments, identifying discrepancies, and determining root causes of discrepancies; and determining and taking necessary actions for improvement. Dravis (2004) identified six factors that should be considered when creating a data quality strategy, including: *context* (data usage as well as data types should be matched against the appropriate types of data cleansing algorithms), *storage issues* (such as distributed vs. centralised, homogenous vs. heterogeneous, and data modelling), *data*

flow (how the data enters and moves through the organisation), *work flow* (how work activities interact with and use the data), *stewardship* (people responsible for managing the data), and *continuous monitoring* (processes for regularly validating the data). Pierce (2004b) showed how existing marketing techniques can be used to construct an information quality strategy, and proposed a methodology for the development, implementation, and monitoring of such strategies. Piro, Knoke & Gebauer (2008) described a reporting and solution process for DQ problems in a Bank, which involved organisational change and an IT tool. Gebauer & Windheuser (2008) proposed a structured data analysis, profiling and business rules approach to information quality management.

Ted Friedman (2002) from Gardner Research proposed a strategic approach to improving data quality (Figure 2.9). He argued that, if data quality efforts are to succeed, they should include organisational change, business process change, continuous monitoring, and improvement. Furthermore, he argued that senior management must recognise data quality as a key business priority, and that measurements, analyses, and quantifications are required to raise visibility of data quality issues. Extract, Transform and Load (ETL) tools, data cleansing and matching, and data enrichment have been taken of Gardner's Hype Cycle, which shows the relative maturity of data management technologies and best practices, because Gartner regards them as mature technologies (Friedman et al. 2007). Data quality dashboards, Enterprise Information Management, and Master Data Management, have been identified as being a technology on the rise.



Figure 2.9: The Key Steps in a Strategic Data Quality Methodology
Source: adopted from (Friedman 2002, p. 3)

According to Gartner Research, a complete information quality management methodology must focus on three critical components: people, processes, and technology (Friedman 2005). Not addressing any of those three components may result in suboptimal results. Furthermore, Gartner argued that information quality methodologies should have the following characteristics: clear milestones and deliverables, a data quality audit, a focus on metrics, recommendations for key roles, governance models, education plans, blueprint technology architectures, independence from specific tools, and linkage points to other methodologies and initiatives (Friedman 2005). Gartner Research has also identified Master Data Management as being paramount to information quality (White et al. 2006), arguing that:

> *"Through 2010, 70 percent of Fortune 1000 organisations will apply MDM programs to ensure the accuracy and integrity of commonly shared business information for compliance, operational efficiency and competitive differentiation purposes (0.7 probability)." (p. 2)*

Master data has been defined as "the consistent and uniform set of identifiers and extended attributes that describe the core entities of the enterprise – and are used across multiple business processes" (White et al. 2006, p. 2). Such data would be infrequently changed, thus creating the single point of truth.

Gartner defines Information Governance as "the collection of decision, rights, processes, standards, policies and technologies required to manage, maintain and exploit information as an enterprise resource" (Newman & Logan 2006, p. 3). They go on to propose a "checks and balances" model for governance of information assets, comprising of (Newman & Logan 2006): *Executive Level* (sponsor, direct and align); *Judicial Level* (enforce, resolve and rule); *Legislative Level* (endorse, approve and enact); and *Administrative Level* (implement, service and recommend). The model involves employees at all levels of the organisation, who are accountable for ensuring that information remains protected, consistent, accurate, transparent, and accessible.

IBM Data Governance Council, which comprises of 55 organisations, proposed a Data Governance Maturity Model. They identified 11 categories of data governance maturity, which were grouped as outcomes, enablers, core disciplines, and supporting disciplines (IBM 2007). Each category has subcategories that further break down the path to maturity.

2.5.8 Maturity Models

Several IM & IQM related maturity models have been proposed in the literature. This section presents a review of those models and identifies the gaps this thesis is aiming to fill.

Chambless & Parker (1998) proposed the application of CMM key process areas to data management. However, there are certain issues that have to be considered with this approach. For instance, the domain of data management is very different from the domain of software engineering, and thus the process areas may not be so easily transferable. Also, software engineering processes are repeatable and the CMM aimed to ensure the repeatability of software development project successes. However, data management is a continuous process, without a clear start and finish.

Caballero et al. (2005) employed a concept of an Information Management Process (IMP) and considered an Information System (IS) as a set of interrelated IMPs. They proposed a maturity model (CALDEA) that is to be applied to each IMP (Table 2.20). However, the model has a strong focus on the process of information quality improvement and it does not really identify organisational, technical, and social factors that may negatively affect the quality of information.

Table 2.20: CALDEA

Definition Level		
	Information Quality Assurance Team Management	*10%*
	IMP Project Management	*15%*
	User Requirements Management	*15%*
	Data Sources and Data Targets Management	*25%*
	Database/DW Acquisition/Development/Maintenance	*25%*
	Information Quality Management in IMP Components	*10%*
Integration Level		
	IP and IMP Components Validation and Verification	*25%*
	Risk and Poor Information Quality Impact Management	*25%*
	Information Quality Standardisation Management	*25%*
	Organisational Information Quality Policies Management	*25%*
Quantitative Management Level		
	IMP Measurement Management	*70%*
	IMP Measurement Plan Automation Management	*30%*
Optimising Level		
	Causal Analysis for Defects Prevention Management	*50%*
	Innovation and Organisational Development Management	*50%*

Source: adapted from (Caballero et al. 2005)

Meta Group started developing an Information Maturity Model (IMM) before they were acquired by Gartner on 01 April 2005 (Gartner 2005). The model development, to begin with, required determining those characteristics that comprise information management

and usage, and Meta Group initially focused on DQ as a key characteristic. Thus they proposed a partial IMM from the DQ perspective (Laney 2002).

Table 2.21: Meta Group's Information Maturity Model – DQ Perspective

Level 1: Aware	Some awareness of DQ problems. No formal DQ initiatives, but performed on ad hoc basis by individuals. To achieve higher levels of DQ maturity such organisations should strive to improve internal awareness and communication about DQ issues and their impact, and become better educated on the various DQ problems and solutions.
Level 2: Reactive	Decisions and transactions are often questioned due to suspicion or knowledge of DQ issues. Application developers implement simple edits/controls used to standardise data formats, and some manual or home-grown batch cleansing is performed. Such organisations should focus on better understanding and quantifying the business impact of DQ, suggesting DQ-related data administration guidelines, and attempt to implement reusable (not disposable) DQ remediation logic.
Level 3: Proactive	DQ is now part of the IT charter, and major DQ issues are documented but not analysed or well-quantified. Data cleansing is typically performed by commercial DQ software. DQ-oriented data administration guidelines have been issued but are not monitored or enforced. Such organisations should concentrate on moving to continuous monitoring and remediation of data closer to the source, and they should implement forms of data management policy enforcement to stem DQ problems at a business process level.
Level 4: Managed	DQ has become a principal IT function and major responsibility, and commercial DQ software has been implemented. DQ is regularly measured and monitored for accuracy, completeness, and integrity at an enterprise level, across systems. DQ is concretely linked to business issues and process performance. Most cleansing and standardisation functions are performed at the source. DQ functions are built into major business applications, enabling confident operational decision making, and DQ related policies are well-established and monitored.
Level 5: Optimised	DQ is an ongoing strategic enterprise initiative with demonstrable ROI. Many fringe DQ characteristics (e.g., latency, currency, breadth, depth, precision, inter-relationships) are continuously measured and monitored. Data is enriched in real time from third-party providers. Mission-critical unstructured information (e.g., documents) is subject to DQ controls. Metadata/data is tagged with quality indicators to associate levels of confidence or known problems with information – particularly in the data warehouse. DQ related data administration governance is automated. Such organisations must not rely on an individual leader, but must ensure that DQ is built into the culture, education, IT architecture/infrastructure, financial model, and business processes.

Source: developed from (Laney 2002, pp. 1-2)

Ryu, Park & Park (2006) proposed a number of maturity stages relating to IM, showing that higher IM maturity may result in improved information quality. On level 1, data is maintained by the physical attribute definition and reference integrity of tables. Level 2 manages the database based on the logical database model. In level 3, the standardisation of metadata is defined and centrally controlled, and level 4 deals with the management of the standard data architecture.

Moss, Abai & Adelman (2005) further extended Larry English's work (1999) by proposing main high-level improvement activities for each of the data quality maturity levels (Figure 2.10).

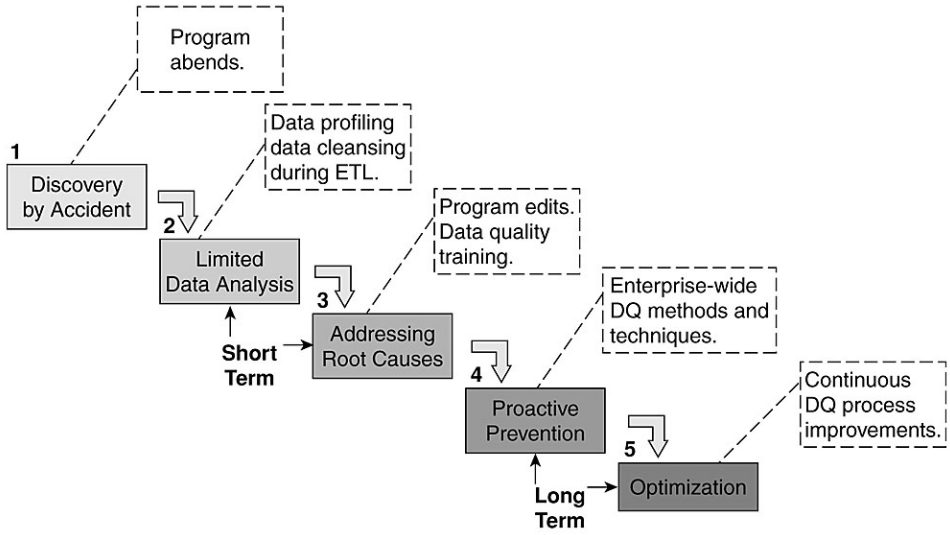


Figure 2.10: Improvement Activities in Data Quality Maturity Levels
Source: adopted from (Moss, Abai & Adelman 2005)

Aiken et al. (2007) deductively proposed a high-level Data Management Maturity Model (Table 2.22), which was based on CMMI and addressed five data management processes (data program coordination, enterprise data integration, data stewardship, data development, and data support organisations).

Table 2.22: Data Management Practice Assessment Levels

Level		Practice	Quality and Results Predictability
1	Initial	The organisation lacks the necessary processes for sustaining data management practices. Data management is characterised as ad hoc or chaotic.	The organisation depends entirely on individuals, with little or no corporate visibility into cost or performance, or even awareness of data management practices. There is variable quality, low results predictability, and little to no repeatability.
2	Repeatable	The organisation might know where data management expertise exists internally and has some ability to duplicate good practices and successes.	The organisation exhibits variable quality with some predictability. The best individuals are assigned to critical projects to reduce risk and improve results.
3	Defined	The organisation uses a set of defined processes, which are published for recommended use.	Good quality results within expected tolerances most of the time. The poorest individual performers improve toward the best performers, and the best performers achieve more leverage.
4	Managed	The organisation statistically forecasts and directs data management, based on defined processes, selected cost, schedule, and customer satisfaction levels. The use of defined data management processes within the organisation is required and monitored.	Reliability and predictability of results, such as the ability to determine progress or six sigma versus three sigma measurability, is significantly improved.
5	Optimising	The organisation analyses existing data management processes to determine whether they can be improved, makes changes in a controlled fashion, and reduces operating costs by improving current process performance or by introducing innovative services to maintain their competitive edge.	The organisation achieves high levels of results certainty.

Source: adopted from (Aiken et al. 2007, p. 46)

Gartner Research defined Enterprise Information Management (Figure 2.11) as "an integrative discipline for structuring, describing and governing information assets, regardless of organisational and technological boundaries, in order to improve operational efficiency, promote transparency and enable business insight" (Bitterer 2007, p. 6). They proposed a staged maturity model addressing several EIM building blocks, including, vision, strategy, governance, organisation, process, enabling infrastructure, and metrics (Table 2.24).

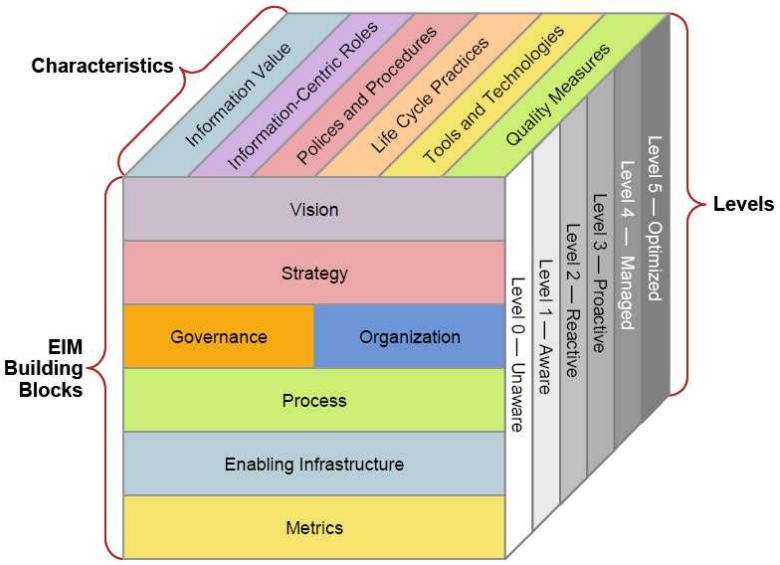


Figure 2.11: Enterprise Information Management Adoption Model
Source: adopted from (Logan & Newman 2006, p. 3)

They also adapted the EIM maturity model to a specialised data quality maturity model (Table 2.23).

Table 2.23: Gartner's Data Quality Maturity Model

Level 1: Aware –	Very little understanding of DQ concepts. Any problems are largely ignored. No formal DQ initiatives. No incentives to improve DQ. General ignorance and belief that all information is correct by default. No DQ responsibilities or accountabilities.
Level 2: Reactive –	Data formats, mandatory fields, and value validations are being enforced. Some limited manual batch cleansing performed. Users are waiting for problems to occur, instead of taking proactive steps. DQ problems are still perceived to be solely the IT department's responsibility.
Level 3: Proactive –	DQ gradually becomes part of the IT charter. DQ tools (for e.g. profiling & cleansing) are in use. DQ is considered "good enough" for most decision-making. Major issues are documented, but not completely rectified. DQ guidelines and data ownership are emerging.
Level 4: Managed –	DQ is a prime concern. Commercial DQ software implemented more widely. Regular DQ assessments and impact analyses performed. DQ functionality is introduced beyond business intelligence and data warehousing programs. Multiple data stewardship roles are established. Metrics-based DQ dashboards in use.
Level 5: Optimising –	Rigorous processes are in place to keep DQ as high as possible, through ongoing housekeeping exercises, continuous monitoring of quality levels, and by attaching quality metrics to the compensation plans of data stewards and other employees. DQ becomes an ongoing strategic initiative. Subjective DQ assessments (e.g. believability, relevance and trust factors). Data is enriched in real time by third-party providers.

Source: developed from (Bitterer 2007)

Table 2.24: Gartner's EIM Maturity Model

	Vision	Strategy	Governance	Organisation	Process	Enabling Infrastructure	Metrics
Unaware	Most are unaware that information is a problem.	Strategic decisions are made without adequate information.	There is no information governance or security.	Everyone stores and manages his/her own information individually.	No one is in charge or accountable for managing data or documents.	E-mail is the de facto document management & workflow system.	No one has any idea how much is spent on information.
Aware	Information is managed in silos. No consistent & decisive action.	People develop strategies to hoard information.	The IT department takes steps to consolidate information silos.	No consolidated views. Private information management.	There are informal IM guidelines, but they're not enforced.	Rogue spreadsheets & independent databases exist.	Reports are inconsistent or redundant.
Reactive	Formalised objectives for information sharing. Progress is hampered by barriers.	Business units share information on cross-functional projects.	Steps toward upstream cross-departmental data sharing.	The organisation remains in 'fire-fighting' mode.	No change management procedures in place.	Integration efforts remain localised and redundant.	Metrics show significant overlaps in master data assets.
Proactive	Cross-functional information sharing.	Embracing top-down strategies, as evidenced by CRM, ERP, etc.	Governance councils support the management of information as an asset.	A formal DQ program is tied to a governance program.	Guidelines for archiving, retention, and metadata.	Data models are aligned to enterprise information architecture.	Metrics focus on cost and quality.
Managed	Information seen as a strategic asset.	The EIM strategy addresses all stakeholders' requirements.	Policies and standards are defined.	A formalised DQ process is adopted.	Automated data profiling for DQ.	EIM becomes a key part of the application planning.	Metrics chart ongoing progress in DQ initiatives.
Optimised	The value of information is known and exploited.	EIM links to strategic initiatives, such as enterprise agility.	Incentives and disincentives are established and carried out.	A formalised EIM program is adopted.	An EIM group is instituted.	Metadata management and semantic integration.	Metrics focus on external factors, such as sourcing, risk and margin.

Source: developed from (Logan & Newman 2006)

2.5.9 Summary

This section has reviewed the literature relevant to data and information quality management. Information quality has been defined and the analogy between the manufacture of traditional products and the manufacture of information products has been explained. Several relevant maturity models have been reviewed; however, it has been found that they have mainly been deductively proposed by researchers and, as such, may not address the complete breadth of factors relevant to effective IQM. This doctoral research project is aiming to fill that gap in the literature.

2.6 Engineering Asset Management

This section briefly describes engineering asset management, the domain in which this doctoral research has been applied – the explanatory case studies mainly involved the application of the Information Quality Management Capability Maturity Model to information systems dealing with the management of engineering assets. The word "asset" derives from the Latin ad satis, meaning "sufficiency " (Stapelberg 2006). As such, "it has been adopted by the accounting profession to denote real property of sufficient value to offset the debt, or liability held by an individual or organisation" (Stapelberg 2006, p. 2). Current assets have an expected short life or are readily turned into cash (e.g. investments or inventory); non-current assets have a potential service life longer than one year and may be either physical assets (e.g. land or buildings) or intangible assets (e.g. computer software or intellectual property). This thesis only deals with the domain of non-current physical assets. Numerous definitions of Asset Management can be found in the literature (DTF 1995; ANAO 1996; Danylo & Lemer 1998; DTFHA 1999; GO-DPW 2002; Mohseni 2003; Campbell & Reyes-Picknell 2006; INGENIUM 2006), including the following definition adopted by CIEAM (Stapelberg 2006, p. 1):

> *"Asset Management is the process of organising, planning and controlling the acquisition, use, care, refurbishment, and/or disposal of physical assets to optimise their service delivery potential and to minimise the related risks and costs over their entire life through the use of intangible assets such as knowledge based decision-making applications and business processes."*

The lifecycle of physical assets can be seen as comprising of three distinct stages: acquisition, operation, and disposal. An additional continuous supporting process may use the information outputs from each stage as the inputs for planning (ANAO 1996). In practice, however, each of the stages may be managed by different people in an organisation. As a result, the whole process may become fragmented and thus cause difficulties with the management of related information.

Table 2.25: Engineering Asset Management Processes/Functions

Computer Aided Design (CAD). CAD systems are mainly used in the design stage of the asset lifecycle.
Asset Register Management. As the heart of the asset management system, asset register forms the link between all modules; records asset attributes in a hierarchical structure, and defines relationships between assets. It may also record the inventory, historical, financial, condition, construction, technical, and financial information about each asset.
Asset Hierarchy Management. Asset hierarchy provides a framework for segmenting an asset base into appropriate classifications. The asset hierarchy can be based on asset function, asset type, or a combination of the two.
Asset Accounting. Asset accounting records all necessary financial information of assets, such as cost information on all assets owned, asset valuation and asset depreciation. This may be required because of legislative commitments and government reporting.
Asset Lifecycle Costing. Initial capital costs constitute a significant up-front cost and often dominate the decision making process when acquiring new assets. However, the ongoing recurrent expenditures usually represent a high proportion of the total lifecycle cost of many assets. There may also be substantial costs associated with the disposal at the end of an asset service life.
Maintenance Management. Since all assets need to be maintained regularly in order to preserve their condition and provide the desired level of service or performance, this process involves planned and unplanned maintenance management, maintenance deferral management, reliability centred maintenance, and the like. Planned maintenance involves: periodic maintenance, predictive maintenance, and preventive maintenance. Unplanned maintenance involves corrective work required in the short-term to restore an asset to working condition so it can continue to deliver the required service or to maintain its level of security and integrity.
Contract Management. Given the growing trend of using outside contractors for carrying out maintenance functions, there is a need to assemble maintenance data, store maintenance plans, generate contract schedules and work orders, and the like.
Resource Management. The effectiveness of job/resource allocation and management is vital to the efficiency of carrying out maintenance operations.
Inventory Control. An integral part of asset management involves the application of spare parts and stock to the repair, renewal, and replacement of assets.
Condition Monitoring. The physical condition of assets needs to be continually assessed. Condition modelling data are frequently collected by maintenance personnel, which they may subsequently be used to develop condition scores and condition ranks. Continuous or periodic inspection, assessment, measurement, and interpretation of the resultant data, may be used to indicate the condition of a specific component so as to determine the need for some preventive or remedial action.
Performance Monitoring. Performance monitoring involves continuous or periodic quantitative or qualitative assessment of the actual performance compared with specific objectives, targets, or standards.
Predictive Modelling. Likely failure modes should be identified, so that decisions may be made as to the type of modelling that may need to be carried out to identify the likely timing for the various failure modes.
Risk Management. Long-term implications of current business strategies need to be evaluated, and future problems and business risks need to be identified and quantified. It involves the application of formal process to the range of possible values relating to key factors associated with a risk in order to determine the resultant ranges of outcomes and their probability of occurrence.
Geographic Information System. Geographic information systems may provide for better management and visualisation of special asset information. It involves a software system, which provides a means of spatially viewing, searching, manipulating, and analysing an electronic database.
Optimised Decision Making. Relative merits of available treatment options need to be evaluated. Optimised decision making is a formal process to identify and prioritise all potential solutions with consideration of financial viability, social and environmental responsibility, and cultural outcomes.
Supervisory Control and Data Acquisition (SCADA). Supervisory Control And Data Acquisition systems are typically used to perform data collection and control at the supervisory level. They are placed on top of a real-time control system to control a process that is external to the SCADA system.

Source: developed from (INGENIUM 2006)

An asset management, information system has been defined as "a combination of processes, data, software, and hardware, applied to provide the essential outputs for effective asset management, such as, reduced risk and optimum infrastructure investment" (INGENIUM 2006, p. 4.2). A typical asset management information system should support a subset of the processes/functions listed in Table 2.25, and may also provide connectivity to other corporate information systems or databases. Therefore, an asset management system may need to integrate various disparate systems, including, Geographical Information Systems (GIS), Computer Aided Design (CAD) systems, diverse Database Management Systems (DBMS), and the like (NRCC 2001), in order to provide continuous data on the physical and financial asset conditions (Amadi-Echendu et al. 2007). A Computerised Maintenance Management System (CMMS), which has been defined as "an integrated set of computer programs and data files designed to provide its user with a cost-effective means of managing massive amounts of maintenance, inventory control, and purchasing data", can cost as little as one thousand dollars or as much as several hundred thousand (Cato & Mobley 2002 p. 13). A CMMS provides functionality that is normally grouped into subsystems or modules (along with relevant databases and/or files for the storage, manipulation, and retrieval of information), which may include asset records maintenance, asset bills of materials maintenance, inventory control, work order management, preventive maintenance plan development and scheduling, human resources management, purchasing and receiving, invoice matching and accounts payable, reporting, and so on (Cato & Mobley 2002).

The United States General Accounting Office (GAO) also sees information management as a key activity in asset management (Figure 2.12), arguing that (GAO 2004 p. 4):

> *"At its most basic level, comprehensive asset management involves the systematic collection of key data and the application of analytical tools such as life-cycle cost analysis and risk assessment … Using a fully integrated decision process, many segments of an organisation, including accounting, engineering, finance, maintenance, and operations, are expected to exchange relevant information, share in the decision making, and take an organisation-wide view when setting goals and priorities."*

GAO investigated the benefits and challenges for water utilities in implementing comprehensive asset management (GAO 2004). They found that "among the challenges to implementing asset management, utilities cited collecting and managing needed data and making the cultural changes necessary to integrate information and decision making across departments" (p. 5). Furthermore, they found that "collecting the appropriate data on utility

assets and managing the information efficiently can be difficult when existing data are incomplete and inaccurate or the data come from multiple departments and are maintained using different and incompatible software programs" (p. 7).



Figure 2.12: Elements of Comprehensive Asset Management
Source: adopted from (GAO 2004)

2.7 Conclusion

This chapter presented a review of the literature fundamental to the development of the Total Quality Management theory. The quality gurus were identified and their contributions were reviewed, TQM CSFs were identified, and Six Sigma was discussed. The chapter also presented a review of leading quality awards and frameworks, including, the Deming Prize, the Malcolm Baldrige National Quality Award, the European Quality Award, as well as Australian, Canadian, Singaporean, and Japan Quality Awards. Various relevant quality management standards and 'best practice' frameworks were reviewed as well. The chapter also presented a review of the literature on data and information quality research. The terms 'data' and 'information' were discussed, and the evolution of the information quality theory was reviewed. Information quality definitions, dimensions, implications, and causes were presented. The product analogy was explained and frameworks for IQ assessment and improvement were reviewed. A review of relevant IM and IQM maturity models was also presented. The final section of this chapter briefly discussed the domain of engineering asset management.

Chapter 3

Research Methodology

"Cogito ergo sum."

—Descartes

3.1 Introduction

The previous chapter presented a review of the literature relevant to the research problem. This chapter outlines the research methodology employed in this doctoral research project and discusses the underlying philosophical research paradigms. The chapter initially reviews the history of the philosophy of science, exploring the goals of science, and discussing theories, models, and causality. Next, two traditional approaches to acquiring new knowledge, rationalism and empiricism, are discussed. The chapter goes on to review four different "logics of discovery", including, inductivism, conventionalism, Popper's methodological falsificationism (including a discussion on hypothesis rejection), and the methodology of scientific research programmes. Also, the concept of scientific paradigms is explained in detail. The qualitative interpretive approach adopted in this research project is justified and the research design, comprising of three stages, is explained. The first stage (the exploratory phase) involves the literature review, and exploratory case studies. Stage two (the theory building phase) involves a four round Delphi study. Stage three (the theory testing and enhancing phase) involves multiple explanatory case studies. Next, the chapter explains the data collection approaches, including a discussion on theoretical sampling, interviewing, document examination, and observations. Data analysis approaches, including, the constant comparative method, hermeneutics, pattern matching, explanation building, within-case analysis, and cross-case analysis, are also discussed. The chapter concludes with a discussion of the criteria used for judging the quality of qualitative interpretive research, ethical considerations, as well as research limitations.

3.2 Philosophy of Science

This section includes a discussion on the history of the philosophy of science, discussing theories, models, causality, rationalism, empiricism, inductivism, falsificationism, conventionalism, scientific research programmes, and scientific paradigms.

3.2.1 Defining Science

Plato defined knowledge as “justified true beliefs” (Figure 3.1), and since acquiring new knowledge is the main goal of science, it is imperative to thoroughly understand all the philosophical underpinnings that are involved in the process (Steup 2006).

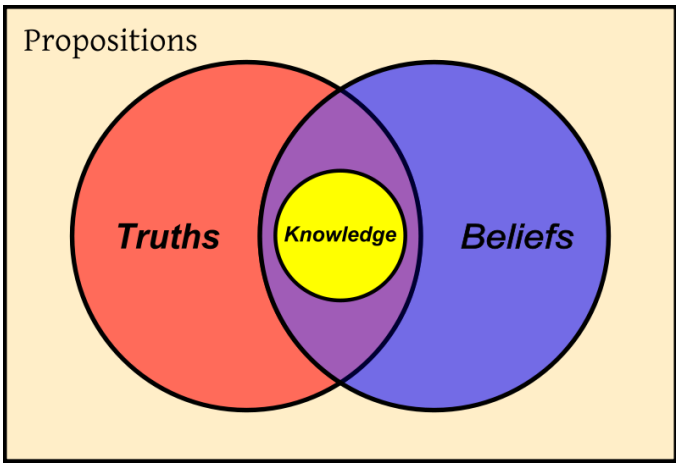


Figure 3.1: Representation of Knowledge
Source: adopted from (Wikipedia 2007)

Feyerabend (1975) cynically commented that “science started in the West when some extraordinary people preferred the results of certain intellectual games to what they could learn from their senses and tradition” (p. 3), and Kuhn even argued that pre-scientific myths should actually be considered as science (Rosenberg 2005). Science has also been described as “something that people do … not [as] a particular set of assertions or theories, but a set of activities that may or may not produce organised theories" (Snyder 1978). Others have proposed that science may be more appropriately described in terms of problem or puzzle solving (Kuhn 1970; Popper 1972b; Toulmin 1972; Laudan 1977). Kuhn even suggested that science is as creative an undertaking as painting or music (Rosenberg 2005). According to Popper (1972a) “what is to be called a ‘science’ and who is to be called a ‘scientist’ must always remain a matter of convention or decision” (p. 52).

It is generally accepted though that the objective of science is to explain and predict phenomena (Forcese & Richer 1973); however, it has also been argued that “as scientists

we must seek a truth which is unambiguous and universal, even though at the same time we must recognise that this is impossible and, indeed, strictly speaking, meaningless" (Polanyi 1950, p. 33). Hull (1943), a renowned American positivist, argued that scientific theories should operate like calculating machines; given the values of one set of variables, science should predict the values of another set. Consequently, philosophy is unavoidable for scientists, dealing with such issues as what questions can and cannot be scientifically answered, why some questions cannot be answered, and how others should be answered (Rosenberg 2005). For instance, some philosophical questions that still remain largely unanswered include the definitions of numbers, space, and time (Rosenberg 2005).

3.2.2 Theories

The phrase 'theory' is regularly used in scientific arguments, but there is no consensus on what the phrase actually means. Feyerabend (1975) argued that "the world of theory is a social world … built up by scientists" (p. 10). According to Popper (1972a), "theories are nets cast to catch what we call 'the world': to rationalise, to explain, and to master it … the empirical sciences are systems of theories … the logic of scientific knowledge can therefore be described as a theory of theories" (p. 59). Rosenberg (2005) argued that theory "goes beyond the explanations of particular phenomena to explain these explanations" (p. 70); thus, "in a theory, the parts must work together to explain" (p. 73). Maxim (1999) defined theories as "sets of verbal statements that synthesise the behaviour of empirical systems" (p. 26). According to Giere (1988) we understand a theory as comprising of two elements: 1) a population of models; and 2) various hypotheses linking those models with systems in the real world. Thus, theories should be internally consistent and potentially open to refutation (Maxim 1999). However, Feyerabend (1975) argued that it is not necessary to "derive [theories] from facts, … guarantee that they will remain successful after their first successes, … guarantee that the facts are as described, … [or] guarantee that the theories we have chosen are in agreement with the demands of formal logic" (p. 9), since the procedure of science is not to praise the good, but to eliminate what is bad, or comparatively inferior. According to Walsham (1993), "in the interpretive tradition, there are no correct and incorrect theories, but there are interesting and less interesting ways to view the world" (p. 6), therefore "there is not, and never will be, a best theory… our quest should be for improved theory, not best theory, and for theory that is relevant to the issue of our time" (p. 478). A model, on the other hand, has been described as "an imitation or abstraction from reality that is intended to order and to simplify our view of that reality while still capturing its essential characteristics" (Forcese & Richer 1973, p. 38). Models

may organise concepts into a structure and include possible explanatory relationships among them. They may also suggest hypotheses without necessarily explaining them (Forcese & Richer 1973). However, it has also been argued that a good model must have some practical use (Hardie & Walsh 1994).

3.2.3 Causality

Numerous scholars have described causality as being central to the methodology of applied sciences (Scriven 1971; Bunge 1979; Holland 1986). However, others have stated that "the word 'cause' is so inextricably bound up with misleading associations as to make its complete extrusion from the philosophical vocabulary desirable" (Bertrand 1913, p. 1). Nancy Cartwright (2004) argued that "the term 'cause' is highly unspecific", since "it commits us to nothing about the kind of causality involved nor about how the causes operate" (p. 1). Furthermore, "there is a great variety of different kinds of causes and even causes of the same kind can operate in different ways" (Cartwright 2004, p. 1). Hume (1975) defined causation twice over, defining it as 1) "an object, followed by another, and where all objects similar to the first are followed by objects similar to the second" (p. 76); and 2) "an object followed by another, and whose appearance always conveys the thought to that other" (p. 77). David Lewis followed Hume's second definition in his counterfactual theories of causation (Lewis 1973; Lewis 2000). Mackie (1980) followed the first definition and argued that causes must be both necessary and sufficient conditions for effects; where "*X is a necessary condition for Y* will mean that whenever an event of type Y occurs, an event of type X also occurs; and *X is a sufficient condition for Y* will mean that whenever an event of type X occurs, so does an event of type Y" (Mackie 1980, p.57). Thus, correlation is a necessary, but not sufficient condition for causality (Maxim 1999). According to Hume (1978), "cause and effect are relations, of which we receive information from experience, and not from any abstract reasoning or reflection" (p. 69). Thus, he argued that "all kinds of reasoning consist of nothing but a comparison, and discovery of those relations, either constant or inconstant, which two or more objects bear on each other" (Hume 1978, p. 73). According to Holland (1986), causality can only be investigated through experimentation; however, this may not be practical in social sciences, since modifying social conditions artificially can affect the subjects involved (Maxim 1999).

3.2.4 Rationalism vs. Empiricism

Philosophers have historically emphasised either reason (rationalism), or experience (empiricism) as the source of knowledge (Miller & Jensen 2004). Rationalism emphasises that some knowledge about reality can be acquired through reason, and empiricism emphasises that all knowledge about reality is delivered through the five senses (the mind as *tabula rasa*) (Peter 2004). Some of the most influential rationalists included Plato (1961), Descartes (1911), and more recently Chomsky (1965), whereas proponents of empiricism have included Aristotle (1941), St. Thomas Aquinas (1945), Locke (1924), and Hume (1888).

René Descartes is considered by many as the father of modern philosophy (Smith 2007). However, the scientific method, or Cartesian science, has its roots with the ancient Greek philosophers Thales, Pythagoras, Plato and Aristotle (Devlin 1996). Descartes argued for methodological scepticism, rejecting Aristotelian physics and any idea that can be doubted (Garber 2000). Descartes also viewed senses as being unreliable and not suitable for scientific inquiry, admitting only deduction as a method. He advocated mathematics as the preferred foundation for science, reducing all properties of material objects to mathematical forms. Descartes proposed dualism, arguing that the mind is a non-physical, separate and distinct, substance from the body (Descartes 1969). Thus, he argued, it wasn't subject to natural laws, and may have to be studied using different methods. Due to this argument, the study of the soul could be left to the theologians, and the study of the physical world could be undertaken by scientists. However, one of the major problems arising from dualism is the mind-body problem, which relates to the interaction of the non-physical mind with the physical body (Devlin 1996). Nevertheless, this idea had an enormous influence on the positivist thought, which focused on studying the physical world as a separate entity from the human observer. Kant (1781), building on the ideas of Hume, argued that there is more to perception than only sensory observations. Thus, he disagreed with Descartes, believing that sensory perceptions need to be mentally interpreted in order to make sense. Similarly, German philosopher Martin Heidegger, while investigating phenomenology, argued that it is wrong to adopt a simple objective or subjective stance, but that both objective and subjective realities have to be considered together (Heidegger 1962). Thus, he argued that the detached Cartesian approach was misleading, because an observer can never be completely objective, always using past experiences to interpret the reality (Devlin 1996). Likewise, Polanyi (1950) advocated that

"we must openly declare the beliefs which we hold about the nature of things, which guide our pursuit of science" (p. 31).

Throughout the twentieth century, empiricism was the dominant epistemology, asserting that scientific knowledge can only be justified by experiences (Rosenberg 2005). Thus, observations, data collection, and controlled experiments are central to empiricism. Logical positivism, also known as logical empiricism, which originated from the Vienna Circle in the 1920s, embraced empiricism and supported it with, at the time, contemporary developments in formal logic, arguing, among others, that no *a priori* propositions can exist. Logical positivists also rejected metaphysics as meaningless. One of the main beliefs of logical positivism was the principle of verification, going back to David Hume (1978), which was later fiercely criticised by Popper, who argued for falsification (Popper 1959). The principle of verification asserts that a statement is meaningful if and only if it is either purely formal (analytic a priori) or empirically verifiable (synthetic a posteriori) (Maxim 1999). On the other hand, Popper argued that scientific hypotheses have to be capable of being tested, and potentially experimentally falsified (Popper 1959). Other critics have argued that the principle of verification itself cannot be verified. Polanyi (1950) argued that positivists "dread to be caught believing – and, in fact, knowing – things which are not demonstrable by the measurement of observed variables" (p.31). Strauss (1957) supported this view and wrote, "things which every ten year old child of normal intelligence knows are regarded as being in need of scientific proof in order to become acceptable as facts … this scientific proof which is nor only not necessary, is not even possible" (p. 352). According to Polanyi (1950), it is logically impossible to completely dissociate the human mind from all uncritically acquired foundations. Thus, the fundamental fallacy of the positivist model of science comes from the fact that it is trying to construct a machine which will produce universally valid results (Polanyi 1950). Polanyi argued that "the attempt to construct something universally valid, prior to any belief, is logically nonsensical" (p. 35). Thus, he argued that "science can never be more than an affirmation of certain things we believe in" (Polanyi 1950, p. 35). The renowned political philosopher Leo Strauss (1957) detailed several further theoretical weaknesses of social science positivism arguing that only factual judgements are within the competence of social science positivism, and that it "must avoid value judgements altogether" (p. 347). Thus, "positivistic social science is 'value-free' or 'ethically neutral'" (p. 347), and it is "impossible to study … important social phenomena without making value judgements" (p. 349). Another important criticism of social science positivism is that "positivism

necessarily transforms itself into historicism" (p. 354); that is to say that, it is in danger of mistaking present peculiarities for essential characteristics of human society. Therefore, social scientists should possess a good historical understanding.

3.2.5 Inductivism

According to Imre Lakatos, contemporary methodologies in philosophy of science are very different from the methodologies in the 17th and 18 centuries (Lakatos 1970). As Lakatos explains, the past hope that a methodology could provide a mechanical set of rules for solving problems has now been given up. He describes four different "logics of discovery", including, inductivism, conventionalism, Popper's methodological falsificationism, and the methodology of scientific research programmes (Lakatos 1970).

Induction is a process of generalisation derived from repeated observations (Forcese & Richer 1973). Inductivism, which "set out to define the probabilities of different theories according to the available total evidence" (Lakatos 1973), has been one of the most influential methodologies of science (Lakatos 1970). Thus, according to Lakatos, probabilism provides a continuous scale from poor theories with low probability to good theories with high probability. However, Hume argued that "justification can be neither by derivation from experience nor by probabilification" (Feyerabend 1975, p. 7). Karl Popper defined the problem of induction as "the question of the validity or the truth of universal statements which are based on experience, such as the hypotheses and theoretical systems of the empirical sciences" (Popper 1972a, p. 28). Popper, who used induction in his early scientific career (Gattei 2004), later argued that "there is no such thing as induction … thus, inference to theories, from singular statements which are 'verified by experience' … is logically inadmissible" (Popper 1972a, p. 40). According to Popper (1972a) "theories are, therefore, never empirically verifiable" (p. 40). However, even though "scientific theories are never fully justifiable or verifiable … they are nevertheless testable" (1972a, p. 44). Popper adopted Kant's definition of objectivity – Kant used the word objective "to indicate that scientific knowledge should be justifiable … a justification is 'objective' if in principle it can be tested and understood by anybody" (p. 44). Thus, according to Popper (1972a) "there can be no ultimate statements in science" (p. 47). For instance, "no matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white" (p. 27). However, Hume (1978) argued that even though induction can only be validated through induction itself, and thus cannot be logically justified, it can be defended pragmatically (Krueger 2001).

3.2.6 Popper's Falsificationism

Inductivism moves from particular to the general by adding higher order statements in an ad hoc passion, thus always creating the illusion of explanation (Forcese & Richer 1973). Hence, Forcese & Richer (1973) argued that a deductive approach is preferred because it derives previously unobserved relationships from existing theories. Popper (1972a) had the same view and argued that science is based on the process of conjecture and refutation. According to Popper, "the act of conceiving or inventing a theory seems … neither to call for logical analysis nor to be susceptible of it" (p. 31). Thus, he argued that "the question of how… a new idea occurs… is irrelevant to the logical analysis of scientific knowledge" (p. 31). But, if "a theory withstands detailed and severe tests… we may say that… it is corroborated by past experience" (p. 33). Thus, according to Popper, conjectured theories are tested empirically and subsequently abandoned if falsified. Popper argued that the goal of theory falsification is "to select the one which is by comparison the fittest, by exposing them all to the fiercest struggle for survival" (p. 42). As a result, "science is not a system of concepts but rather a system of statements" (p. 35).

Hypothetico-Deductive Method

A hypothesis has been defined as "an untested or unproven relationship among two or more variables" (Forcese & Richer 1973, p. 40), and the primary steps of the hypothetico-deductive method have been described as follows (Maxim 1999, p. 21):

1. Propose some theory, T.
2. From T draw a series of logical predictions or hypotheses, H, which propose empirical or observable consequences. The H should be stated along with any caveats or *ceteris paribus* (all other things being equal) assumptions.
3. Collect data for testing H using standard test procedures (e.g. experimentation).
4. Decide whether T is or is not disconfirmed depending upon whether the data collected in step 3 are or not congruent with H.

The hypothesis supporting the prediction is usually called the alternative hypothesis and the hypothesis describing all other possible outcomes, the null hypothesis (Trochim & Donnelly 2007). A one-tailed alternative hypothesis specifies direction (e.g. H_A: A will cause a decrease in B, H_0: A will cause either no significant difference or an increase in B) and a two-tailed alternative hypothesis does not specify direction (e.g. H_A: A will cause significant difference in B, H_0: A will cause no significant difference in B).

Hypothesis Rejection

Let H be a hypothesis and let I be a statement describing the observable occurrence to be expected (Hempel 1966):

If H is true, then so is I.

<u>But (as evidence shows) I is not true.</u>

H is not true.

The above seen argument, called *modus tollens* in logic, is deductively valid, however:

If H is true, then so is I.

<u>(As the evidence shows) I is true.</u>

H is true.

The above mode of reasoning, called *fallacy of affirming the consequent*, is deductively invalid. Thus, the favourable outcome of an experiment (or even multiple experiments) does not prove the hypothesis to be true, but corroborates it. To follow Maxim (1999):

If null-H is true, then so is I.

<u>But (as evidence shows) I is not true.</u>

Null-H is not true.

Thus, showing that the null hypothesis is not true leads us to accept the validity of the working hypothesis (Maxim 1999). However, it has to be noted that the inability to disprove a hypothesis does not necessarily confirm it. The Pearson-Neyman approach to hypothesis testing states that (Maxim 1999, p. 82):

1. The hypothesis to be tested is to be stated (in null form) a priori, before the trial (survey, experiment, etc.) is conducted; and
2. The decision concerning the outcome of that trial is a binary one, resulting in either the rejection or non-rejection of the null hypothesis.

However, null hypothesis significance testing has been criticised by arguing that "the primary aim of scientific experiment is not to precipitate decisions, but to make an appropriate adjustment in the degree to which one accepts, or believes, the hypothesis or hypotheses being tested" (Rozeboom 1960, p. 420). Others have argued that the null hypothesis "is usually formulated for the express purpose of being rejected" (Siegel 1956, p. 7). Rozeboom (1997) referred to it as "the most bone-headedly misguided procedure ever institutionalised in the rote training of science students" (p. 335), and Nickerson (2000) argued that the contemporary availability of statistical software packages has exacerbated the problems. Furthermore, the Duhem-Quine thesis states that it is not possible to falsify single hypotheses, because it is invariably conjunctions of hypotheses

which are being tested (Cross 1982). That means that any theory can be made compatible with any empirical evidence by the addition (or modification) of auxiliary hypotheses (Lakatos 1980). According to Feyerabend (1975), "Popper's theory of falsification … arose from the trivial observation that while a singular statement may entail the negation of a universal statement it never entails any universal statement … one soon realised that the suggested rules were either useless or devastating" (pp. 1-2). Furthermore, Popper did not discuss corroboration to a great extent (Grattan-Guinness 2004). Additionally, Kuhn has shown that historically, scientists do not regard theories with anomalies as falsified, but only reject a theory when a better alternative is presented (Lakatos 1970). Polanyi (1950) also described as a "pure myth" the presumption that scientists immediately drop hypotheses the moment conflicting empirical evidence is found. According to Polanyi (1950), "no true scientist acts in this clumsy manner" (p. 28). He further argued that scientists will often tolerate such anomalies hoping to eliminate them by enhancing the theory.

3.2.7 Conventionalism

On the other hand, based on conventionalism, theories are "justified because of the order they bring into the known facts and because they provide concepts and ordering principles for things as yet to be discovered" (Feyerabend 1975, p. 8). Conventionalists do not regard any theory as proven true, but only as "true by convention" (Lakatos 1970, p. 95). Accordingly, theories are modified when anomalies arise (Lakatos 1970).

3.2.8 Scientific Research Programmes

Imre Lakatos argued for a methodology of scientific research programmes (Lakatos 1980). He defined a 'research program' as development of a theory, in combination with its auxiliary belt, over time. Auxiliary hypotheses explain why theory's prediction didn't eventuate without modifying the theoretical hard core, thus making sure that the theory stays constant as the auxiliary belt changes. The theoretical hard core consists of the assumptions and propositions widely accepted as true by the scientist within the research programme. Heuristic is a rule for theory development; negative heuristic is a convention that the theoretical hard core is not modified; and positive heuristic is instructions on how auxiliary hypotheses are adjusted in the case of anomalies. Lakatos described a research programme as progressive if its positive heuristic lead to novel findings and predictions that are empirically corroborated, and as degenerative if modifications to the auxiliary hypotheses only serve to explain the anomalies, and do not generate any novel findings.

According to Lakatos, possibly the most successful research programme ever is the classical example of Newton's gravitational theory. However, Feyerabend (1975) compared science with Darwinism and argued that in evolution “there was no aim, there was no 'method of justification', and it is doubtful whether conscious planning could ever have produced a comparable result” (p. 10).

3.2.9 Scientific Paradigms

Kuhn’s (1962) analysis of the history of science ‘The Structure of Scientific Revolutions’ was published in 1962 and has since become one of the most cited academic books of all time (Bird 2004; Rosenberg 2005). In the book, he argued that science doesn’t progress through linear accumulation of new knowledge, but through paradigm shifts, or scientific revolutions (Kuhn 1962). Paradigm shifts occur when scientists encounter anomalies, which cannot be explained under existing paradigm. Kuhn (1962) described science as “a strenuous and devoted attempt to force nature into the conceptual boxes supplied by professional education” (p. 5). He argued that normal science “means research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice” (p. 10). Kuhn (1962) called those achievements “paradigms” (p. 10), and argued that “man whose research is based on shared paradigms are committed to the same rules and standards for scientific practice” (p. 11). Thus, normal science “is predicated on the assumption that the scientific community knows what the world is like” (p. 5). Also, normal science is practiced within a single paradigm and works as puzzle solving. Revolutionary science, on the other hand, leads to transformation from one paradigm to another. According to Kuhn (1962), “the successive transition from one paradigm to another via revolution is the usual developmental pattern of mature science” (p. 12). Paradigms gain their status because “they are more successful than their competitors in solving a few problems that the group of practitioners has come to recognise as acute” (p. 23). Furthermore, “one of the things a scientific community acquires with a paradigm is a criterion for choosing problems that, while the paradigm is taken for granted, can be assumed to have solutions” (p. 37). Otherwise, “in the absence of a paradigm or some candidate for paradigm, all the facts that could possibly pertain to the development of a given science are likely to seem equally relevant” (p. 15). Skepticism, for example, “assumes that theories and world views are all equally good or equally bad and that any attempt to distribute praise and blame is sooner or later bound to run into difficulties” (Feyerabend 1975, p. 16). Similarly, Paul Feyerabend (1993) argued that “anything goes”,

since science is essentially an anarchistic enterprise. He argued that science shouldn't be run according to fixed and universal rules, and he objected to any single prescriptive scientific method. According to Feyerabend (1993) "given any rule, however 'fundamental' or 'rational', there are always circumstances when it is advisable not only to ignore the rule, but to adopt its opposite" (p. 14).

Definitions of ontology, epistemology and methodology, which are foundational to research and theory making, have varied over time as Philosophy has developed (Love 2000; Khazanchi & Munkvold 2003). A research paradigm (Kuhn 1962) has also been defined as the "basic belief system or world view that guides the investigation" (Guba & Lincoln 1994, p. 105). More specifically, it is defined by the ontology (the study of reality and being), deriving from the Greek ontos – being and logos – study; the epistemology (the study of knowledge), deriving from the Greek episteme – knowledge and logos – study; and methodology (the study of methods to generate knowledge), deriving from the Greek methodos – method and logos – study (Kuhn 1962; Guba & Lincoln 1994; Greco 1999; Love 2000). Hence, it has been argued that epistemology determines ontology and thus that they are inseparable (Guba 1990; Archer 1995). Accordingly, epistemology links ontology and methodology through the application of research methods (Love 2000). Guba and Lincoln (1998) argued that "both qualitative and quantitative methods may be used appropriately with any research paradigm … questions of method are secondary to questions of paradigm" (p. 195). They go on to assert that "paradigm issues are crucial; no inquirer ought to go about the business of inquiry without being clear about just what paradigm informs and guides his or her approach" (p. 218).

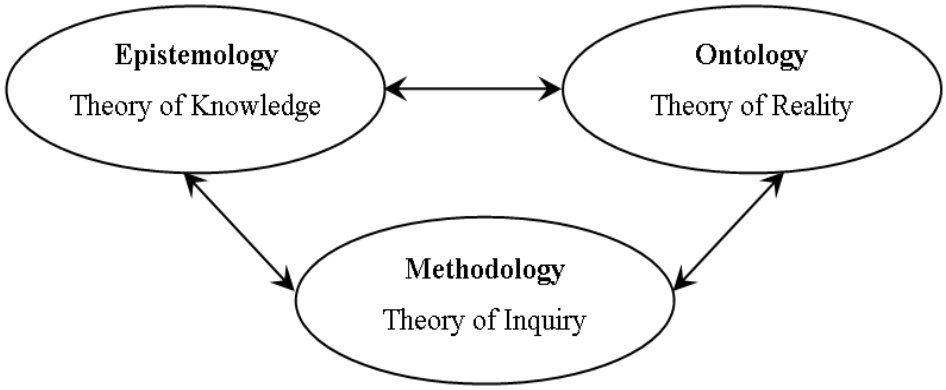


Figure 3.2: The Research Triangle
Source: adopted from (Travis 1999, p. 1041)

Scientific paradigms guiding research have, most recently, been grouped into four categories: positivism (empiricism), critical theory, constructivism and realism (Guba 1990; Guba & Lincoln 1994; Perry, Riege & Brown 1998; Healy & Perry 2000). Realism also being known as critical realism (Hunt 1991; Dobson 2001), postpositivism (Denzin & Lincoln 1994; Guba & Lincoln 1994), and neopostpositivism (Manicas & Secord 1982). Myers (1997) adopted a three-fold classification for qualitative research in information systems, based on the underlying research epistemology: positivist, interpretive, and critical, which were advocated by Chua (1986) and adopted by Orlikowski & Baroudi (1991). Myers (1997) further argued that while these three research epistemologies are philosophically distinct, in the practice of social research these distinctions are not always so clear cut. Thus, he argued that "there is considerable disagreement as to whether these research 'paradigms' or underlying epistemologies are necessarily opposed or can be accommodated within the one study" (Myers 1997). Similarly, Lee (1991) advocated the adoption of a mix of paradigms to maximise the understanding of IS phenomena.

Positivism views the social world like the natural word "as if it were a hard, external, objective reality" that can be represented by "an analysis of relationships and regularities between the various elements which it comprises" (Burrell & Morgan 1979, p. 3). Accordingly, positivist paradigm has been summarised as being based on five pillars: unity of the scientific method; search for causal relationships; belief in empiricism; science (and its process) is value-free; and the foundation of science is based on logic and mathematics (Hirschheim 1992). However, "a fundamental difference exists between the bulk of the phenomena of concern to the natural as opposed to the sociobehavioral scientist … there is ample reason to believe that the phenomena of focal concern to the latter are far less stable (enduring, reliable, or replicable) than those of the interest to the former" (Gergen 1993, p. 12). Positivism emphasises deduction and thus is the predominant paradigm for quantitative research, while critical theory, constructivism and realism emphasise induction and thus are more relevant in qualitative research (Guba 1990; Guba & Lincoln 1994; Neuman 1994; Perry, Riege & Brown 1998; Healy & Perry 2000). Furthermore, positivists separate themselves from the world they study, while researchers within the three other paradigms actively participate in the research situation (Healy & Perry 2000). The roles of ontology and epistemology change between positivist and realist research situations, since in positivist research human considerations are excluded, whereas the realist ontology focuses on the factors that influence individual human beings' senses of reality (Love 2000). IS research can be classified as positivist if there is evidence of formal propositions,

quantifiable measures of variables, hypothesis testing, and statistical generalisation (Vitalari 1985; Jönsson 1991; Olaisen 1991; Orlikowski & Baroudi 1991; Hirschheim 1992; Shanks, Rouse & Arnott 1993). Thus, positivist studies generally attempt to "test theory, in an attempt to increase predictive understanding of phenomena" (Orlikowski & Baroudi 1991, p. 5). Orlikowski & Baroudi (1991) found that 96% of articles published in selected IS journals from 1983 to 1988 adopted a positivist perspective. However, it has been argued that positivist view is inappropriate for research in social sciences, which involve humans and their experiences (Robson 1993; Healy & Perry 2000). Thus, in recent times, the IS research community has gradually been moving towards non-positivist and interpretive techniques and approaches, which have emerged as an important research strand (Walsham 1995; Lee 1999).

IS research can be classified as critical if the main task is seen as being one of social critique (Klein & Myers 1999). Myers (1997) further argued that critical research seeks to be emancipatory in nature, by focusing on oppositions, conflicts, and contradictions in the contemporary society.

Constructivism holds that reality actually consists of multiple realities that people have in their minds; thus, this paradigm largely depends on interactions between the interviewer and the respondents (Lincoln & Guba 1985; Hunt 1991; Guba & Lincoln 1994; Manning 1997; Healy & Perry 2000). Since it is based on the notion that there are multiple realities, it views all knowledge as being constructed by our awareness (Hunt 1991; Corbetta 2003). Constructivism legitimises multiple interpretations of contexts and accepts that research findings are also partly constructed by the research process (Pickard & Dixon 2004).

Realist paradigm deals with open (fuzzy boundary) systems (Bhaskar 1979; Yin 1994), assuming that the reality under study is independent of the researcher, albeit it is only imperfectly apprehensible since there are many perceptions of it (Outhwaite 1983; Pawson & Tilley 1997; Perry, Alizadeh & Riege 1997; Easton 1998; Naude & Turnbell 1998; Perry, Riege & Brown 1998; Healy & Perry 2000). Furthermore, Healy & Perry (2000) argued that realism research must be primarily theory-building. In contrast to the other three paradigms, realism recognises that prior theory should be improved although precise knowledge of reality remains uncertain, given the fact that there are many perceptions of the truth (Outhwaite 1983; Hirshman 1986; Guba & Lincoln 1994; Aronson, Hare & Way 1995; Perry, Riege & Brown 1998; Healy & Perry 2000).

Walsham (1993) summarised interpretive research as methods that start from the proposition that our knowledge of reality is a social construction by human actors, and thus "there is no objective reality which can be discovered by researchers and replicated by others, in contrast to the assumptions of positivist science" (p. 34). Hence, interpretive approaches reject the possibility of creating generic laws (Bain 1989). Thus, in the interpretive tradition, "there are no correct and incorrect theories but there are interesting and less interesting ways to view the world" (Walsham 1993, p. 6). Interpretive approaches focus on people's individual and collective subjective realities, by seeking to explain phenomena in terms of the meanings they hold for people (Orlikowski & Baroudi 1991; Smith & Stewart 2001). Klein & Myers (1999) argued that IS research can be classified as interpretive if it is assumed that our knowledge of reality is only gained through social constructions such as language, shared meanings, documents, and on so. Additionally, interpretive research does not predefine dependent and independent variables, in contrast focusing on the full complexity of human sense making (Kaplan & Maxwell 1994). In other words, it attempts to understand phenomena through the meanings that people assign to them (Boland 1985; Boland 1991; Orlikowski & Baroudi 1991; Deetz 1996). Interpretivism asserts that "reality, as well as our knowledge thereof, are social products and hence incapable of being understood independent of the social actors (including the researchers) that construct and make sense of that reality" (Orlikowski & Baroudi 1991, p. 13). However, 'interpretive' is not a synonym for 'qualitative' in the research context (Klein & Myers 1999). Qualitative research may or may not be interpretive, depending upon the underlying philosophical assumptions of the researcher (Myers & Avison 2002).

Figure 3.3 shows the mapping of several methodologies and their related paradigms. The figure shows that qualitative methods in the constructivist paradigm apply to theory building research, whereas quantitative methods in the positivist paradigm apply more to theory testing research.

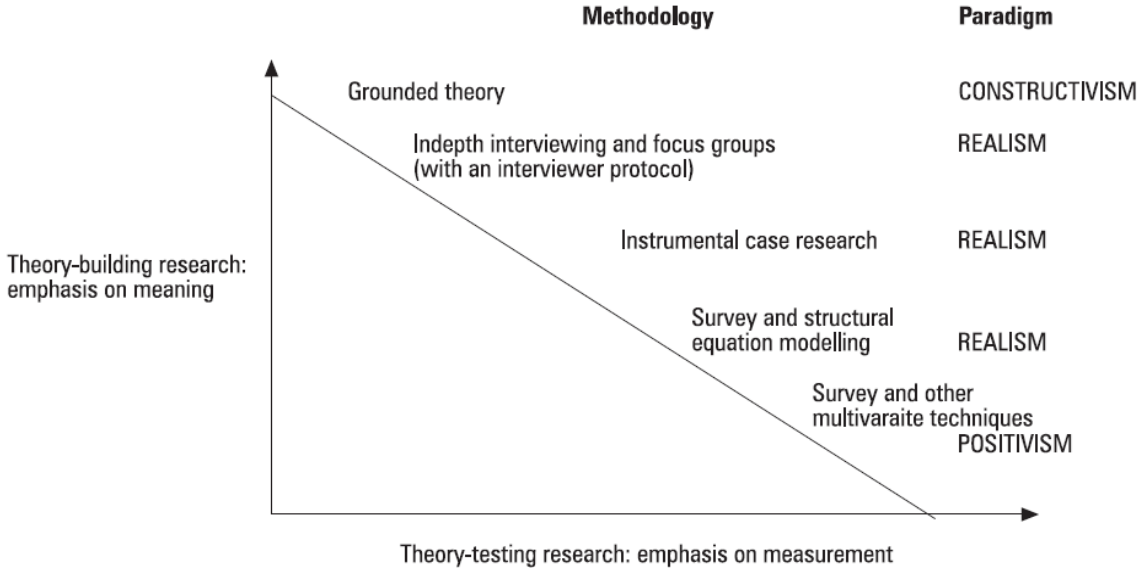


Figure 3.3: Methodologies and their Related Paradigms
Source: adopted from (Healy & Perry 2000, p. 121)

Numerous researchers have argued for the combined use of qualitative and quantitative methods (Kaplan & Duchon 1988; Gable 1994). Allen Lee (1991) proposed an integrated framework for the positivist and interpretive research in information systems by proposing three levels of understanding. The first level consists of everyday commonsense and meanings (the subjective understanding). The second level refers to researcher's interpretation of the first level understanding (the interpretive understanding). The third level refers to positivist understanding that the researcher creates and tests in order to explain the empirical reality (the positivist understanding). Figure 3.4 shows the cyclical nature of the relationships that exist among the three levels. Arrow 1 indicates that the subjective understanding provides the basis on which to develop the interpretive understanding. Arrow 2 shows that to test the validity of the resulting interpretive understanding, the researcher may refer back to the subjective understanding. Similar process applies to other arrows shown in the figure.

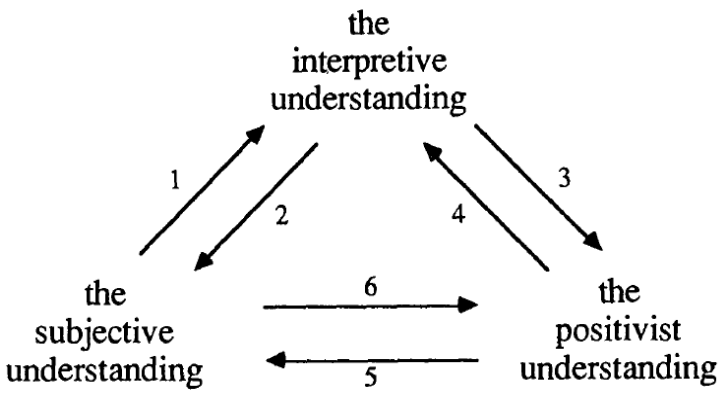


Figure 3.4: A Framework for Positivist and Interpretive Research
Source: adopted from (Lee 1991, p. 351)

Table 3.1: A Comparative Overview of the Major IS Research Paradigms

	Positivist	**Interpretivist**	**Critical Research**
Ontological Assumptions	"Naive Realism" in which an understandable reality is assumed to exist, driven by immutable natural laws. True nature of reality can only be obtained by testing theories about actual objects, processes or structures in the real world.	Relativist – the social world is produced and reinforced by humans through their action and interaction.	Historical Realist – social reality is historically constituted; human beings, organisations, and societies are not confined to existing in a particular state.
Epistemological Assumptions	Verification of hypothesis through rigorous empirical testing. Search for universal laws or principles. Tight coupling among explanation, prediction and control.	Understanding of the social world from the participants' perspective, through interpretation of their meanings and actions. Researchers' prior assumptions, beliefs, values, and interests always intervene to shape their investigations.	Knowledge is grounded in social and historical practices. It is generated and justified by a critical evaluation of social systems in the context of researchers' theoretical framework adopted to conduct research.
Relationship between Theory and Practice	It is possible to discover universal laws that govern the external world.	Generative mechanisms identified for phenomena in the social sciences should be viewed as 'tendencies', which are valuable in explanations of past data but not wholly predictive for future situations.	Generalisations focus on the totality of relationships and point to regularities of process rather than cross-sectional differences. There can be no theory independent collection and interpretation of evidence to conclusively prove or disprove a theory.
Role of the Researcher	Objective, impartial observer, passive, value-neutral	Interactive – the researcher interacts with the human subjects of the enquiry, changing the perceptions of both parties.	Transformative – initiating change in social relations and practices, helping to eliminate the bases of alienation and domination.

Source: adopted from (Khazanchi & Munkvold 2003)

Weber (2004) argued that there are deep similarities, rather than differences, between positivism and interpretivism. He considered various methodological assumptions, including, ontology, epistemology, research object, research method, truth, validity, and reliability. Regarding ontology, Weber argued for the middle-ground, that is, he argued that there must be some sort of reality that exists beyond our perception of it. On the other hand, he also conceded that our perception of that reality may be subjective. Concerning epistemology, Weber contended that all researchers accept that theories, frameworks, constructs, and so on, are socially constructed. He wrote, "research is a continuous journey to find improved ways to understand reality" (p. vi). Furthermore, Weber noted that "the research object and the researcher cannot be independent; thus, the 'True' inherent qualities of the research object are inaccessible" (p. vii). Consequently, Weber argued that there is no clear-cut distinction between positivist and interpretivist research methods. For instance, case study research used to be a primarily interpretivist, whereas many contemporary case studies are conducted within the positivist paradigm; and interpretivists' application of the hermeneutic circle is similar to positivist cycles of theory building and theory testing (Weber 2004). He further argued that there are no differences between positivist and interpretivist notions of validity, given that numerous positivist scientific experiments have shown that, it appears, one cannot measure reality without affecting what is being measured. He also argued that there was little difference in the notions of reliability since both groups of researchers are ultimately concerned with replicability.

3.3 Justification for the Qualitative Interpretive Research Approach

Qualitative research is an ongoing process of interpretation and analysis. Strauss & Corbin (1994) defined it as "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (p. 17). Thus, qualitative research, "an empirical enterprise" involving "the close study of everyday life in diverse social contexts" (Miller 1997, p. 3), places less emphasis on causation than quantitative research, and it focuses on investigating the nature of the research problem, rather than the amount of characteristics (Cropley 2002). Qualitative research, a "multimethod in focus, involving an interpretive, naturalistic approach to its subject matter" (Denzin & Lincoln 1994, p. 2), focuses on the meaning and understanding of people's perceptions, opinions, beliefs, and practices (Patton 1990). Thus, qualitative researchers study phenomena in their natural

settings and interpret them through the meanings that people bring to them (Denzin & Lincoln 1994).

Whereas quantitative research is mainly concerned with the testing of hypothesises and statistical generalisations, qualitative research is mainly concerned with understanding the nature of the phenomena (Labuschagne 2003). Qualitative research is also a more creative process than quantitative research, which is restricted by statistical analysis (Patton 1990). Additionally, whereas quantitative methods generally separate the researcher from the context, qualitative methods assume that the reality is a human creation (Sarantakos 1993; Denzin & Lincoln 1994).

The aim of this research has been to identify factors that correlate to different stages of organisational maturity with respect to the management of information quality. The 'maturity' concept is interpretive by nature, since it is determined through the meanings that people assign to it. What's more, according to Denzin & Lincoln (1994), "all research is interpretive, guided by a set of beliefs and feelings about the world and how it should be understood and studied" (p. 13). Furthermore, this research is mainly concerned with theory building. Thus, it has been necessary to approach the problem through the qualitative interpretive perspective.

The research aims to explore the concept of information quality management capability maturity and develop the corresponding maturity model, rather than to test any existing theory. Interpretative research does not predefine dependent and independent variables, but focuses on the full complexity of human sense making as the situation emerges (Kaplan & Maxwell 1994). Additionally, when a subject area is not well understood, qualitative methods may be used to build theory and testable hypotheses; theory may then later be tested using quantitative methods such as surveys and experiments (Moody & Shanks 2003). Thus, the model development can further be described as qualitative research since it is subjective, holistic, interpretative and inductive in nature.

Qualitative data was interpreted by research participants to initially identify relevant candidate information quality management maturity indicators, and subsequently to build and test the maturity model. Given the complexity and nature of the research problem, the inductive approach was deemed suitable, since the theory had to emerge out of the data (Glaser & Strauss 1967).

3.4 Research Design

The information quality management capability maturity model has been developed in three stages (Figure 3.5). Stage one was used to identify a range of candidate information quality management maturity indicators, through six exploratory case studies, and a comprehensive literature review. Stage two involved a four round Delphi study (comprising of 20 participants), which was used to validate and group the candidate maturity indicators into staged levels. The final stage of the research methodology ensured further external validation and enhancement though the application of the model in seven international case studies. Following Walsham (1993), the research design was aimed at achieving a suitable combination of theory and practice, so that the research results can eventually be used by practitioners.

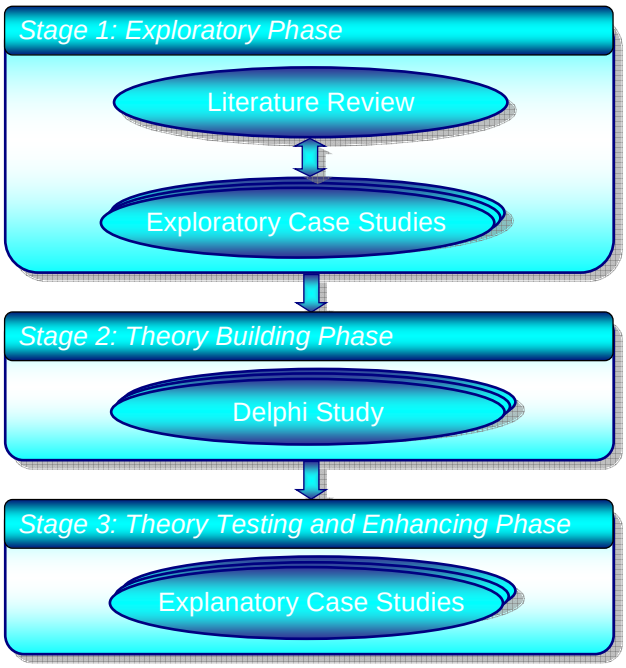


Figure 3.5: Research Methodology
Source: (developed by the author)

3.4.1 Stage 1: Exploratory Phase

Stage one was used to identify a range of candidate information quality management maturity indicators, through six exploratory case studies, and a comprehensive literature review. The candidate maturity indicators were examined from three perspectives (Figure 3.6): organisational, social, and technological (Linstone 1981).

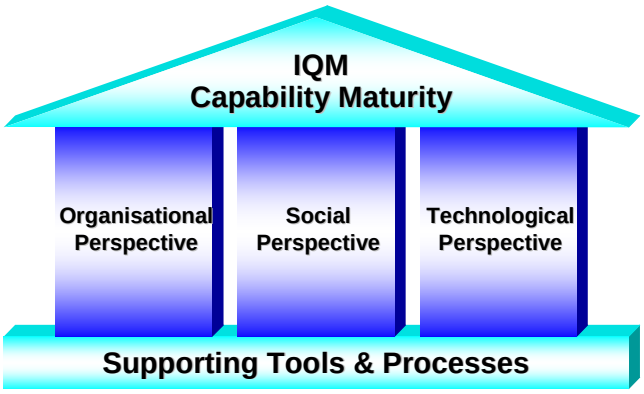


Figure 3.6: IQM Capability Maturity Framework
Source: (developed by the author)

Literature Review

The first stage of the research approach involved a comprehensive literature review in the fields of quality assurance; total quality management; quality awards, frameworks, and best practices; data and information quality management; and maturity models. This literature review can be found in Chapter 2. The literature review, together with the findings from the exploratory case studies resulted in a set of candidate information quality management maturity indicators. A comprehensive literature review was undertaken, in order to gain an in-depth understanding of the research problem, as well as identify gaps in the existing literature. Due to the 'Information Product' analogy, it was found that a lot of the classic TQM ideas could potentially also be applied to the domain of data/information quality. TQM success factors (top management commitment, quality measurements and benchmarking, process management, product design, employee training and empowerment, supplier quality management, and customer involvement and satisfaction), as well as various aspects of the quality models, frameworks, awards, standards and best practice approaches, were incorporated into the set of candidate maturity indicators, and were used to set the direction of the exploratory interviews. One limitation found with the existing IM and IQM maturity models was that, for the most part, they were deductively proposed by researchers and thus presented a somewhat limited view of information quality management capability maturity.

Exploratory Case Studies

Yin (1994) defined the scope of a case study as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident" (p. 13). Case studies provide an opportunity for the researcher to gain a holistic view of the research problem

(Feagin, Orum & Sjoberg 1991; Gummesson 1991), and may facilitate describing, understanding and explaining a research problem or situation (Tellis 1997). The fields of Law and Medicine were ones of the first to adapt case study as a methodology (Tellis 1997), but it has been argued that case studies "can be of particular value in the applied social sciences where research often aims to provide practitioners with tools" (Gummesson 1991, p. 76). According to Yin (2002), case studies are useful when the objective is to study contemporary events. He also argued that case study methodology is suitable when the problem under study is difficult to distinguish from its context, so that there is a need to rely on multiple sources of evidence (Yin 1993; Yin 1994). However, he also warned that "case study research is remarkably hard, even though case studies have traditionally been considered to be 'soft' research … paradoxically, the 'softer' a research strategy, the harder it is to do" (Yin 1994, p. 16).

Yin (1993) distinguished between three different types of case studies. Exploratory case studies may be undertaken prior to the definition of the research questions and hypothesises. Accordingly, they are mainly used for theory building. Descriptive case studies try to completely describe different characteristics of a phenomenon in its context, and so they are also mainly used for theory building. Explanatory case studies may be undertaken to investigate causal relationships. Hence, they are mainly used for theory testing. They are characterised by "how and "why" research questions because they investigate the relationships that are proposed between different theory components (Yin 1994). Inconsistencies between a preliminary theory and the evidence are accommodated in an explanatory case study design by revising the preliminary theory (Diezmann 2002).

Table 3.2: Criteria for Selecting the Case Study Research Method

Research Method	**Form of Research Question**	**Requires Control of Behavioural Events?**	**Focuses on Contemporary Events?**	**Suitable for this Research Project**
Experimental Research	How? Why?	Yes	Yes	**No**
Survey	Who? What? Where? How many? How much?	No	Yes	**No**
Case Study	How? Why?	No	Yes	**Yes**

Source: adapted from (Yin 2002, p. 5)

Stake (1994) also identified three different types of case studies. Intrinsic case studies only aim at acquiring better understanding of the particular case of interest. Thus, such case studies are not aimed at theory building. Instrumental case studies provide insights into an issue or are used to refine a theory. And, collective case studies are comprised of several

instrumental case studies. However, Stake further argued that studies seldom fit neatly into such categories. Furthermore, researchers have to make a strategic choice in deciding on the scope of the case study, since everything cannot and need not be understood (Stake 1994).

Case study research can be positivist (Lee 1989; Yin 1994), interpretive (Walsham 1993; Walsham 1995), or critical. However, none of the approaches is inherently superior, given that they depend on the research objectives (Lee 1991). Cavaye (1996) argued:

> *"Case research can be carried out taking a positivist or an interpretive stance, can take a deductive or an inductive approach, can use qualitative and quantitative methods, and can investigate one or multiple cases. Case research can be a highly structured, positivist deductive investigation of multiple cases; it can also be an unstructured interpretive, inductive investigation of one case; lastly, it can be anything in between these two extremes in almost any combination." (p. 277)*

Allen Lee (1989) presented a scientific methodology for conducting management information systems case studies, supporting his illustrations with the Markus (1983) article. He based his argument on the natural science model for social science, which assumes that "natural science is the ideal on which social science should model itself" (Lee 1989, p. 34). Thus, he followed Popper's approach of falsificationism, and argued that even though most theories or propositions in science are not directly verifiable (they concern unobservable phenomena), it may be possible to deductively hypothesise predictions of events that if the theory were true would be observable. He illustrated this with the Markus (1983) article, where three competing theories were presented and subsequently subjected to attempted falsification.

There is no real consensus in the literature about how many case studies should be conducted in a doctoral research project. Perry (1998) analysed the suggestions that can be found in the literature and concluded that the range seems to fall between "two to four as the minimum and ten, 12 or 15 as the maximum" (p. 749). Perry (1998) argued that "several case studies should usually be used in postgraduate research because they allow cross-case analysis to be used for richer theory building". However, according to Glaser & Strauss (1967), the number of cases needed for a study will be determined by saturation. That is to say, the researcher should not seek any further case studies when additional cases stop bringing new, theory relevant, information. Thus, "the validity, meaningfulness and insights generated from qualitative inquiry have more to do with the information-richness

of the cases selected and the observational/analytical capabilities of the researcher than with sample size" (Patton 1990, p. 185).

Six exploratory case studies were conducted in the first stage of this doctoral research project. Table 3.3 summarises the types of organisations.

Table 3.3: Exploratory Case Study Organisations

Case A	Transport Services Organisation
Case B	Telecommunications Organisation
Case C	Building Management Organisation
Case D	Oil and Gas Organisation
Case E	Water Utility Organisation
Case F	Defence Organisation

Source: (developed by the author)

A total of 18 exploratory, in-depth interviews were conducted between July 2006 and February 2007. Table 3.4 summarises the job descriptions of the interviewees and the dates of the interviews. All interviews were approximately one hour in length. Interviewees were selected based on their expertise in information management and their experience with information quality issues in their organisations. Case F involved seven interviews with the same technical specialist. It is not believed that the variation in the number of interviews conducted per case study has had any significant effects on the development of the candidate maturity indicators. In order to prevent any potential case study induced bias, the candidate maturity indicators were also sourced from the literature. In addition, the Delphi study provided a further opportunity for the refinement of candidate maturity indicators by the IQ experts.

Table 3.4: Exploratory Case Studies' Interview Details

Case	Interviewee's Role in the Organisation	Date
A	Operations and Systems Manager	20/07/2006
B	State Director	21/08/2006
C	Principal Consultant	28/08/2006
D	Asset Management Finances Manager	30/08/2006
D	Asset Register Manager	07/09/2006
E	Spatial Solutions Manager	06/09/2006
E	Asset Information Management Technical Specialist	15/09/2006
E	Asset Management General Manager	21/09/2006
E	Senior Engineer	19/09/2006
E	Information Management Manager	27/09/2006
E	Information Management Officer	27/09/2006
F	Technical Specialist, Asset Information Management	06/02/2006
F	Technical Specialist, Asset Information Management	27/02/2006
F	Technical Specialist, Asset Information Management	13/06/2006
F	Technical Specialist, Asset Information Management	23/06/2006
F	Technical Specialist, Asset Information Management	24/08/2006
F	Technical Specialist, Asset Information Management	24/11/2006
F	Technical Specialist, Asset Information Management	20/02/2007

Source: (developed by the author)

3.4.2 Stage 2: Theory Building Phase

In the first stage, the research problem was explored in detail and a set of candidate information quality management maturity indicators was identified. That is to say, organisational (business process), technological, and human factors that have an impact on the information quality management maturity were identified. Those candidate maturity indicators were further validated and organised into a staged evolutionary maturity model through a four round Delphi study in the second stage of the research.

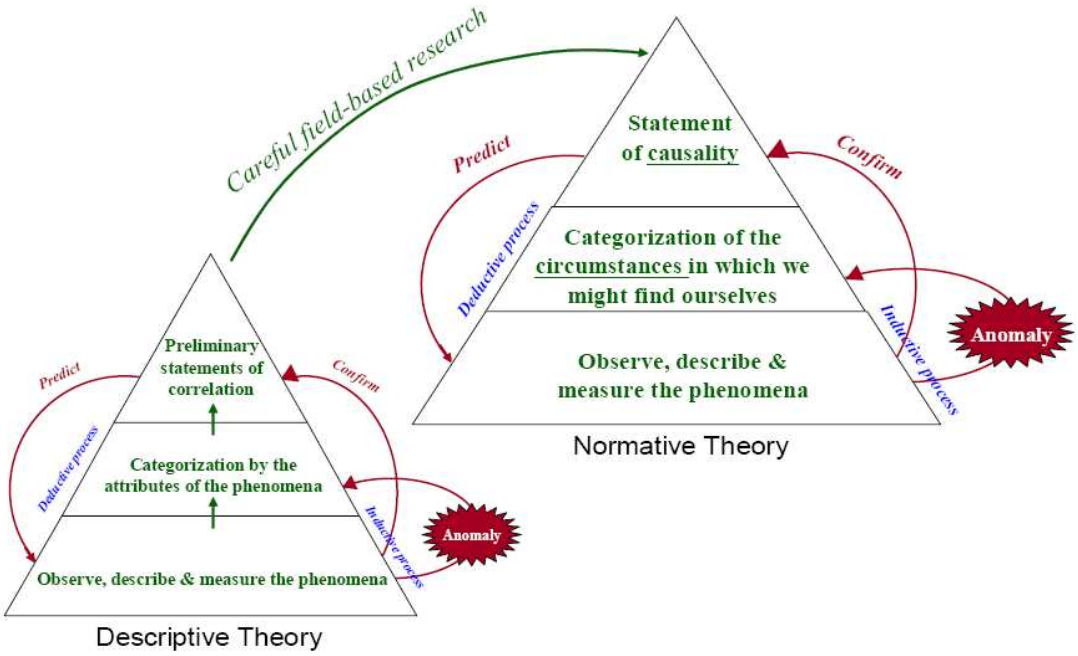


Figure 3.7: The Transition from Descriptive Theory to Normative Theory
Source: adopted from (Carlile & Christensen 2005, p. 6)

Carlile & Christensen (2005) synthesised models of theory building that have been developed by a range of scholars including (Popper 1959; Kuhn 1962; Campbell & Stanley 1963; Kaplan 1964; Glaser & Strauss 1967; Stinchcombe 1968; Simon 1976; Roethlisberger 1977; Yin 1984; Kaplan 1986; Eisenhardt 1989; Weick 1989; VanDeVen 2000), to describe a three-step process by which researchers build theory that is at first descriptive, and ultimately normative (Figure 3.7). Descriptive theory is built through careful observations and subsequent descriptions, followed by classifications of the phenomena into categories, and examination of the relationships between the category-defining attributes and the outcomes observed (Carlile & Christensen 2005). In this inductive part of the theory building process researchers first build constructs, followed by frameworks and ultimately models (stage 2 of this research project). Those models (or hypotheses) can then be deductively tested by moving from the top to the bottom of the

pyramid in, typically in a different set of data than the data from which the hypothesised relationships were induced. Theory can then be further enhanced by discovering anomalies – outcomes for which the theory cannot account (stage 3 of this research project). Normative theory, which can also be enhanced by following the same steps that were used in the descriptive stage, finally attempts to establish the causes of the phenomena (causal relationships).

According to Walsham (1993), "in the interpretive tradition, there are no correct and incorrect theories, but there are interesting and less interesting ways to view the world" (p. 6). He goes on to argue that:

> *"There is not, and never will be, a best theory. Theory is our chronically inadequate attempt to come to terms with the infinite complexity of the real world. Our quest should be for improved theory, not best theory, and for theory that is relevant to the issues of our time." (p. 478)*

Delphi Study

The Delphi technique was developed in the 1950s by the Rand Corporation to forecast the impact of technology on warfare (Benarie 1988; Woundenberg 1991), but it has also been suggested that it should also be used for studies of industries that are undergoing rapid changes (Jillson 1979). The name itself refers to the Delphi Greek oracle Pythia, who forecasted future events from the temple of Apollo at Delphi (Parke & Wormell 1956; Woundenberg 1991). It is a useful technique for discovering new issues and moving study participants towards consensus (Delbecq, Ven & Gustafson 1975; Paliwoda 1983; Cho, Jeong & Kim 1991), and it is used to generate theories and hypotheses rather than to test them (Kaynak & Macaulay 1984). The Delphi method employs a series of questionnaires where each successive round summarises the preceding round (Fontana & Frey 1994). In each successive round participants are asked to re-evaluate their opinions based on the results from the previous round, thus moving towards group consensus (Delbecq, Ven & Gustafson 1975; Rowe, Wright & Bolger 1991). Thus, the Delphi technique is a useful method where judgemental information is necessary in order to solve complex problems (Linstone & Turoff 1975; Milar 1984; Rowe, Wright & Bolger 1991; Kaynak, Bloom & Leibold 1994; Mitchell & McGoldrick 1994). The final round usually involves distribution of the final results, providing an opportunity for the panel members to agree or disagree with the findings (Prendergast & Marr 1994). Rowe & Wright (1999) argued that it provides forecasts that are more accurate than those from unstructured groups. There are three main aspects of a Delphi study including, anonymity, controlled feedback, and

statistical group response (Wheatly & Flexner 1987; Rowe & Wright 1999). Furthermore, the expert panel selection and composition are vital aspects of any Delphi study (Linstone & Turoff 1979; Mitchell & McGoldrick 1994; Cantrill, Sibbald & Buetow 1996). The selections of panellists cannot be random; they have to be selected based on their expert knowledge (Martino 1983; Deitz 1987). Also, panellists from various backgrounds should be selected, so that more holistic results can be obtained (Delbecq, Ven & Gustafson 1975; Rowe, Wright & Bolger 1991; Keeney, Hasson & McKenna 2001). Hence, validity and reliability of results obtained through Delphi studies are attained by obtaining a consensus of expert judgements (Bardecki 1984; Parente et al. 1984). Fowles (1978) argued that panel sizes should be no less than seven participants, while others argued that panels should contain between 10 and 50 participants (Dalkey 1969; Day & Aaker 1990; Miller 1993; Mitchell & McGoldrick 1994; DeLoe 1995). Delbecq, Van de Ven & Gustafson (1975) on the other hand, suggested that there is no set number of panellists required, providing there are enough panellists to facilitate the pooling of judgments. Prendergast & Marr (1994) argued that increasing the panel size beyond 12 provides little group error reduction.

The first round of the Delphi study (comprising of 20 participants) was conducted at the 11th International Conference on Information Quality (ICIQ06), which was held at the Massachusetts Institute of Technology (MIT), Cambridge, USA. Study participants included a wide range of world's leading information quality practitioners and academics. Subsequent rounds were conducted online and additionally included members of the International Association for Information and Data Quality (IAIDQ). The participants were first presented with a set of 45 candidate information quality management maturity indicators (see Appendix I), and asked to place each candidate maturity indicators into the lowest capability maturity level they thought it should belong to. Thus, the resulting model should consist of evolutionary (staged) levels, where each subsequent level addresses more advanced IM & IQM practices. Second round was used to build consensus based on the results of the first round. Rounds three and four were used to assess the relative importance of each candidate maturity indicator (see Appendix J). A number of additional candidate maturity indicators were identified in the Delphi study as well. The study participants were also asked to provide qualitative comments on the model. Furthermore, phone interviews were conducted with two IAIDQ members. The interviews were conducted on 05/01/2007 and on 04/04/2007. They were approximately one hour in duration.

Delphi study results were analysed using descriptive statistics, including the mean, the standard deviation, the median, and the interquartile range. The mean and median values indicated the preferred capability maturity level for each candidate maturity indicators, where 1 indicated the lowest and 5 the highest information quality management capability maturity. Interquartile ranges are commonly used in Delphi studies to indicate the degree of group consensus. When using a 5-point Likert scale, responses with a quartile deviation less than or equal to 0.6 should be deemed high consensus, those greater than 0.6 and less than or equal to 1.0 should be deemed moderate consensus, and those greater than 1.0 should be deemed low consensus (Faherty 1979; Raskin 1994). The Delphi study results (including qualitative comments provided by the participants) were then further analysed to identify the most important aspects of each capability maturity level. The candidate maturity indicators were grouped into categories which led to emerging themes of each level. Next, two more Delphi rounds, which investigated the relative significance of each maturity indicators factor were conducted. The participants were asked to rate the impact of each candidate maturity indicators on the level that it was allocated to, where 1 indicated the lowest and 5 the highest impact.

Inductive Grounded Theory Approach

Grounded theory has also been used to inductively build the model. Grounded theory was developed by Glaser and Strauss in 1967 (Glaser & Strauss 1967), and it has been described as “a general methodology for developing theory that is grounded in data systematically gathered and analysed” (Strauss & Corbin 1994, p. 273). The central feature is the constant comparative analysis, a method used to analyse qualitative data. The theory developed consists of “plausible relationships proposed among concepts and sets of concepts” (Strauss & Corbin 1994, p. 278); the actual plausibility is to be strengthened through ongoing research. Furthermore, such theories are always provisional, due to the interpretive paradigm, as well as temporal (Strauss & Corbin 1994). Therefore, given that theories are embedded in history, they may need to be periodically updated.

Design Research Approach

> *“If we were to go back in time 100 years and ask a farmer what he'd like if he could have anything, he'd probably tell us he wanted a horse that was twice as strong and ate half as many oats. He would not tell us he wanted a tractor. Technology changes things so fast that many people aren't sure what the best solutions to their problems might be.” (Quigley 2000)*

Design science consists of two basic activities (build and evaluate), which parallel the discovery/justification approach from natural science (Figure 3.8). Building is the process of constructing an artefact, while evaluation is the process of determining how well the artefact performs. However, "whereas natural science tries to understand reality, design science attempts to create things that serve human purposes" (March & Smith 1995, p. 253). Thus, it may be particularly applicable to IS research since "information systems and the organisations they support are complex, artificial, and purposefully designed" (Hevner, March & Park 2004, p. 78). Consequently, this research projects also incorporates aspects of design science philosophy. Design science products are of four types including, constructs, models, methods, and implementations (March & Smith 1995, p. 253). March & Smith defined a model as "a set of propositions or statements expressing relationships among constructs" (p. 256), and argued that design research should be classified as prescriptive research, since it aims at improving, rather than purely understanding. Furthermore, design research involves "the analysis of the use and performance of designed artefacts to understand, explain and very frequently to improve on the behaviour of aspects of Information Systems" (Kuechler & Vaishnavi 2007). Such an approach to research has already been very successfully applied in the fields of engineering and computer science and has recently been also advocated for IS research (Hevner, March & Park 2004; Kuechler & Vaishnavi 2007).

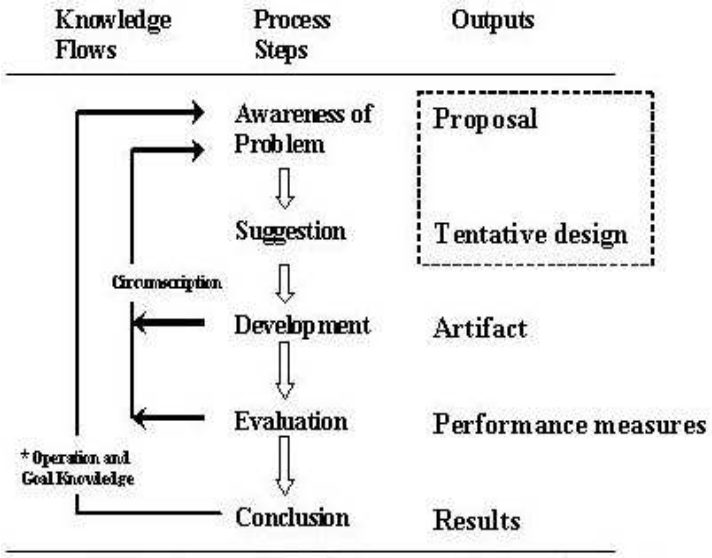


Figure 3.8: The General Methodology of Design Research
Source: adopted from (Kuechler & Vaishnavi 2007)

Hevner, March & Park (2004) proposed seven guidelines for design science research:

1. **Design as an Artefact.** Design science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation. This principle is

satisfied with the construction of the Information Quality Management Capability Maturity Model (IQM-CMM).

2. **Problem Relevance.** The objective of design science research is to develop technology-based solutions to important and relevant business problems (see section 1.3 “Justification for the Research”).
3. **Design Evaluation.** The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods. In line with the recommendations proposed by Hevner, March & Park (2004), IQM-CMM has been evaluated in depth, through its application in business environment (stage 3 of the research methodology).
4. **Research Contributions.** Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies. IQM-CMM, as the design artefact, represents the research contribution.
5. **Research Rigor.** Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact. The research methodology is presented in this chapter.
6. **Design as a Search Process.** The search for an effective artefact requires utilising available means to reach desired ends while satisfying laws in the problem environment. IQM-CMM has been developed iteratively, enhancing the theory after each iteration.
7. **Communication of Research.** Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences. The various stages of this research project have been published in book chapters, journals, and conference proceedings.

3.4.3 Stage 3: Theory Testing and Enhancing Phase

The third stage of this research project involved the application of the model developed in stage two in seven international case studies. Those case studies can be classified as being explanatory in nature, since they are used to test and further refine existing theory (Yin 2002).

Explanatory Case Studies

Explanatory case studies are mainly used for theory testing. They are characterised by “how and “why” research questions because they investigate the relationships that are

proposed between different theory components (Yin 1994). Inconsistencies between a preliminary theory and the evidence are accommodated in an explanatory case study design by revising the preliminary theory (Diezmann 2002).

Table 3.5: Explanatory Case Studies' Interview Details

Case	Interviewee's Role in the Organisation	Date
G	ILS Manager	20/09/2006
G	ILS Project Manager	20/09/2006
G	ILS Systems Support Manager	20/09/2006
G	Logistic Engineering Manager	20/09/2006
G	ILS Product Manager	20/09/2006
G	ILS Data Manager	20/09/2006
G	ILS Manager	09/10/2006
G	Systems Support Member	27/10/2006
G	Database Administrator	30/11/2006
G	Business Analyst	30/11/2006
G	Business Analyst 2	02/02/2007
G	Logistic Information Systems Manager	06/02/2007
G	ILS Manager	22/10/2007
G	Innovation Manager	22/10/2007
H	Information Quality and Delivery Manager	05/11/2007
H	Chief Information Officer	05/11/2007
H	Process Analyst	05/11/2007
H	IQ Analyst	05/11/2007
H	IQM Team Meeting	06/11/2007
H	Supervisor of Operations	06/11/2007
H	Information Security Manager	06/11/2007
H	Data Modeller	07/11/2007
H	Information Quality Manager	07/11/2007
H	Enterprise Architect	07/11/2007
I	Chief Technology Officer	20/11/2007
I	Database Administrator	20/11/2007
I	Chief Financial Officer	20/11/2007
I	Enterprise Services Administrator	20/11/2007
I	Quality Manager	20/11/2007
I	Business Intelligence Developer	20/11/2007
J	Information Quality Manager	21/11/2007
J	IM Development Manager	21/11/2007
J	IM Operations Manager	21/11/2007
J	Information Quality Analyst	21/11/2007
J	Enterprise Information Architect	21/11/2007
K	Senior Manager	28/11/2007
K	Data Centre Manager	29/11/2007
L	TQM Team Leader (Information Management)	04/01/2008
M	Head of Data Governance	24/01/2008
M	Data Architect	24/01/2008
M	System Owner	24/01/2008
M	DQ Manager DW	24/01/2008
M	Enterprise Architect	24/01/2008
M	Enterprise Architect	24/01/2008
M	Head of Data Management	25/01/2008
M	Solution Architect	25/01/2008
M	Business Object Owner	25/01/2008
M	IT Specialist	25/01/2008
M	Head of Security	25/01/2008

Source: (developed by the author)

The information quality management capability maturity model has been tested in seven organisations (Table 3.6). A total of 50 explanatory, in-depth, interviews were conducted between September 2006 and January 2008. Table 3.5 summarises the job descriptions of the interviewees and the dates of the interviews. Additionally, a tour of the Case J's data centre was undertaken on 29/11/2007. However, it should be noted that the variation in the number of interviews conducted per case study may have had an impact on the maturity ratings presented in section 4.4.3. This particularly applies to Case L, where only one interview was conducted. In some cases, additional interviews may have provided further information; however, the researcher was restricted by the willingness and the availability of the interviewees for providing access.

Table 3.6: Explanatory Case Study Organisations

Case G	Defence Organisation	Australia
Case H	Oil and Gas Organisation	USA
Case I	Government Department Organisation	USA
Case J	Telecommunications Organisation	USA
Case K	Data Management Organisation	USA
Case L	Rail Organisation	Europe
Case M	Telecommunications Organisation	Europe

Source: (developed by the author)

3.5 Data Collection

Based on the recommendations from the literature, case study data were collected from various sources including documents, interviews, and observations (Yin 1994; Stake 1995). Theoretical sampling was used as the guiding approach to data collection.

3.5.1 Theoretical Sampling

Theoretical sampling, which differs from statistical sampling, was used to guide the data collection in this study. It originated with the development of grounded theory (Glaser & Strauss 1967), and its goal is not the representative capture of all possible variations, but to gain a deeper understanding of the cases and to facilitate the development of theories. Theoretical sampling "implies that the researcher decides what data will be gathered next and where to find them on the basis of provisionary theoretical ideas" (Boeije 2002, p. 393). Thus, it enables answering of questions that have arisen from the analysis of and reflection on previous data, since each piece of analysed data provides indications about where to look next. Thus, the theory is continually modified as a consequence of further research.

3.5.2 Interviewing

Interviewing was chosen as one of the main data collection strategies in this research project. However, even though the interview conversation has been described as a "pipeline for transmitting knowledge" (Silverman 1997, p. 113), effective interviewing remains a very difficult undertaking (Fontana & Frey 1994). Interviews can be used for different research purposes; in view of that, Weiss (1994) mapped several categories of research aims to the qualitative interview method, including developing a detailed description, integrating multiple perspectives, describing a process, learning how events are interpreted, bridging inter-subjectivities, and identifying variables and framing hypotheses for quantitative research. Interviews can be structured, semi-structured, or even unstructured (Fontana & Frey 1994). Structured interviews involve asking of predefined questions, with a limited set of response categories. Furthermore, the responses are coded by the interviewer based on an already established coding scheme, thus being somewhat similar to written surveys. Semi-structured interviews can be more flexible and allow the researcher to better understand the perspective of the interviewees (Daymon & Holloway 2002). In semi-structured interviews, a researcher is able to refocus the questions, or prompt for more information, if something interesting or novel emerges. Unstructured interviews, on the other hand, do not impose any predefined answer categories (Fontana & Frey 1994). They utilise open-ended questions, thus allowing for even more flexibility. According to Daymon & Holloway (2002), unstructured interviews "generate the richest data and often uncover surprising evidence, but they also have the highest 'dross rate' – the amount of material that is of no particular use" (p. 170). Perry (1998) advocated for the use of probe questions in unstructured interviews; they "usually start with How…?" and can definitely not be answered with a yes or a no (Perry 1998, p. 792).

The first stage of this research utilised unstructured, open ended interviews for the purpose of gaining a holistic picture of the research problem and identifying candidate information quality management maturity indicators. This preceded the theory building phase (stage 2). Stage 3 case studies employed semi-structured, in-depth interviews, which were based on the theory developed in stage 2. Semi-structured interviews were preferred to structured-interviews because of the complexity of the research problem. Due to the complexity of the theory, no simple yes/no, or categorised answers were expected.

In addition to the interviews, a wide range of documents provided by the case study organisations were also examined. They involved business process documentation, use

case descriptions, policies, procedures, architectural frameworks, system documentation, and the like. They were mainly used in the explanatory phase (stage 3) as a source of evidence for organisational practices, often as a corroborating evidence for the interviews. They were analysed in line with the data analysis methods presented in section 3.6.

Observations may provide the researcher with a rich source of data about the research problem, the participants, the location, and so on (Jorgensen 1989). However, due to the nature of the research problem, observations were only used to a limited extent in this research project. Several interviewees were observed while using respective information systems. Also, an information quality management team meeting was observed in one of the case studies (Case H). Any observations were mainly directed toward gaining a better understanding of the organisations and their systems in use.

3.6 Data Analysis

This section explains the data analysis techniques that have been employed in this research project. Qualitative analysis has been described as both the most difficult and the lest codified part of the case study process (Eisenhardt 1989). Qualitative research aims towards analytical generalisation, as opposed to statistical generalisation in quantitative studies. Where statistical generalisation aims to make an inference about a population on the basis of empirical data collected from a sample, analytical generalisation uses previously developed theory with which empirical casse study results are compared. According to Yin (1994), analytical generalisation is made to theory and not to population; however, the theory can be further strengthened by performing cross-case comparisons. Furthermore, since the case research method allows for confirmatory (deductive) as well as explanatory (inductive) findings (Yin 1993; Yin 1994; Hyde 2000), it also allows for analytic generalisation of theories (Yin 1993; Yin 1994; Easton 1998; Amaratunga & Baldry 2001). Also, since direct quotations are the basic source of raw data in qualitative evaluation, and are also most commonly used to report the results of qualitative research (Patton 2002; Labuschagne 2003), all recorded interviews were transcribed and subsequently verified for accuracy. Six complementary qualitative data analysis approaches have been utilised including, constant comparative analysis, hermeneutics, pattern matching, explanation building, within-case analysis, and cross-case analysis.

3.6.1 Constant Comparative Analysis

According to Boeije (2002), "the constant comparative method (CCM) together with theoretical sampling constitute the core of qualitative analysis" (p. 391). It was developed by Glaser & Strauss (1967), who proposed it for development of a theories that are grounded in the data. The constant comparative method works inductively (Boeije 2002) to "discover the latent pattern in the multiple participant's words" (Glaser 2002, p. 2). Tesch (1990) explains it as follows:

> *"The main intellectual tool is comparison. The method of comparing and contrasting is used for practically all intellectual tasks during analysis: forming categories, establishing the boundaries of the categories, assigning the segments to categories, summarizing the content of each category, finding negative evidence, etc. The goal is to discern conceptual similarities, to refine the discriminative power of categories, and to discover patterns." (p. 96)*

Or, according to Jorgensen (1989):

> *"Analysis is a breaking up, separating, or disassembling of research materials into pieces, parts, elements, or units. With facts broken down into manageable pieces, the researcher sorts and sifts them, searching for types, classes, sequences, processes, patterns or wholes. The aim of this process is to assemble or reconstruct the data in a meaningful or comprehensible fashion." (p. 107)*

Strauss & Corbin (1994) advocated three sequential stages to constant comparative analysis. Open coding is the first stage, and it is used to perform initial coding on the words, phrases, or ideas in the text. Axial coding groups similar codes from the previous stage into categories. Finally, selective coding is applied on the axial categories, identifying a central category and explaining inter-category relationships. This approach has been followed in this research project. In the first stage of this research project, all interviews were coded, resulting in a set of candidate information quality management maturity indicators. This set was subsequently further refined through the Delphi study. Axial coding was used to group similar candidate maturity indicators into 'Process Areas', which were selectively coded and related to the central category 'Maturity'. The constant comparative method was utilised in the third stage to map the practices encountered in the case study organisations against the IQM-CMM Diagnostic Tool, as well as to perform cross-case analysis.

3.6.2 Hermeneutics

Hermeneutics has been described as the "methodology of true interpretation" (Bauman 1978, p. 246), with the hermeneutic circle forming "the very logic of understanding" (p. 28). The word hermeneutics derives from the Greek god Hermes, who was a messenger of the gods, interpreting and passing on their messages to humans (Ezzy 2002, p. 24). Hermeneutics originated as a study of interpretations of religious text, but has since evolved into a generic theory of interpretation (Ezzy 2002). The hermeneutic circle, which is at the core of the theory, refers to the idea that the understanding of a concept as a whole can only be achieved through the understanding of its parts; at the same time, the understanding of each individual part is dependent on the understanding of the whole concept. Hence, neither the concept, nor its parts can be understood without the reference to each other, thus forming a circle. As a result, hermeneutics heavily emphasises the importance of the context. Thomas Kuhn (1977) described its implications in the following way (p. xii):

> *"When reading the works of an important thinker, look first for the apparent absurdities in the text and ask yourself how a sensible person could have written them. When you find an answer … when those passages make sense, then you may find that the more central passages, ones you previously thought you understood, have changed their meaning."*

In this research project hermeneutic has been used in conjunction with the constant comparative method to understand and interpret the concept of information quality management capability maturity. The individual indicators had to be related to and understood within the context of maturity (Figure 3.9).

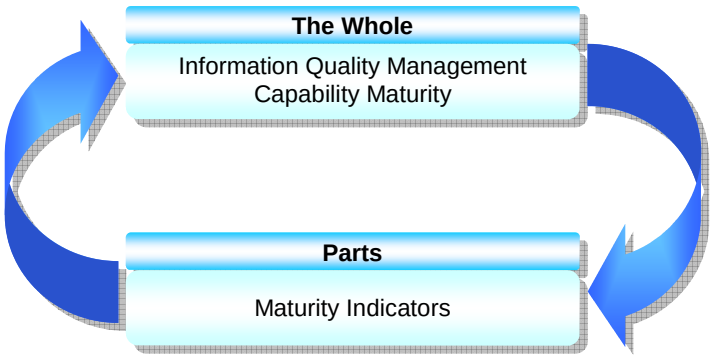


Figure 3.9: The Hermeneutic Circle as Applied in this Research
Source: (developed by the author)

3.6.3 Pattern Matching

Pattern matching compares an empirically based pattern with the one predicted by the theory (Trochim 2006). If the patterns correspond, the results can reinforce the internal

validity of the theory. Thus, it has been argued that all research employs pattern matching principles, although this may seldom be done consciously (Trochim 2006). In this research project, the Information Quality Management Capability Maturity Model (developed in stage 2) represented the pattern. This pattern was then compared with the practices in the explanatory case study organisations (stage 3). Since the maturity model is evolutionary in nature, it was expected to find a pattern where an organisation would easier satisfy the maturity indicators found in lower levels than factors found in higher levels. In other words, for instance, it was expected that an organisation may satisfy the maturity indicators found in level 2, while not satisfying the indicators found in level 3. Furthermore, it was expected that when mapped to the model, the practices would form a cluster and not be randomly spread through the model (e.g. an organisation shouldn't partially satisfy all the levels).

3.6.4 Explanation Building

Explanation-building can be seen as an alternative or supplement to pattern matching, where the researcher carries out the case study analysis by building an explanation of the case (Yin 2002). This research project utilised this approach while building explanations about how and why individual indicators contributed to the concept of information quality management capability maturity. For instance, an explanation was need on why level 3 constitutes higher maturity than level 2, and how/why this provides for improved information quality.

3.6.5 Within-Case Analysis

Within-case analysis (Yin 2002) allowed for triangulation of data sources; data about an individual maturity indicator was gathered form multiple informants as well as from documented evidence. Multiple data sources were subsequently cross-analysed before arriving at the final conclusion. However, the purpose of within-case analysis was not to seek corroborating evidence, but to look for conflicting data. When conflicting data was found, the research participants were again contacted for follow-up explanation.

3.6.6 Cross-Case Analysis

Cross-case analysis (Yin 2002) was used to investigate how different organisations addressed each of the maturity indicators. For instance, it was found that different organisations were addressing the data governance maturity indicators in very diverse

ways. Yin's multiple case study method illustrated in Figure 3.10 has been followed in this research project.

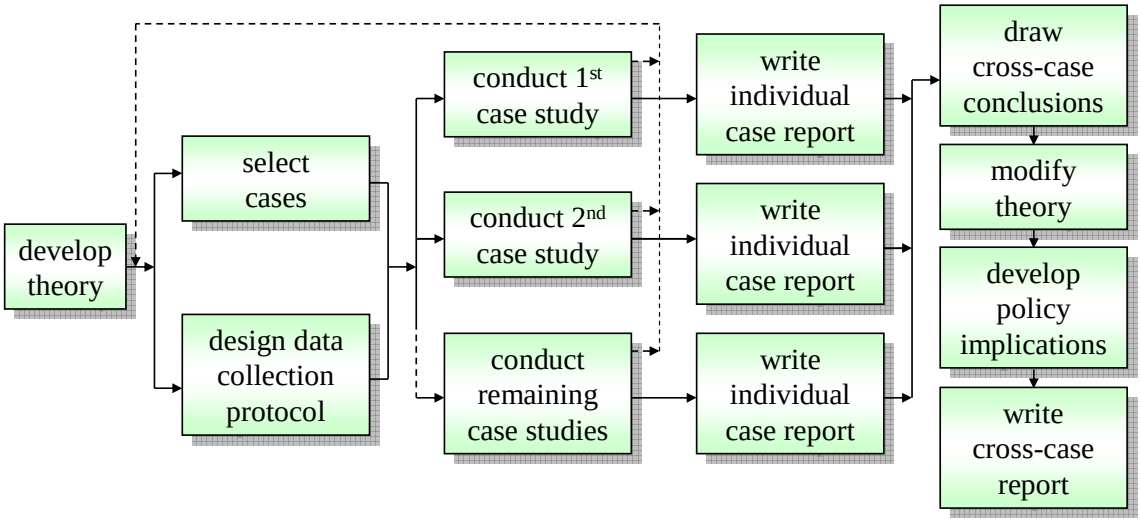


Figure 3.10: Multiple Case Study Method
Source: developed from (Yin 2002, p. 50)

3.7 Criteria for Judging the Quality of Qualitative Interpretive Research

The following guidelines for judging the quality of qualitative interpretive research have been followed in this research project.

The conceptual framework for evaluating IS research, developed by Hevner, March & Park (2004), has been followed in this doctoral research project (Figure 3.11). The *environment* section defines the problem space – the candidate information quality management maturity indicators were explored from three perspectives: technological, social, and organisational. *IS research* section includes development and justification of theories, and building and evaluation of artefacts; *justify/evaluate* activities may identify weaknesses in theories or artefacts – the artefact (IQM-CMM) was built and evaluated in multiple explanatory case studies. The *foundation* section of the *knowledge base* indicates that prior research should be used to develop theories or build artefacts, where as the *methodologies* section provides guidelines for the *justify/evaluate* phase – this research has been based on prior research (presented in chapter 2), with the research methodology presented in this chapter.

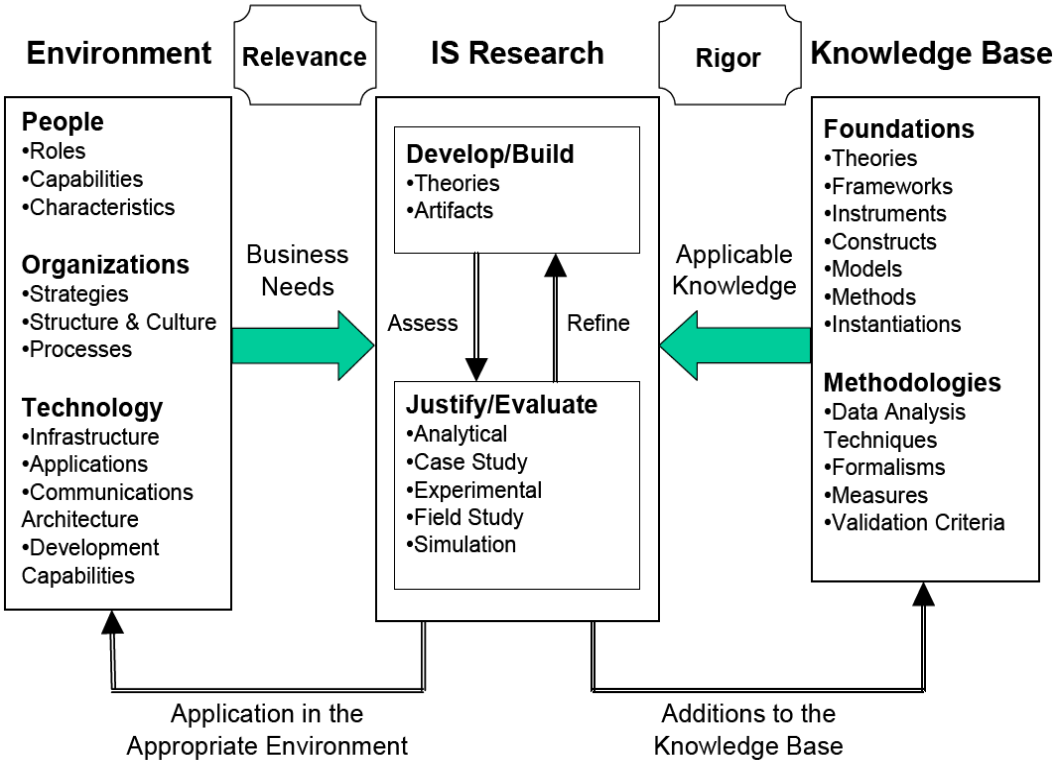


Figure 3.11: Information Systems Research Framework
Source: adopted from (Hevner, March & Park 2004, p. 80)

The following six criteria for judging the quality of research in the realist paradigm have been followed (Healy & Perry 2000):

1. **Ontological Appropriateness**. Research problem deals with complex social science phenomena.
2. **Contingent Validity**. Open (fuzzy boundary) systems involving generative mechanisms rather than direct cause-and-effect. Causal impacts of social phenomena are not fixed, but are dependent upon their environment.
3. **Multiple Perceptions of Participants and of Peer Researchers**. Multiple perception of reality should be triangulated with each other.
4. **Methodological Trustworthiness**. The research can be audited.
5. **Analytic Generalisation** (Theory-Building). Realism research must be primarily about theory-building, rather than theory-testing (statistical generalisation)
6. **Construct Validity**. Degree to which inferences can be made from the measurements in the study to the theoretical constructs on which those measurements were based. In other words, are we really measuring what we want to measure?

Additionally, the following seven principles for conducting and evaluating interpretive field studies in IS have been followed (Klein & Myers 1999, p. 72):

1. **The Fundamental Principle of the Hermeneutic Circle.** All understanding is achieved by iteratively correlating the interdependent meaning of parts and the whole that they form. The principle suggests that understanding of a complex whole is built through preconceptions about the meanings of its parts and their relationships.
2. **The Principle of Contextualisation.** Requires critical reflection on the background of the research setting.
3. **The Principle of Interaction between the Researchers and the Subjects**. Requires critical reflection on the data was collected, through the interaction between the researchers and participants, taking into account any impact that the researcher may have had on the research setting.
4. **The Principle of Abstraction and Generalisation.** Requires relating the findings, revealed by applying principles one and two, to theoretical general concepts.
5. **The Principle of Dialogical Reasoning.** Critical reflection on any theoretical preconceptions based on actual findings. If research findings do not support theoretical preconceptions, the theory may have to be modified, or even abandoned.
6. **The Principle of Multiple Interpretations.** Requires critical reflection on any differences in interpretations by participants.
7. **The Principle of Suspicion.** Requires critical reflection on any possible biases in the data collected from the participants.

3.7.1 Construct Validity

In line with Yin's (1989) recommendations, three strategies for improving construct validity have been employed: using multiple sources of evidence, having key informants review the case study report, and maintaining a chain of evidence. Yin argued that multiple sources of evidence contribute to construct validity by providing multiple measures of the same phenomenon. Regarding the review by the informants, Yin (1989) states:

> *"The corrections made through this process will enhance the accuracy of the case study, hence increasing the construct validity of the study….In addition, where no objective truth may exist…the procedure should help to identify the various perspectives, which can then be represented in the case study report." (p. 139)*

Yin (1989) also recommends designing the case study, so that the chain of evidence is maintained. Thus, anyone should be able to trace from conclusions back to the initial research questions, or from questions to the conclusions (Sarker & Lee 1998).

It is thought that the construct validity of the maturity indicators identified in this research has also been supported through the use of the Delphi study during the model development. It is believed that the construct validity of the appraisal criteria is supported by the underlying literature, which was used for their development.

3.7.2 Internal Validity

According to Yin (1994), theory's internal validity is the extent to which its conclusions are logically drawn from its premises, and the researchers have ruled out all plausible alternative explanations that might link the phenomena with the outcomes of interest. The use of methodological and data source triangulation (including cross-case comparisons) has been used to ensure internal validity of this research project (Jick 1979; Denzin & Lincoln 1994; Yin 1994; Stake 1995; Perry 1998; Hall & Rist 1999; Healy & Perry 2000; Amaratunga & Baldry 2001). Denzin (1978) identified four types of triangulation including data triangulation, investigator triangulation, theory triangulation, and methodological triangulation. Thus, theory is enhanced and validated by continually and iteratively evaluating cases against it (Sykes 1990). Yin (1989) has also argued that pattern matching may be used to enhance the internal validity, whereby, involving qualitative but logical deduction (Lee 1989), an empirically based pattern is logically compared against a predicted pattern.

3.7.3 External Validity

The external validity of a theory is the extent to which a relationship that was observed between phenomena and outcomes in one context can be trusted to apply in different contexts as well (Yin 1989). Lee (1989) and Yin (1989) have argued that the use of one case is similar to the use of one experiment, in the sense that neither one is sufficient to reject or disprove propositions, and that several are necessary to demonstrate accuracy of a theory. According to Yin (1994):

> *"Case studies, like experiments, are generalisable to theoretical propositions and not to populations or universes. In this sense, the case study, like the experiment, does not represent a "sample", and the investigator's goal is to expand and generalise theories [analytic generalisation] and not to enumerate frequencies [statistical generalisation]." (p. 10)*

In line with Yin's arguments, the goal of this thesis has not been statistical but analytical generalisation. Given the time and resource constraints, only a limited number of case studies could be conducted – the case studies do not form a statistically valid sample. Thus, given the limited number of case studies conducted, it cannot be guaranteed or expected that the findings shall be fully applicable to any future case studies. In line with analytical generalisation, any future case studies should be used to test and further enhance the existing theory.

3.7.4 Reliability

Two strategies for ensuring reliability of case studies, suggested by Yin (1989), have been followed: creation of the case study protocol, and development of a case study database. The case study protocol contributes to the reliability by standardising the investigation. Yin recommends following documents: overview of the project (project objectives and case study issues), field procedures (credentials and access to sites), questions (specific questions that the investigator must keep in mind during data collection), and guide for the report (outline, format for the narrative). This approach has been followed in this research project.

3.8 Ethical Considerations

Bailey (2007) identified informed consent, deception, and confidentiality as three major ethical concerns that face field researchers. Informed consent is required whenever data are collected from research participants through any form of communication. For this purpose, UniSA's "Model Consent Form for use when taped materials, photographs or original works are to be retained" (UniSA 2007) was used (see Appendix F). Deception in research can occur in a variety of ways including, when participants are not informed that they participate in a study, are misled about the research purpose, are not aware about the exact identity of the researcher, and so on (Bailey 2007). In the case of deception, the informed consent may become invalid. Some researchers have however advocated that deception may be necessary in certain research situations (Galliher 1982). One of the important aspects of informed consent is to inform the participants whether the research is anonymous (whether the participants will be identified in the research findings). In complying with university's requirements, an ethical approval was obtained from UniSA's Human Research Ethics Committee for this study.

3.9 Limitations

It has been argued that single case study findings may be specific to particular organisation and thus may not be generalisable (Gable 1994). This may be avoided to some extent by conducting multiple case studies (Yin 2002). Furthermore, Kerlinger (1986) identified three major shortcomings of qualitative research including the inability to manipulate independent variables, the subjective interpretations, and the lack of randomisation. Lee (1989) identified the lack of controllability, deductibility, replicability, and generalisability as potential issues in case study research. Guba & Lincoln (1982) argued:

> *"The aim of inquiry is to develop an idiographic body of knowledge. This knowledge is best encapsulated in a series of 'working hypotheses' that describe the individual case. Generalisations are impossible since phenomena are neither time- nor context- free (although some transferability may be possible from situation to situation, depending on the degree of temporal and contextual similarity)." (p. 238)*

3.10 Conclusion

This chapter discussed the philosophical underpinnings of science, reviewing paradigms and justifying the qualitative interpretive approach employed in this research project. Next, the research design, comprising of three stages, was explained. Stage one (the exploratory stage) involved a comprehensive literature review, and exploratory case studies. Stage two (the theory building stage) involved a four round Delphi study, while stage three (theory testing and enhancing stage) involved multiple explanatory case studies. Data collection and analysis approached were explained, and criteria for judging the quality of qualitative interpretive research were discussed. The chapter finally discussed major ethical considerations as well as the research study limitations.

Chapter 4

Analysis of Data

"*The unexamined life is not worth living.*"

—Socrates

4.1 Introduction

The previous chapter discussed the philosophical underpinnings and detailed the research design. This chapter presents the results of the data analysis from each stage of this research project. Firstly, the results of the exploratory stage are discussed. This stage involved a comprehensive literature review and six exploratory case studies. It was used to gain a comprehensive understanding of the research problem and to identify a set of candidate maturity indicators. Next, the results of stage two, the theory building phase, are presented. This stage involved a four round Delphi study, which was used to validate the candidate maturity indicators, identify new ones, and to construct the staged evolutionary maturity model. Finally, the stage three details the results of seven international explanatory case studies, where the model, developed in stage two, was mapped to the practices of those organisations, and was used as a tool to assess their capability maturity with respect to IQM.

4.2 Exploratory Stage

This section details the analysis of the exploratory stage of this research project (Figure 4.1). The exploratory stage involved a comprehensive literature review (see chapter 2) and six exploratory case studies. The purpose of this stage was to gain a comprehensive, in-depth, understanding of the research problem, and to identify a set of candidate maturity indicators. Those candidate maturity indicators were then used as input for the theory building phase of this research project.

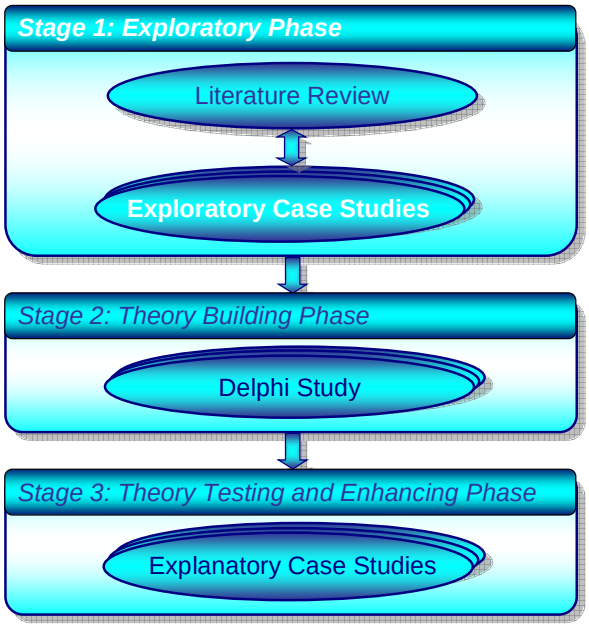


Figure 4.1: Exploratory Stage of the Research Methodology
Source: (developed by the author)

4.2.1 Profiles of the Exploratory Case Study Organisations

Table 4.1: Profiles of the Exploratory Case Study Organisations

Case	Organisation Type	Description
A	Transport Services	Case A, an Australian government organisation, is involved in the maintenance of transport assets and management and operation of a transport system and related infrastructure.
B	Telecoms	Case B organisation is a major Australian provider of local and long distance telephone services, mobile services, dialup, wireless, DSL and cable Internet access.
C	Building Management	Case C, an Australian government organisation, is involved in building procurement, asset management, building maintenance, and commercial office accommodation construction.
D	Oil & Gas Exploration / Production	Case D organisation is a major Australian oil and gas exploration and production company, which has several billion dollars worth of engineering assets.
E	Water Utility	Case E is an Australian water utility organisation, delivering water and wastewater services to more than one million people, and managing assets worth several billion dollars.
F	Defence	Case F is a major Australian Government Defence organisation, which has several billion dollars worth of engineering assets

Source: (developed by the author)

4.2.2 Candidate Maturity Indicators

Following the literature, the following model of the information lifecycle was developed. (Figure 4.2) In order to ensure information quality, processes associated with any of the lifecycle stages must be appropriately managed.

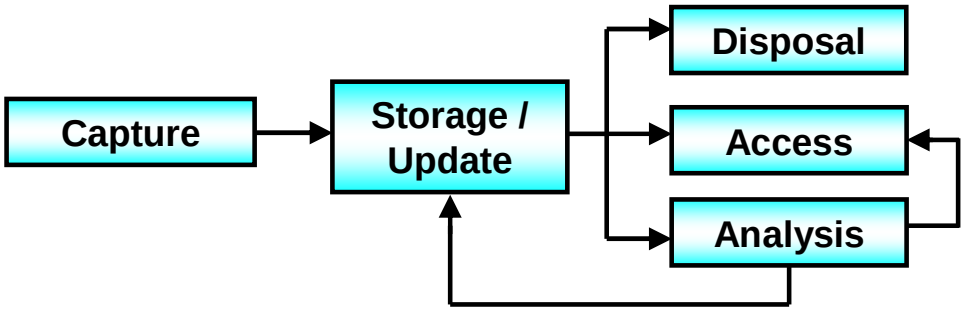


Figure 4.2: Information Lifecycle Model
Source: (developed by the author)

Using the information lifecycle model as a framework for analysis, the following candidate maturity indicators were identified in the exploratory stage of this research project (including the literature review and the exploratory case studies). Complete descriptions of each candidate maturity indicator can be found in Appendix H.

Maturity indicators pertaining to **information capture**:

- Real-time information capture.
- Correction and resubmission of erroneously entered information.
- Erroneous transactions are identified dynamically without being processed.

Maturity indicators pertaining to **information analysis**:

- Scripted (SQL based) data cleansing.
- Information product classification.
- Management of derived information products.

Maturity indicators pertaining to **information access**:

- Presentation templates for information products.
- Access control.
- Critical review, identification and handling of errors contained in the output.

Maturity indicator pertaining to **information disposal**:

- Disposal management.

Maturity indicators pertaining to **information storage/update**:

- Conceptual data modelling.
- Logical data modelling.
- Physical data modelling.
- DBMS constraints.
- Storage and archival.
- Backup of critical information.
- Redundant storage management.
- Single point of truth.
- Extract Transform Load.

Maturity indicators pertaining to **the whole of information lifecycle**:

- Stakeholder management.
- Information management roles and responsibilities.
- Stewardship and ownership.
- Security requirements management.
- Education, training, and mentoring.
- Secure transmission of classified information.
- Information product configuration management.
- Meta-information management.
- Enterprise information architecture.
- Information integration management.
- Audit trail.

Maturity indicators pertaining to **information quality management**:

- Information quality management team and project management.
- Information quality requirements management.
- Information quality management policies management.
- Information quality is everyone’s responsibility.
- Information quality management roles and responsibilities.
- Best practices for IQM have been identified and are used.
- Information quality risk management and impact assessment.
- Information quality metrics and assessments.

- Information profiling.
- Information enhancement.
- Continuous improvement (Kaizen).
- Information quality root-cause-analysis.
- Information quality management cost-benefit analysis.
- Information quality management alignment with ICT and organisational strategies.
- Information quality accountability.

4.3 Theory Building Stage

The previous stage identified a set of candidate information quality management maturity indicators. The results of the four round Delphi study, which was used to validate the candidate maturity indicators, identify new ones, and build the staged evolutionary capability maturity model, are presented in this section (Figure 4.3).

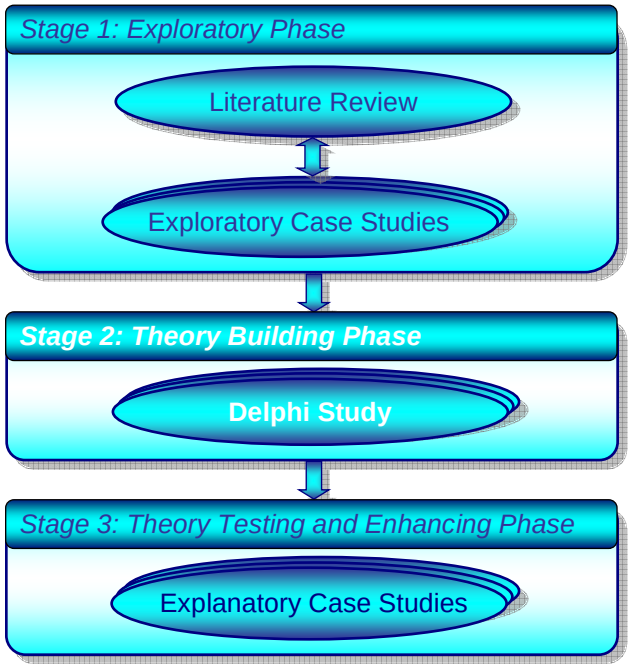


Figure 4.3: The Theory Building Stage of the Research Methodology
Source: (developed by the author)

4.3.1 Constructing the Staged Capability Maturity Model

What candidate maturity indicators may be found in an organisation will depend on that organisation's capability maturity in information quality management. Less mature organisations may only address a few basic factors, whereas more mature organisations may address most of them. The Delphi study was used to reach consensus within a panel of information quality experts on how the candidate maturity indicators should be grouped

within a staged evolutionary capability maturity model. Several additional maturity indicators were identified in the first round of the Delphi study, including:

- Business process reengineering for information quality improvement;
- Information quality is in the corporate balanced scorecard;
- Information quality governance;
- Master Data Management (MDM);
- Semantic modelling;
- Information quality rules management;
- Dedicated information quality function exists; and
- Information quality requirements in job performance measurements.

The results of the first two rounds are partially summarised in Table 4.2. The mean and median values indicate the preferred capability maturity level for each candidate maturity indicator, where 1 indicates the lowest and 5 the highest information quality management capability maturity. Interquartile ranges indicate the degree of group consensus. When using a 5-point Likert scale, responses with a quartile deviation less than or equal to 0.6 should be deemed high consensus, those greater than 0.6 and less than or equal to 1.0 should be deemed moderate consensus, and those greater than 1.0 should be deemed low consensus. After the second round, the interquartile ranges for all candidate maturity indicators were between 0.0 and 1.0. The drop in IR values (higher consensus) could possibly be explained with the fact that the candidate maturity indicators were presented to the participants in a random order in the first round, whereas the factors were organised into capability maturity levels in the second round. The second round, which was conducted online, also had the results of the first round selected as the default values in the online form. The first two Delphi rounds only asked the expert panel to group the candidate maturity indicators in to the capability maturity levels. However, there was still a possibility that some of the maturity indicators were perhaps not very relevant, and as such may not need to be included in the model. For that reason, two more Delphi rounds, which investigated the relative significance of each candidate maturity indicator, were conducted. The participants were asked to rate the impact of each candidate maturity indicator on its level, where 1 indicates the lowest and 5 the highest impact. Partial summary of the results of the Delphi rounds three and four are shown in Table 4.3. They indicate that all candidate maturity indicators were deemed relevant, with all factors being rated from 3 to 5. The complete results of all four Delphi study rounds can be found in Appendix K.

Table 4.2: Partial Summary of the Delphi Study Results (rounds 1 and 2)

Evidence of this Maturity Indicators exists in the Organisation	Round 1				Round 2			
	Mean	SD	Median	IR	Mean	SD	Median	IR
Security Requirements Management	2.58	1.17	3	1.0	2.95	0.21	3	0.00
IQM Team and Project Management	3.10	0.81	3	1.0	2.95	0.38	3	0.00
IQM Roles and Responsibilities	3.10	1.05	3	1.5	2.77	0.43	3	0.00
IQ Risk Management and Impact Assessment	3.68	0.94	4	1.0	3.64	0.73	4	0.75
IQ Metrics and IQ Assessment	3.26	0.93	3	1.0	2.73	0.63	3	0.75
Redundant Storage Management	2.63	1.06	3	1.0	2.68	0.48	3	1.00
Meta-Information Management	3.31	0.88	4	1.5	3.50	0.86	4	1.00
IQ Root-Cause-Analysis	3.47	0.96	4	1.0	3.64	0.85	4	1.00
IQM Cost-Benefit-Analysis	3.47	0.90	4	1.0	3.64	0.73	4	0.00
Alignment of IQM with ICT and Organisational Strategies	4.05	1.02	4	1.5	3.68	0.72	4	0.00
IQ Accountability	3.78	0.78	4	1.0	3.68	0.89	4	0.00
Information Integration Management	3.10	0.80	3	1.0	2.77	0.43	3	0.00
Single Point of Truth (SPOT)	3.42	0.90	4	1.0	3.59	0.8	4	0.75
Information Quality Rules Management	3.50	0.70	3	0.5	2.73	0.46	3	0.75
Business Process Reengineering for IQ Improvement	4.50	0.70	5	0.5	4.77	0.69	5	0.00
Dedicated IQ Function Exists	4.00	1.41	3	0.5	2.82	0.39	3	0.00
IQ in Corporate Balanced Scorecard	4.50	0.70	5	0.5	4.68	0.89	5	0.00

Source: (developed by the author)

Table 4.3: Partial Summary of the Delphi Study Results (rounds 3 and 4)

Evidence of this Maturity Indicators exists in the Organisation	Round 3				Round 4			
	Mean	SD	Median	IR	Mean	SD	Median	IR
Security Requirements Management	3.56	1.20	4.0	1.00	3.93	0.46	4	0.0
IQM Team and Project Management	3.78	1.11	4.0	2.00	4.00	0.53	4	0.0
IQM Roles and Responsibilities	2.44	1.42	2.5	2.00	3.33	0.62	3	0.5
IQ Risk Management and Impact Assessment	2.83	0.99	3.0	1.75	3.47	0.52	3	1.0
IQ Metrics and IQ Assessment	3.56	1.15	3.5	1.75	4.00	0.38	4	0.0
Redundant Storage Management	3.61	1.29	4.0	2.50	4.00	0.53	4	0.0
Meta-Information Management	3.83	0.62	4.0	0.75	4.13	0.35	4	0.0
IQ Root-Cause-Analysis	2.67	1.28	2.0	1.75	2.67	0.72	3	1.0
IQM Cost-Benefit Analysis	3.22	0.88	3.0	1.00	2.93	0.59	3	0.0
Alignment of IQM with ICT and Organisational Strategies	4.06	0.73	4.0	0.00	4.00	0.53	4	0.0
IQ Accountability	3.44	1.04	4.0	1.00	3.73	0.46	4	0.5
Information Integration Management	3.44	1.20	4.0	1.00	4.27	0.46	4	0.5
Single Point of Truth (SPOT)	3.72	1.13	4.0	2.00	4.47	0.52	4	1.0
Information Quality Rules Management	3.33	1.50	4.0	2.75	3.93	0.46	4	0.0
Business Process Reengineering for IQ Improvement	3.72	0.75	4.0	1.00	4.20	0.41	4	0.0
Dedicated IQ Function Exists	3.50	1.15	3.0	1.75	3.47	0.74	3	1.0
IQ in Corporate Balanced Scorecard	4.28	1.02	5.0	1.75	4.73	0.46	5	0.5

Source: (developed by the author)

The qualitative comments provided by the Delphi study participants after round four indicated a strong consensus that the preliminary model included too many maturity indicators in Level 3 and that the indicators pertaining to basic information management should be moved to Level 2. As a result, the candidate maturity indicators pertaining to basic information management were moved from Level 3 to Level 2. Next, the Delphi study results (including the qualitative comments provided by the participants) were further analysed by means of constant comparative analysis. Open coding was used to perform initial coding on the words and phrases comprising each candidate maturity indicator; and axial coding was used to group similar codes into categories (Process Areas). Thus, the candidate maturity indicators were grouped into Process Areas which led to emerging themes of each level. Several candidate maturity indicators, such as data warehousing and Extract Transform Load (ETL), were either merged with other indicators, or altogether removed from the model. The resulting high-level description of the Information Quality Management Capability Maturity Model (IQM-CMM) is shown in Figure 4.4.

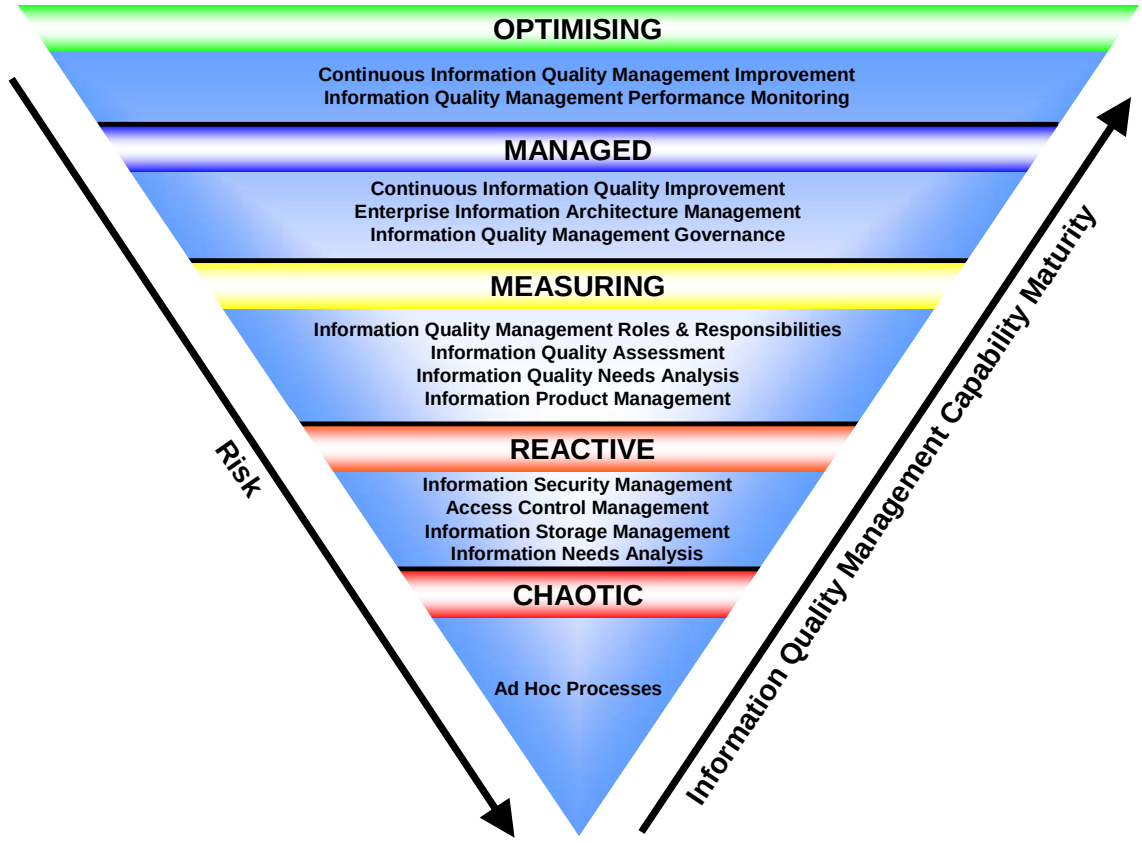


Figure 4.4: Information Quality Management Capability Maturity Model (IQM-CMM)
Source: (developed by the author)

More detailed descriptions of each level are provided on the following five pages. The level names have been based on the expert suggestions provided in the Delphi study (especially in the first round). The name of each level was chosen on the basis of its ability to succinctly summarise the information quality management capability of an organisation of such maturity. The arrow on the right hand side of the triangle in Figure 4.4 indicates that the CHAOTIC level represents the lowest IQM capability maturity. Moving up the triangle results in higher IQM capability maturity. The arrow on the left hand side indicates that lower IQM capability maturity leads to increased risk due to poor information quality.

Level 1: CHAOTIC

The first level (Figure 4.5), by definition, does not address any maturity indicators. Organisations that do not satisfy all the appraisal criteria from level two are classified as CHAOTIC. Such organisations may have some basic information management processes in place; however, they are not documented, standardised, or consistently implemented. Furthermore, CHAOTIC organisations do not attempt to assess or enhance the quality of information they manage; what's more, they may even be ignorant of any information quality problems or issues.

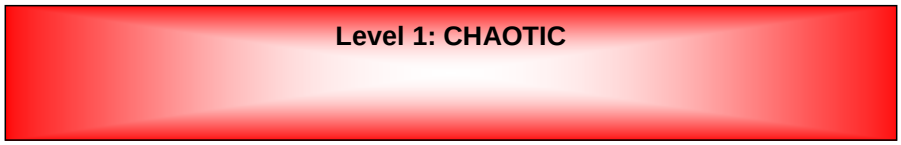


Figure 4.5: Level 1 (CHAOTIC)
Source: (developed by the author)

Level 2: REACTIVE

Organisations on level two (Figure 4.6) are becoming more aware of any information quality issues that may exist; however, they are still only reacting to information quality problems as they occur. REACTIVE organisations have documented, standardised and consistently implemented basic information management processes in place, although they may not have any explicit information quality management initiatives. Such organisations have clearly identified their stakeholders' (information suppliers, stewards, owners, and users) information needs, and developed conceptual, logical, and physical data models. Storage management policies are used to ensure that critical information is backed-up and archived at regular intervals, that any replicated information is managed appropriately, and that information is regularly reviewed for destruction. Access control policies make sure that only authorised personnel interact with the information system, and audit trailing ensures that all user activities are being chronologically logged. In addition, security policies guarantee appropriate classification, transmission, and disposal of any sensitive information.

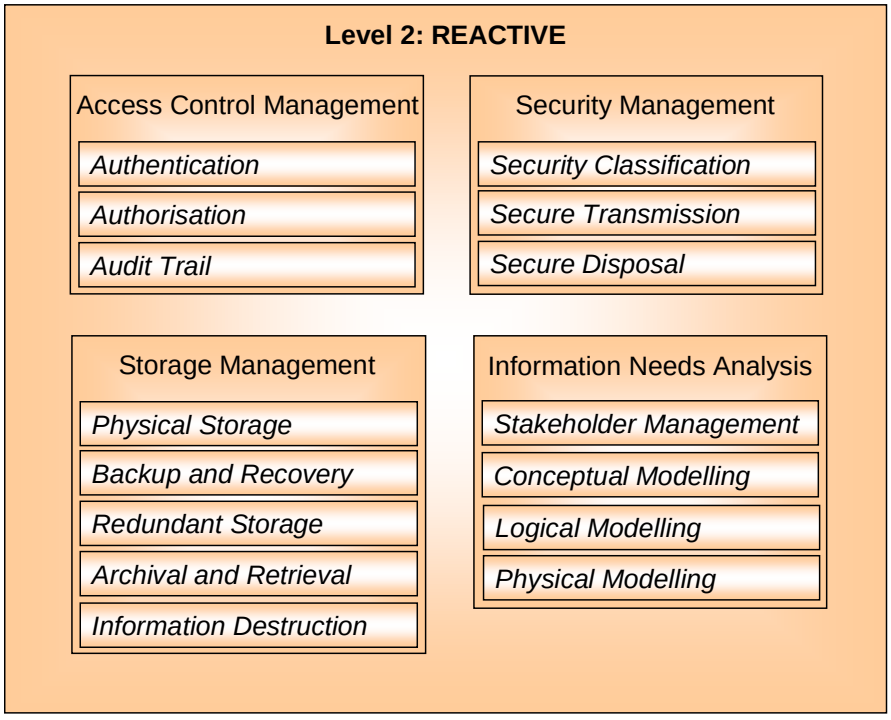


Figure 4.6: Level 2 (REACTIVE)
Source: (developed by the author)

Level 3: MEASURING

Organisations on level three (Figure 4.7) begin to manage their information as a product throughout its lifecycle. Accordingly, such organisations have documented the information flow, and are appropriately managing the information supply chain. Furthermore, configuration management processes, which ensure that any changes are recorded and can be rolled back, are in place, and consistent representation is achieved by utilising the same 'look-and-feel' with all information products. Additionally, MEASURING organisations will have established a metadata registry, which means that metadata is managed separately from regular information. Relevant information quality dimensions will have been identified and information quality requirements will have been elicited from all the major stakeholders, resulting in qualitative and quantitative IQ metrics, and regular IQ assessments. Most importantly, a dedicated project manager is responsible for all information quality management efforts, with training programs making sure that all personnel have the necessary skills.

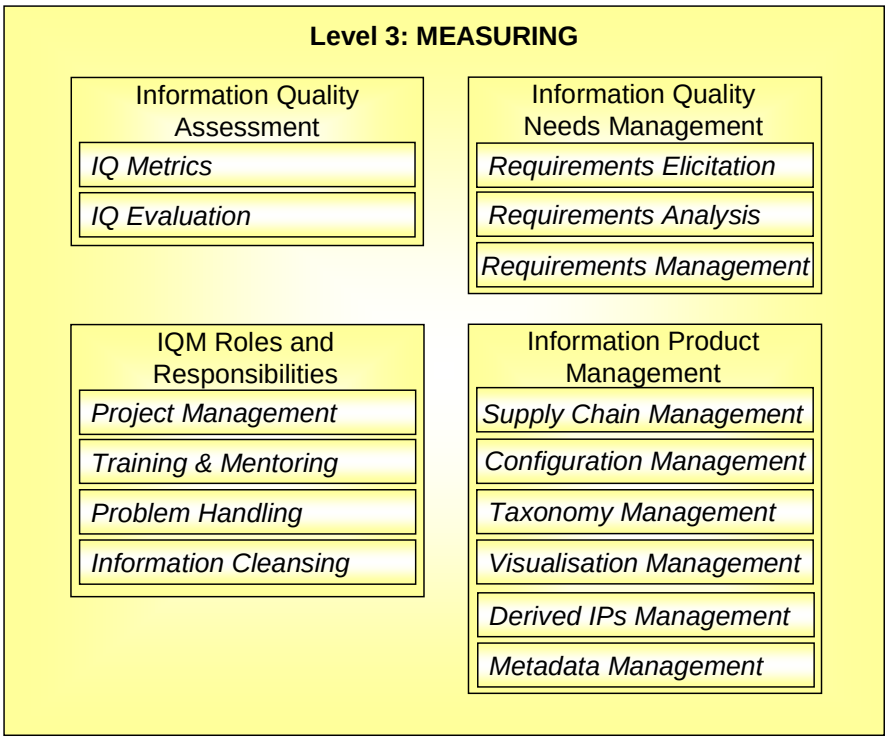


Figure 4.7: Level 3 (MEASURING)
Source: (developed by the author)

Level 4: MANAGED

Organisations on level four (Figure 4.8) have strict governance of information quality management roles and responsibilities, ensuring accountability, and providing rewards and incentives. MANAGED organisations benchmark information quality internally within the organisation, and externally against the leading organisations in their industry. Therefore, information quality is managed strategically, thus aligning information quality management efforts with organisational strategies and Key Performance Indicators (KPIs). Such organisations continuously enhance information quality by addressing the root causes of any problems through business process improvements. Moreover, MANAGED organisations have developed and documented their information architecture, which maximises information integration and interoperability.

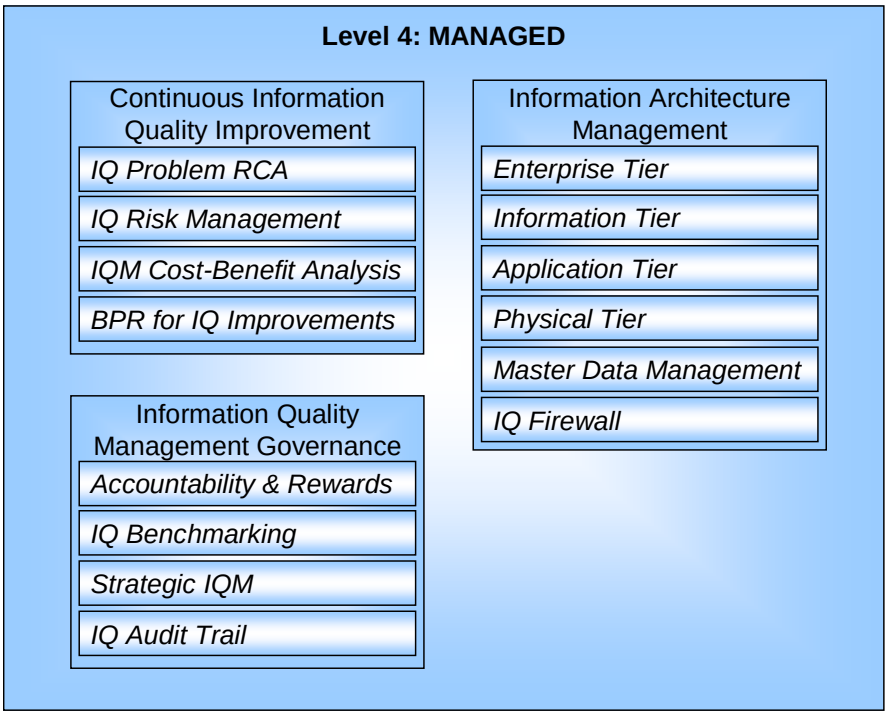


Figure 4.8: Level 4 (MANAGED)
Source: (developed by the author)

Level 5: OPTIMISING

Organisations on level five (Figure 4.9) continuously monitor the performance of their information quality management efforts, through internal/external benchmarking, thus ensuring continuous information quality management improvement. OPTIMISING organisations are world-leaders in information quality management.

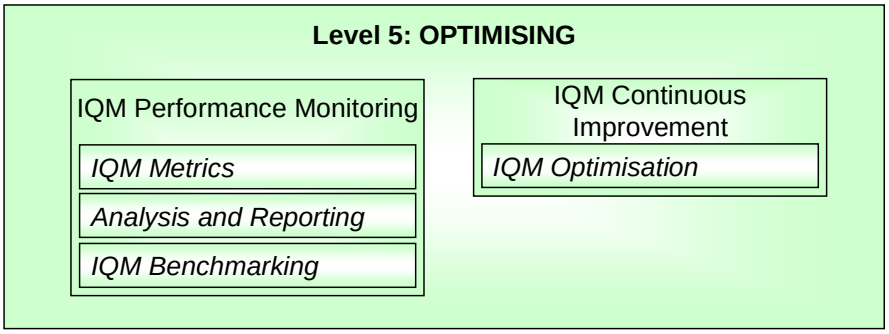


Figure 4.9: Level 5 (OPTIMISING)
Source: (developed by the author)

4.3.2 Constructing the IQM-CMM Diagnostic Tool

The next step involved the design of a diagnostic tool for the Information Quality Management Capability Maturity Model. The construction of the diagnostic tool involved identification/definition of several appraisal criteria for each maturity indicator (Figure 4.10). This was done, because, in order to assess the capability maturity of an organisation, it is required to determine what maturity indicators that organisation addresses. And, in order to determine what maturity indicators an organisation addresses, it is required to assess each indicator, based on a set of criteria. The assessment criteria were identified/defined based on the literature, the exploratory case studies, and the results of the Delphi study (including the qualitative comments). The complete Information Quality Management Capability Maturity Model Diagnostic Tool can be found in Appendix M. Furthermore, Table 4.4 (shown on the next page) provides a mapping between IQM-CMM maturity indicators and CMMI for development (v1.2) Process Areas (PAs). As a result, CMMI could also potentially be used in conjunction with IQM-CMM to provide a more detailed guidance on how each maturity indicator may be assessed.

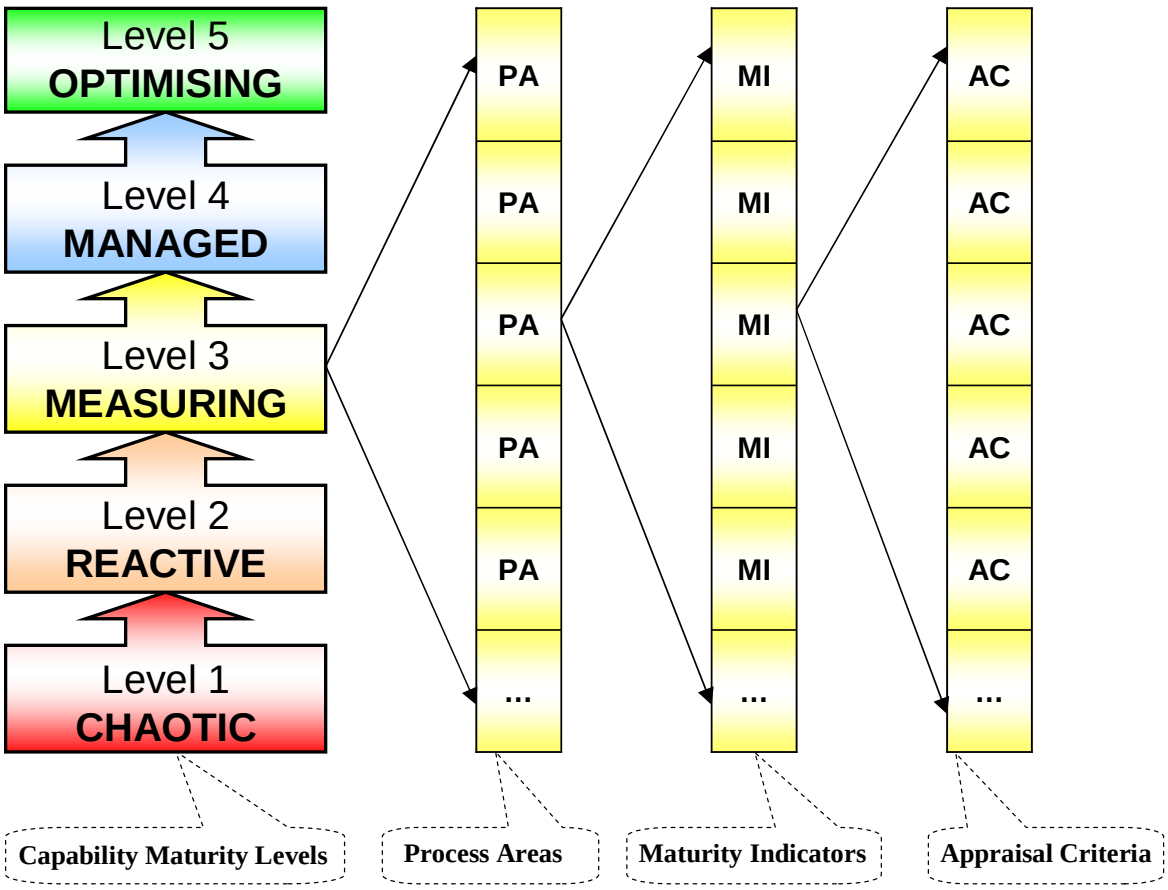


Figure 4.10: The Hierarchical Structure of IQM-CMM
Source: (developed by the author)

Table 4.4: Mapping between IQM-CMM Maturity Indicators and CMMI PAs

IQM-CMM Maturity Indicators	CMMI for Development, v1.2 PAs
IQM Optimisation	Organisational Innovation and Deployment (OID)
IQM Metrics	Measurement and Analysis (MA), Organisational Process Performance (OPP), Quantitative Project Management (QPM)
Analysis and Reporting	Measurement and Analysis (MA), Organisational Process Performance (OPP), Process and Product Quality Assurance (PPQA), Quantitative Project Management (QPM)
IQM Benchmarking	Organisational Process Definition (OPD), Technical Solution (TS)
IQ Problem Root-Cause-Analysis	Causal Analysis and Resolution (CAR)
IQ Risk Management and Impact Assessment	Risk Management (RSKM)
IQM Cost-Benefit Analysis	Organisational Process Definition (OPD)
Business Process Reengineering for IQ Improvements	Organisational Innovation and Deployment (OID), Process and Product Quality Assurance (PPQA)
Enterprise Tier Management	Product Integration (PI), Technical Solution (TS)
Information Tier Management	Product Integration (PI), Technical Solution (TS)
Application Tier Management	Product Integration (PI), Technical Solution (TS)
Physical Tier Management	Product Integration (PI), Technical Solution (TS)
Master Data Management	Technical Solution (TS)
IQ Firewall	Technical Solution (TS)
IQM Accountability, Rewards and Incentives	Organisational Process Definition (OPD)
IQ Benchmarking	Organisational Process Definition (OPD), Technical Solution (TS)
Strategic IQM	Organisational Process Definition (OPD)
IQ Audit Trail	Technical Solution (TS)
IQM Team and Project Management	Integrated Project Management, Organisational Process Definition (OPD), Project Monitoring and Control (PMC)
Education, Training and Mentoring	Organisational Training (OT)
IQ Problem Reporting and Handling	Organisational Process Definition (OPD)
Scripted information Cleansing	Technical Solution (TS)
IQ Metrics	Measurement and Analysis (MA), Process and Product Quality Assurance (PPQA), Quantitative Project Management (QPM)
IQ Evaluation	Measurement and Analysis (MA), Process and Product Quality Assurance (PPQA), Quantitative Project Management (QPM), Validation (VAL), Verification (VER)
IQ Requirements Elicitation	Requirements Development (RD)
IQ Requirements Analysis	Requirements Development (RD)
IQ Requirements Management	Requirements Management (REQM)
Information Supply Chain Management	Supplier Agreement Management (SAM)
Information Product Configuration Management	Configuration Management (CM)
Information Product Taxonomy	Technical Solution (TS)
Information Product Visualization	Technical Solution (TS)
Derived Information Products Management	Organisational Process Definition (OPD)
Meta-Information Management	Technical Solution (TS)
Security Classification of Information Products	Organisational Process Definition (OPD)
Secure Transmission of Sensitive Information	Technical Solution (TS), Organizational Process Definition (OPD)
Sensitive Information Disposal Management	Organisational Process Definition (OPD)
Authentication	Technical Solution (TS)
Authorization	Technical Solution (TS)
Audit Trail	Technical Solution (TS)
Physical Storage	Technical Solution (TS)
Backup and Recovery	Technical Solution (TS), Organisational Process Definition (OPD)
Redundant Storage	Technical Solution (TS)
Archival and Retrieval	Technical Solution (TS), Organisational Process Definition (OPD)
Information Destruction	Organisational Process Definition (OPD)
Stakeholder Management	Project Planning (PP), Requirements Development (RD), Requirements Management (REQM)
Conceptual Modelling	Requirements Development (RD), Technical Solution (TS)
Logical Modelling	Technical Solution (TS)
Physical Modelling	Technical Solution (TS)

Source: (developed by the author)

4.4 Theory Testing and Enhancing Stage

The previous section presented the results of the four round Delphi study, which was used to validate the candidate maturity indicators, identify new ones, and build the staged evolutionary capability maturity model. This section of the chapter illustrates the application of the IQM-CMM Diagnostic Tool in seven international explanatory case studies (Figure 4.11). More specifically, this section discusses how different organisations address different aspects of the Information Quality Management Capability Maturity Model.

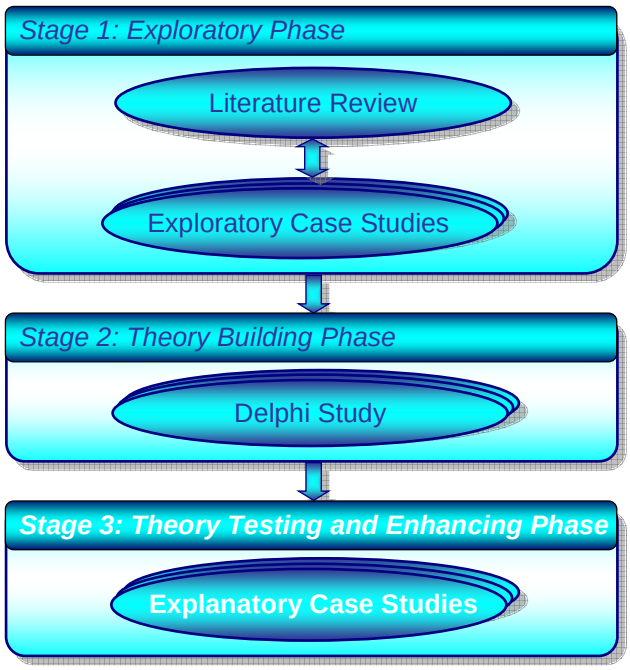


Figure 4.11: Theory Testing and Enhancing Stage
Source: (developed by the author)

4.4.1 Assessment Method

The assessment method has been based on the appraisal requirements for CMMI (ARC, v1.2) (ARC 2006), and the standard CMMI appraisal method for process improvement (SCAMPI A, v 1.2) (SCAMPI 2006). This section illustrates how each of the SCAMPI A, v1.2 processes were addressed by the IQM-CMM assessment method. A number of appraisal principles have also been adopted from the Systems Engineering Capability Model (EIA 1998; ARC 2006); they include: start with an appraisal reference model; use a formalised appraisal process; involve senior management as the appraisal sponsor; focus the appraisal on the sponsor's business objectives; observe strict confidentiality and non-attribution of data; approach the appraisal collaboratively; and focus on follow-on activities and decision-making based upon the appraisal results.

1 Plan and Prepare for Appraisal

1.1 Analyse Requirements. The purpose of the appraisal is twofold. From the researcher's point of view, the appraisal is used to provide further external validation for IQM-CMM. From the case study organisations' point of view, the appraisal is used to provide an independent critical examination of the information quality management processes and systems in use. Thus, the appraisal has the following objectives: to provide a comprehensive assessment of the information quality management processes and systems in use by the case study organisation; to provide recommendations for potential process enhancements and process optimisation, leading to improvements in information quality; and to provide further external validation and enhancements for IQM-CMM. The appraisal has the following scope: the appraisal focuses on the engineering asset management information systems in the case study organisation; and the appraisal is based on IQM-CMM, thus investigating the information quality management maturity indicators covered by IQM-CMM. Contact with the appraisal sponsor was established and access to members of the case study organisation was obtained.

1.2 Develop Appraisal Plan. The appraisal schedule and the interview plan were developed in cooperation with the case study organisation. Also, the commitment to the appraisal plan was obtained from the appraisal sponsor.

1.3 Select and Prepare Team. The leader of the appraisal team was identified. The researcher was considered as an appropriate assessor since he had a very good knowledge of IQM-CMM, given that he developed it.

1.4 Obtain and Inventory Initial Objective Evidence. Documents describing the information systems under investigation as well as high-level use cases illustrating the business processes in use were identified and obtained. This initial evidence was used by the researcher to familiarise himself with the case study organisation before any further, detailed, interviews were conducted.

1.5 Prepare for Appraisal Conduct. The initial objective evidence was reviewed in order to determine the feasibility of the appraisal plan. Also, the data collection plan and strategies for verifying and discovering objective evidence were developed. Furthermore, interviewees and relevant artefacts were identified.

2 Conduct Appraisal

2.1 Prepare Participants. All appraisal participants were contacted and informed about the nature of the research project. Where possible, a research information sheet, together with sample interview questions, was sent to the participants.

2.2 Examine Objective Evidence. Findings were based on one or more types of objective evidence, including, evidence gathered through interviews, and evidence obtained through reviewing documentation. Three types of appraisal criterion implementation indicators were considered: direct artefacts – the tangible output resulting directly from implementation of an appraisal criterion; indirect artefacts – artefacts that are a consequence of implementing an appraisal criterion, but which are not the purpose for which the criterion has been implemented; and affirmations – oral or written statements confirming or supporting implementation of an appraisal criterion.

2.3 Document Objective Evidence. All interviews were recorded and subsequently transcribed. Additionally, copies of relevant documentation were obtained from the case study organisation.

2.4 Verify Objective Evidence. The extent to which IQM-CMM appraisal criteria were implemented in the case study organisation was verified, and the appropriate quality ratings were determined for each criterion.

2.5 Validate Preliminary Findings. The findings were validated according to the following criteria: the finding were based on corroborated objective evidence, and the finding were consistent with other verified findings (ARC 2006). Furthermore, the appraisal sponsor was presented with the preliminary findings in order to solicit his/her responses for validation of the findings' accuracy and clarity.

2.6 Generate Appraisal Results. A gap analysis between the preliminary findings and the IQM-CMM reference model was performed and the organisation's information quality management capability maturity level was determined. Additionally, recommendations for maturity enhancements were developed and documented.

3 Report Results

3.1 Deliver Appraisal Results. All final finding and recommendations were delivered to the appraisal sponsor and opportunities for any future research with the case study organisation were discussed.

3.2 Package and Archive Appraisal Assets. Interview recordings and transcriptions as well as all hard-copy documents were archived in line with the University's research policy. The findings were documented, anonymised, and communicated in appropriate academic conferences and journals. The findings are also to be considered for future improvements to IQM-CMM.

Quality Ratings

Three quality ratings for each appraisal criterion were used: not-satisfied, partially-satisfied, and fully-satisfied (Table 4.5).

Table 4.5: Quality Ratings

Rating	Description	Comparable SCAMPI A, v1.2 Rating
Not Satisfied	There is no documentation and there is limited or no evidence to confirm the implementation.	**Not Implemented (NI).** • Direct artefacts are absent or judged to be inadequate. • No other evidence (indirect artefacts or affirmations) supports the practice implementation. • One or more weaknesses are noted.
Partially Satisfied	Some documentation exists, however there is inconsistent implementation through ad-hoc processes.	**Partially Implemented (PI).** • Direct artefacts are absent or judged to be inadequate. • One or more indirect artefacts or affirmations suggest that some aspects of the practice are implemented. • One or more weaknesses are noted. OR • One or more direct artefacts are present and judged to be adequate. • No other evidence (indirect artefacts, affirmations) supports the direct artefact(s). • One or more weaknesses are noted.
Fully Satisfied	Entirely documented, consistently implemented, effective and efficient, with above expectations results, utilising industry best practices.	**Fully Implemented (FI).** • One or more direct artefacts are present and judged to be adequate. • At least one indirect artefact and/or affirmation exists to confirm the implementation. • No weaknesses are noted.

Source: developed from (SCAMPI 2006)

4.4.2 Profiles of the Explanatory Case Study Organisations

Table 4.6: Profiles of the Explanatory Case Study Organisations

Case	Type of Organisation	Description
G	Australian Defence Organisation	Case G, an Australian Defence organisation, has designed and constructed several large and complex engineering assets. It also holds a multi-billion dollar contract for the through-life support of those assets. The IQM-CMM Diagnostic Tool was applied in Case G's Integrated Logistic Support (ILS) department, which manages and controls the integrated logistic support activities.
H	US Oil & Gas Exploration / Production Organisation	Case H is one of California's largest independent oil and gas companies. It operates exploration and production oilfield assets in California, managing more than 15,000 wells, and producing more than 150,000 barrels of oil and more than 50 million cubic feet of natural gas each day. It has revenue of several billion dollars.
I	US State Government Department	Case I organisation provides telephony, networking, and data management services to various state agencies in one of the US states.
J	US Telecoms Organisation	Case J is a major US telecommunications organisation, with over 10 million customers, and a network, which spans across more then 30 states. The organisation has revenue of more then $8 billion.
K	US Data Management Organisation	Case K is a leading information management organisation, which also develops business intelligence and marketing databases, and provides information technology outsourcing services for a number of Fortune 500 companies. It has revenue of more than $1 billion.
L	European Rail Organisation	Case L is a major European national rail organisation. It operates several thousand trains, and has revenue of more than €25 million.
M	European Telecoms Organisation	Case M is a major European telecommunications organisation, with more than 5 million customers, offering services for mobile, landline, and IP-based voice and data communication.

Source: (developed by the author)

4.4.3 Capability Maturity Ratings of the Explanatory Case Study Organisations

This section presents the capability maturity ratings of the explanatory case study organisations. The results provide further support for construct validity of the maturity indicators by showing that organisations tend to more easily satisfy the factors from lower levels than the factors from higher levels. That is to say, IQM-CMM appears to model an evolutionary information quality management maturity continuum. Since most explanatory case study organisations partially satisfied several IQM-CMM levels, filled radar diagrams are used to illustrate their appraisal results. Approximate maturity ratings are then derived by adding up the capability ratings of each level.

For instance, if:

L1 = 100%, L2 = 100%, L3 = 80%, L4 = 60%, and L5 = 10%; then

1 + 1 + 0.7 + 0.5 + 0.1 = 3.3; thus, resulting in an approximate maturity rating of Level 3.

It has to be noted, however, that no quantitative measures were actually used in the appraisals and, thus, that the resulting ratings are only approximate.

Case G: Australian Defence Organisation

The results of Case G assessment (Figure 4.12) indicate a medium level of information quality management capability maturity, thus approximately placing Case G on IQM-CMM Level 3 (MEASURING).

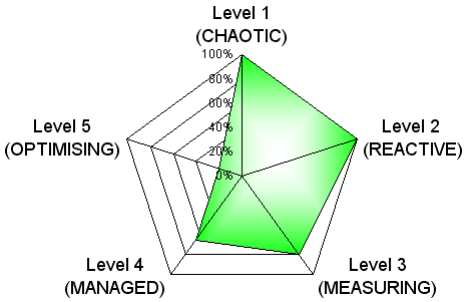


Figure 4.12: Case G IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.7: Case G IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Partially Satisfied*	Some information is being recorded on paper and subsequently copied into the information system.
	IQ Needs Analysis	*Fully Satisfied*	
	IQ Assessments	*Partially Satisfied*	There are no explicitly defined qualitative and/or quantitative IQ-KPIs. Heavy reliance is being placed on IQ problem reporting and subsequent correction.
	IQM Roles and Responsibilities	*Partially Satisfied*	Information quality is being managed implicitly. No dedicated IQM project manager is in place.
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	No internal or external IQ benchmarking is being performed.
	Information Architecture Management	*Partially Satisfied*	No proactive, dynamic real-time IQ checking is being performed. Also, it was found that there is insufficient integration between certain systems. As such, information is periodically being transferred over tape.
	Continuous IQ Improvement	*Partially Satisfied*	No formalised IQ risk management and impact assessment is in place.
Level 5 OPTIMISING	IQM Performance Monitoring	*Partially Satisfied*	There are no explicitly defined qualitative and/or quantitative IQM-KPIs. No internal IQM benchmarking is being performed.
	IQM Optimisation	*Partially Satisfied*	Information quality management isn't being performed explicitly, thus, any optimisations are implicit in nature.

Source: (developed by the author)

Case H: US Oil and Gas Exploration and Production Organisation

The results of Case H assessment (Figure 4.13) indicate quite a high level of information quality management capability maturity, thus approximately placing Case H on IQM-CMM Level 4 (MANAGED).

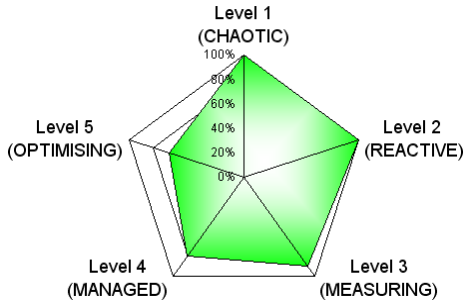


Figure 4.13: Case H IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.8: Case H IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Fully Satisfied*	It is not possible to easily generate the information flow of Business Objects reports (to find the original source of a particular piece of data in a report).
	IQ Needs Analysis	*Fully Satisfied*	
	IQ Assessments	*Partially Satisfied*	No checking for accuracy is performed (it is considered too labour intensive).
	IQM Roles and Responsibilities	*Fully Satisfied*	
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	No information quality management for financial KPIs is in place.
	Information Architecture Management	*Partially Satisfied*	No proactive, dynamic, real-time IQ checking is being performed.
	Continuous IQ Improvement	*Fully Satisfied*	
Level 5 OPTIMISING	IQM Performance Monitoring	*Partially Satisfied*	There are no explicitly defined qualitative and/or quantitative IQM-KPIs. No internal IQM benchmarking is being performed.
	IQM Optimisation	*Fully Satisfied*	

Source: (developed by the author)

Case I: US State Government Department

The results of Case I assessment (Figure 4.14) indicate a relatively low level of information quality management capability maturity, thus approximately placing Case I on IQM-CMM Level 2 (REACTIVE).

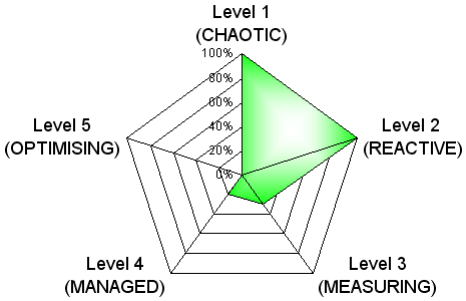


Figure 4.14: Case I IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.9: Case I IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Partially Satisfied*	No metadata management is in place.
	IQ Needs Analysis	*Partially Satisfied*	Some IQ requirements for some of the systems were identified.
	IQ Assessments	*Partially Satisfied*	IQ assessments for one aspect of one system are in place.
	IQM Roles and Responsibilities	*Partially Satisfied*	No dedicated IQ function was in place. DBAs are responsible for data integrity
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	No IQ benchmarking is in place. Any data governance is managed locally, in a fragmented fashion.
	Information Architecture Management	*Partially Satisfied*	There is no enterprise logical data model; there are individual silos of information. No proactive, dynamic, real-time IQ checking is being performed.
	Continuous IQ Improvement	*Partially Satisfied*	Informally performed for some of the systems.
Level 5 OPTIMISING	IQM Performance Monitoring	*Not Satisfied*	No evidence to confirm the implementation.
	IQM Optimisation	*Not Satisfied*	No evidence to confirm the implementation.

Source: (developed by the author)

Case J: US Telecommunications Organisation

The results of Case J assessment (Figure 4.15) indicate a medium level of information quality management capability maturity, thus approximately placing Case J on IQM-CMM Level 3 (MEASURING).

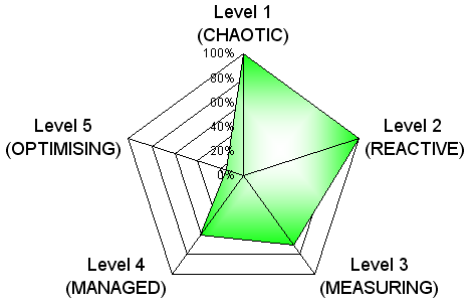


Figure 4.15: Case J IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.10: Case J IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Fully Satisfied*	
	IQ Needs Analysis	*Partially Satisfied*	Mainly geared toward the data warehouse.
	IQ Assessments	*Partially Satisfied*	Mainly geared toward the data warehouse. Performed when requested by the end users.
	IQM Roles and Responsibilities	*Fully Satisfied*	
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	Information producers are not currently being rewarded for IQ.
	Information Architecture Management	*Partially Satisfied*	Much information is still being stored redundantly, due to the use of autonomous applications. No proactive, dynamic, real-time IQ checking is being performed.
	Continuous IQ Improvement	*Partially Satisfied*	Any IQ improvements are reactive in nature and are only performed when problems are reported by the users.
Level 5 OPTIMISING	IQM Performance Monitoring	*Not Satisfied*	No evidence to confirm the implementation.
	IQM Optimisation	*Partially Satisfied*	No formalised IQM optimisation process in place.

Source: (developed by the author)

Case K: US Data Management Organisation

The results of Case K assessment (Figure 4.16) indicate quite a high level of information quality management capability maturity, thus approximately placing Case K on IQM-CMM Level 4 (MANAGED).

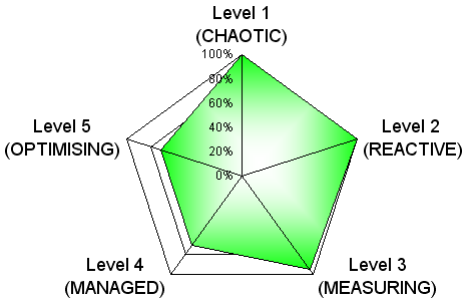


Figure 4.16: Case K IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.11: Case K IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Fully Satisfied*	
	IQ Needs Analysis	*Fully Satisfied*	
	IQ Assessments	*Fully Satisfied*	
	IQM Roles and Responsibilities	*Partially Satisfied*	No IQ problem reporting is in place.
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	No accountability for producing poor IQ is in place.
	Information Architecture Management	*Partially Satisfied*	No proactive, dynamic, real-time IQ checking is in place.
	Continuous IQ Improvement	*Not Satisfied*	Not achievable since all data is supplied by external parties.
Level 5 OPTIMISING	IQM Performance Monitoring	*Partially Satisfied*	There are no explicitly defined qualitative and/or quantitative IQM-KPIs.
	IQM Optimisation	*Fully Satisfied*	

Source: (developed by the author)

Case L: European Rail Organisation

The results of Case L assessment (Figure 4.17) indicate a relatively low level of information quality management capability maturity, thus approximately placing Case L on IQM-CMM Level 2 (REACTIVE).

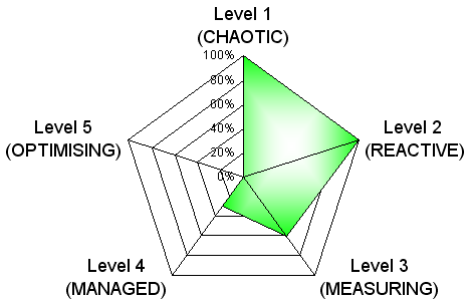


Figure 4.17: Case L IQM-CMM Appraisal Results
Source: (developed by the author)

Table 4.12: Case L IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Partially Satisfied*	A metadata initiative has been planned. No management of derived information products. No uniform representation of information.
	IQ Needs Analysis	*Partially Satisfied*	A one-off project addressing IQ needs analysis has been completed.
	IQ Assessments	*Partially Satisfied*	A one-off project addressing IQ assessments has been completed.
	IQM Roles and Responsibilities	*Partially Satisfied*	No formalised IQ problem reporting and handling.
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	No IQ based rewards and incentives.
	Information Architecture Management	*Partially Satisfied*	No Master Data Management is in place. No proactive, dynamic, real-time IQ checking is in place.
	Continuous IQ Improvement	*Partially Satisfied*	A one-off project partially addressing continuous IQ improvement has been completed.
Level 5 OPTIMISING	IQM Performance Monitoring	*Not Satisfied*	No evidence to confirm the implementation.
	IQM Optimisation	*Not Satisfied*	No evidence to confirm the implementation.

Source: (developed by the author)

Case M: European Telecommunications Organisation

The results of Case M assessment (Figure 4.18) indicate quite a high level of information quality management capability maturity, thus approximately placing Case M on IQM-CMM Level 4 (MANAGED).

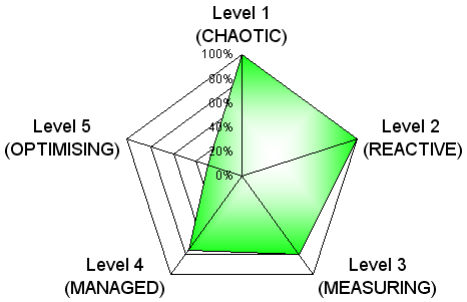


Figure 4.18: Case M IQM-CMM Appraisal Results
Source: (developed by the authors)

Table 4.13: Case M IQM-CMM Appraisal Summary

	Process Area	Rating	Issues
Level 1 CHAOTIC	None by definition	*Satisfied by default*	
Level 2 REACTIVE	Information Needs Analysis	*Fully Satisfied*	
	Storage Management	*Fully Satisfied*	
	Access Control Management	*Fully Satisfied*	
	Security Management	*Fully Satisfied*	
Level 3 MEASURING	Information Product Management	*Partially Satisfied*	The ETL transformations to some of the data warehouses haven't been entirely documented. Information representation is system dependant.
	IQ Needs Analysis	*Partially Satisfied*	Has been done for some of the systems.
	IQ Assessments	*Partially Satisfied*	Is being performed for some systems.
	IQM Roles and Responsibilities	*Partially Satisfied*	This is still somewhat fragmented.
Level 4 MANAGED	IQM Governance	*Partially Satisfied*	The data governance board and the data stewards' community are currently being formed.
	Information Architecture Management	*Partially Satisfied*	There is a lack of an enterprise logical information model. Some information appears to be stored redundantly; this is now being identified and recorded. No proactive, dynamic, real-time IQ checking is in place.
	Continuous IQ Improvement	*Partially Satisfied*	No formal/standardised information quality risk management and impact assessment seems to be performed.
Level 5 OPTIMISING	IQM Performance Monitoring	*Not Satisfied*	No evidence to confirm the implementation.
	IQM Optimisation	*Partially Satisfied*	Performed in an ad hoc fashion.

Source: (developed by the author)

4.4.4 Cross-Case Analysis

This section presents the cross-case analysis, illustrating the relevance of the IQM-CMM maturity indicators to the explanatory case study organisations.

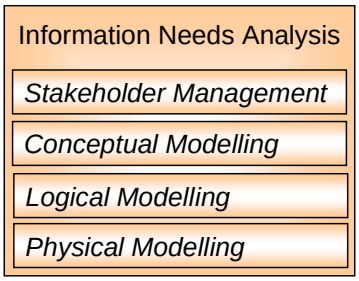
Level 1: CHAOTIC

The first level does not address any maturity indicators, and as such it does not warrant any further discussion in this section.

Level 2: REACTIVE

This section illustrates the relevance of each of the IQM-CMM Level 2 (REACTIVE) maturity indicators to the explanatory case study organisations.

Information Needs Analysis



Information needs analysis addresses four maturity indicators, including, stakeholder management and conceptual/logical/physical data modelling. Identifying and documenting all key stakeholders, including information suppliers, stewards, consumers, and owners, is a prerequisite for effective information quality management. Stakeholders are the ones judging the quality of information and, therefore, their input is critical in any IQM efforts. In Case M, due to the relative autonomy of the individual systems, stakeholders have historically been managed by the individual system owners/managers. Other organisations may have a more centralised structure for stakeholder management. One of the interviewees illustrated the significance of establishing a relationship between the stakeholders as follows:

> *"We know who our big users are. That's a good thing. So we listen to them. We have a very strong relationship. I think we have done a lot over the past several years to build a strong internal relationship with those groups, so that they feel comfortable coming to us when they have issues and we feel comfortable going to them when we find issues. … We are confident that we can address them about it and they are confident that we can fix it. I think that made a big difference!"*
>
> IQ Manager (Case J)

Also, it is essential to identify the relationships between the stakeholders and individual information products. For instance:

> *"Data elements may have different business sponsors and they may have different stewards."*
>
> Enterprise Information Architect (Case J)

However, having a high level of transparency by clearly defining, documenting, and communicating all stakeholders' roles and responsibilities can induce other unforseen issues. As one of the interviewees observed:

> *"There are a lot of political discussions going on in the background about who owns the data. Do we want this kind of transparency? This is a very important question, not only from the view of management but also from the view of the engineers – 'I am a guru. Who can do my job? Can everyone do my job if I have this level of transparency?' – and that is an argument nobody really tells you, but you can see the facts."*
>
> Head of Data Governance (Case M)

This argument may be of even more relevance to larger organisations, which have a large number of staff who are involved in information management. As one manager explained:

> *"In my department here, there are 75 people, who really are totally focused on doing nothing more than the creation, the management, the packaging, and the delivery of that data."*
>
> ILS Manager (Case G)

Another case study organisation also had a large group of personnel dedicated solely to information management. According to their enterprise information architect:

> *"Our IT organisation is application development, technology, and information management. Most IT organisations are just the two – application development and technology."*
>
> Enterprise Information Architect (Case J)

Furthermore, identifying the consumers of information products is the first step in information needs analysis, since:

> *"There is actually one other base question that underlies everything – What decides on what data you need to collect? What says, that's what we need in there? How do you establish what you need to capture in the first place?*
>
> ILS Manager (Case G)

Therefore, it is essential to align the needs of the business with the capabilities of the IT department. One of the interviewees provided the following example:

> *"We have a business view with special interests and we have an IT view with special interests, and those views didn't match for a long time. … So, we have established some new functions in the company, who are responsible for bringing together business and IT."*
>
> SLA Manager (Case M)

Identifying all the requirements is necessary not only when developing a new system, but also when acquiring a Commercial Off The Shelf (COTS) system. According to one interviewee:

> *"For our new system, we did have a big effort to define what the requirements were, even though it was a purchased system."*
>
> Enterprise Services Administrator (Case I)

However, COTS systems do have some limitations, as shown by the following example:

> *"We are limited with what we can do in a packaged application, because the more customisation we do the more likely it is that an upgrade will require more effort."*
>
> Enterprise Services Administrator (Case I)

Also, it is essential to document the business requirements in a standard language or notation. A business analyst in one of the organisations explained:

> *"We have documented system interfaces and functionality in a high-level use case UML document."*
>
> Business Analyst (Case G)

Once all the key stakeholders have been identified and their requirements have been gathered, it is then possible to model those requirements in conceptual, logical, and physical data models. Those models should preferably be documented in a standard notation/language, such as Entity Relationship Modelling (ERM) notation, or the Unified Modelling Language (UML). One interviewee explained:

> *"Whenever we model something we do it in UML, we use an Australian tool – Enterprise Architect."*
>
> Head of Data Governance (Case M)

Another interviewee stated:

> *"We use ERwin as our tool for database development, and yes we would go through conceptual, logical, and physical modelling. We work with the third normal form."*
>
> DBA (Case I)

Additionally, any such data modelling would have to be centrally controlled, as the following example illustrates:

> *"We developed the majority of the software in-house…so people went off and developed various systems to satisfy their requirements. Whilst the systems held similar sorts of information, the attributes were named differently."*
>
> ILS Manager (Case G)

Data modelling efforts should ideally start with the development of a conceptual data model. Such a model would identify high-level entities (objects), together with their relationships. Conceptual schema should also be mapped to explicit business requirements, which should been gathered from the key stakeholders. Most importantly, the business requirements should be reviewed on an ongoing basis and the conceptual data model should be updated periodically. Such conceptual data models can then be used as input for the development of logical data models. Alternatively, some organisations may choose to purchase logical data models that best represent their business domain.

"We purchased an enterprise data model last year. We looked at several different models… and the one that most closely represented the way our business viewed our industry we ended up purchasing and customising it to really make it [our] model. …It's in the third normal form; we are mapping that to existing data structures and we are deriving new data structures from it."

Enterprise Information Architect (Case J)

Thus, logical data models can then be used as a basis for the development of physical data models. A data architect from one of the case study organisations explained:

"We use the logical model to document the business requirements in a form that we can give to the developers."

Data Architect (Case M)

The logical data models should specify the attributes for each entity as well as identify unique attributes and relationships between entities. They are also usually normalised to the third normal form. Physical data models may then instantiate parts of the logical model, taking into account any DBMS specific requirements. Physical data models may also enforce business rules through the use of DBMS constraints, including not null, check, referential integrity, and unique constraints. Of course, documenting the business rules in the first place is the key; as one of the interviewees emphasised:

"Every project I've worked on has had extensive documentation of business rules."

BI Developer (Case I)

On the other hand, not documenting business rules may have severe consequences.

"Most our problems have to do with wrong definitions of business rules."

IQ Manager, DW (Case M)

It is also essential to enforce the referential integrity in the DBMS; one DBA explained:

"Basically, we use referential integrity wherever we can. … It may be a little bit of pain upfront, but down the road, it can be a lot of pain; because, once the data starts getting corrupted it is almost irreversible."

DBA (Case I)

Instead through DBMS constraints, the business rules may also be enforced on the application level. According to one manager:

"Most of the systems that we run have mandatory fields defined. Most of them also have foreign key checks built into the software."

ILS Product Manager (Case G)

However, such controls may not be very effective at ensuring accuracy. A CFO in one of the organisations explained:

"There are controls in the system that will prevent you from entering an invalid code, not necessarily a wrong code, but an invalid one."

CFO (Case I)

There are however strong arguments for enforcing business rules on the DBMS level. According to a DBA in one of the organisations:

> *"We always say 'put it in the database'. That's what E.F. Codd said, and that's what everyone says, all the experts they still say that. … Because, if you put it in applications, you have to replicate it. You have change management issues and, you know, it can become a nightmare. Instead you have it in one location."*
>
> DBA (Case I)

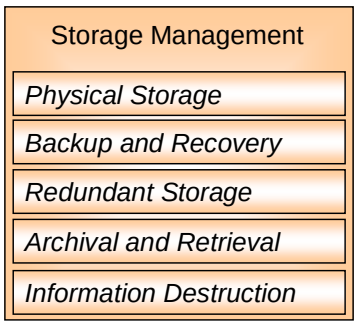
If the business rules are enforced by the applications, any updates to the business rules would require modifying the software. If the business rules have been hard-coded, the software source code would have to be recompiled. Other organisations use a hybrid approach. According to one enterprise information architect:

> *"We do have field level constraints like, is-null and foreign key constraints. We don't use constraints like valid values, ranges of values, this field has to be A, B, or C, at the database level. That's enforced through the software."*
>
> Enterprise Information Architect (Case J)

Another option is to manage the business rules in a dedicated business rule management system, as the following example shows:

> *"We are trying to externalise the business rules from applications to a business rules management system, real-time decision engine, not only to standardise them, but also to put them in the hands of the business."*
>
> Enterprise Information Architect (Case J)

Storage Management



Appropriate storage management is crucial for ensuring the accessibility dimension. Organisations have to make sure that information is stored in dedicated areas that have physical access control procedures in place, which are environmentally appropriate, and have proper disaster management plans. Case H employed physical access controls based on access card readers, where written approvals had to be given for physical access to the data storage areas. The physical access list was reviewed every year. Furthermore, humidity and temperature detectors were used to monitor the dedicated storage areas 24/7, with water monitors in use under the floors. A waterless fire protection system would be activated if any fire was detected, and a power generator was in place in the case of any blackouts. Recovery prioritisation plans detailing what systems to recover and how to recover them were also found to be in place. What's more, disaster management is directly linked to backup and recovery; one of the interviewees explained:

"We have a secure data centre. We also have disaster recovery processes, and we ship our data out daily."

DBA (Case I)

Therefore, critical information need to be regularly backed up and those backups should be stored off-site, in the case of any disasters. The physical security of the backups should be appropriately maintained and they should periodically be restored to a test machine. Case H backed up its SAP system every night, with full backups being performed by another company once a week and stored off-site. Case H would visit that company every year and audit the backups. Furthermore, physical access procedures for backups were found to be in place and backups were secured in a locked box during transportation. Periodic test were in place, since recovery requests were coming in on a weekly basis. Yearly backup tests (full restores) were performed for certain systems, and all backups were treated as confidential, and labelled appropriately. Moreover, backups were organised in pools (e.g. Windows, UNIX, and so on). Another issue that has to be taken into account is the redundant storage of information; as one interviewee explained:

"Redundancy is the number one enemy of information quality."

IAIDQ Member

However, if organisations use COTS software packages, redundant storage may be unavoidable; one of the enterprise information architects provided the following example:

"There is software for managing the inventory and maintenance schedules, there is software for managing the faults… there are five different systems that overlap that have independently entered information."

Enterprise Information Architect (Case J)

This can cause various IQ problems; another enterprise architect explained:

"The process for capturing information worked, but if any changes to the information were later applied, then they weren't necessarily updated in the central system. That's because information has been stored redundantly."

Enterprise Architect (Case M)

Additionally, there are certain cultural issues that have to be considered; one CTO stated:

"I like my silo. I control my silo. And you can go and do whatever you want because I can do it better and faster and smarter than you can. When you look at unmanaged redundancy, it's everywhere. But people fear the managed redundancy."

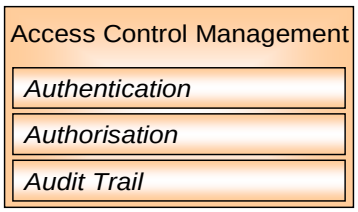
CTO (Case I)

Another aspect of storage management is that some information may need to be archived for longer periods of time. Any such requirements should be clearly identified and documented, and any such information should be catalogued. Furthermore, the media used for archiving as well as the file formats should have appropriate longevity. On the other hand, some information may also need to be periodically destroyed. Any such actions

should only be performed by authorised personnel, who are following clearly defined and documented rules for information disposal. One DBA explained:

> *"There is a whole documented process by which databases may be decommissioned. It's not like someone just goes and drops the database."*
>
> DBA (Case I)

Access Control Management



Access control is critical for ensuring that only authorised personnel have access to information. Thus, user accounts should be formally managed and regularly reviewed, and the information system should verify the identity of every user. Additionally, users should have the least set of privileges they need in order to perform their functions. Any such privileges should also be regularly reviewed. One manager supported this view by providing the following example:

> *"We have restricted entry, where only authorised persons can enter data into the system."*
>
> ILS Manager (Case G)

A CFO in one of the organisations illustrated the importance of access control by stating:

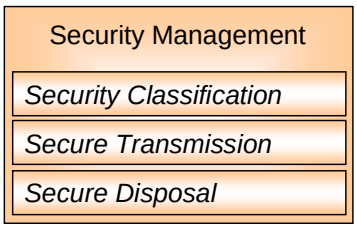
> *"The main thing, from the financial perspective, is when we build processes, we are always looking to build in controls to ensure the quality of the transactions that go into the financial systems."*
>
> CFO (Case I)

Furthermore, audit trailing should chronologically log all users' activities, thus enabling reconstruction of events. Any such logs should also be regularly analysed for any access control breaches.

To obtain a user ID and gain access to the systems in Case H, a form had to be filled out and sent to their HR department. Contractor IDs were only valid for a certain period of time (max 6 months), while employee accounts were valid until termination of employment. Passwords had to be changed every 90 days and a Help-Desk was in place in the case of forgotten passwords. The Help-Desk would send the passwords to the employee's voice mail, but Case H was moving toward a self service approach widely used on the Internet (e.g. answer a question). All accounts were being locked after 5 minutes of inactivity; exceptions to this were allowed, but they first had to be formally approved. User accounts were reviewed every month for Windows, and every quarter for UNIX, ORACLE, remote access, and most other systems. A debate about access control, based on two different schools of thought, was under way in Case H. One school of thought

advocated giving everyone read access to all non-confidential information, while the other school of thought advocates the "need to know" access restrictions. About 70% of Windows share folders were found to be providing read access for everybody; however, the system would send reminders to owners to periodically check access to shared Windows folders. ORACLE accounts had to be approved by the data modeller, and justified for access. Furthermore, the separation of duties matrix (for SAP) was being reviewed every 6 months. It mapped job functions against certain access areas, which could then be matched against employee records (this was primarily used in financial areas). All user activities, such as information access and system commands, were being automatically logged in Case H's SAP system. SAP system logs were reviewed every week and the audit trail was regularly analysed. Internet access was also logged; however, no audits were preformed without prior authorisation from HR, who may get a request from a supervisor. Privacy was considered important, so any reviews required a strong reason. Approximately one investigation per month regarding the use of the Internet was being carried out. Not much logging outside of SAP was being performed.

Security Management



Security management is an extremely complicated topic with a very large and ongoing research effort. As such, it will only be addresses on a very high-level in this section. Some of the main issues relevant to information quality involve developing security classifications for information products, ensuring secure transmission of sensitive information, and guaranteeing secure disposal. Commercial in confidence as well as intellectual property issues are of high relevance; as the following example illustrates:

> *"We have to deal with intellectual property issues for suppliers. … We also have our internal restrictions of commercial in confidence classification."*
>
> ILS Data Manager (Case G)

In Case H, security policies were reviewed with the CIO once a year as part of the control framework. Confidential and most-confidential documents had to be labelled on the surface, while unlabeled documents were assumed to be internal-use. The security guidelines dictated how confidential and most-confidential information should be handled. That way a lot of the responsibility was shifted to the information creators and users; thus, information creators and consumers were responsible for document classifications. Tight

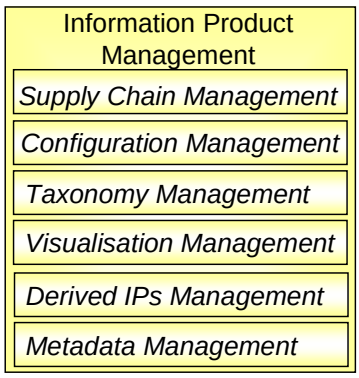
restrictions applied around most-confidential classifications. Classification examples matrices were provided and could be used for some guidance; however, only certain things had been defined, while others were left to the judgements of the creators/users. Information security awareness training was in place, and monthly desk inspections were ensuring that no classified information was left unlocked. Any security incidents were handled through internal investigations. Classifications for export control were found to be a big issue, since Case H was being held accountable by the government, based on the Export Control Act.

Requirements for encryption, with very limited use, were identified in Case H. This mainly applied to HR information, which was being transmitted over the public Internet. Email attachments were also getting occasionally encrypted with WinZIP encryption, which may require some enhancements, perhaps through digital certificates. Staff were encouraged not to store any confidential information on any portable devices and authorisation was needed to take any confidential information off the network. Hard copies were transported in locked containers, and confidentiality agreements were required from all employees and contractors. Furthermore, most systems generated automatic alerts in the case of any security incidents occurring. No organisation-wide clean desk policy was in place in Case H, since most groups did not really need it. Information security guidelines advised how to properly dispose of sensitive information, by shredding any hard copies or by putting them into designated bins. Hard disks were being sent to an external company for shredding, while shedders for CDs and DVDs were available onsite.

Level 3: MEASURING

This section illustrates the relevance of each of the IQM-CMM Level 3 (MEASURING) maturity indicators to the explanatory case study organisations.

Information Product Management



Managing information as a product is also a key information quality management maturity indicator. One of the relevant aspects is identifying and documenting the information flow within the organisation as well as between the organisation and any external parties. A manager from one of the case study organisations provided the following example, illustrating the significance of appropriately managing the information flow:

> *"System ABC, actually, only uses the data that's recorded in other systems. Now, the problem that we have is that if you suddenly have development in your target system that doesn't take into account that you are linked to it, then the interacting systems will have problems."*
>
> Data Manager (Case G)

Other organisations heavily rely on Extract Transform Load (ETL) tools for information exchange between systems, using either COTS tools or writing their own custom code. In any case, appropriately documenting the information flow is the key.

> *"There was no governance, no documentation, no development guidelines, and no version control. Now we have all this data, and scripts that transform the data, and nobody can handle it. Data flows every way possible, and there are countless ways data is transformed – even the same data."*
>
> IQ Manager, DW (Case M)

However, ETLs can also be used to perform some information quality assessments.

> *"Business rules could sometimes be implemented in ETLs."*
>
> Enterprise Services Administrator (Case I)

Nevertheless, it is crucial to document the information flow within the organisation as well as between the organisation and any external parties. In Case M, a "data homology" repository was being used to record information about the information supply chain – capturing all tasks, applications, interfaces between applications, and all data elements which were being transferred. Figure 4.19 shows a partial information flow diagram that was developed as a part of the Case G study. Although, it has to be noted that many large organisations may in reality have several hundreds of different system operating at any one time.

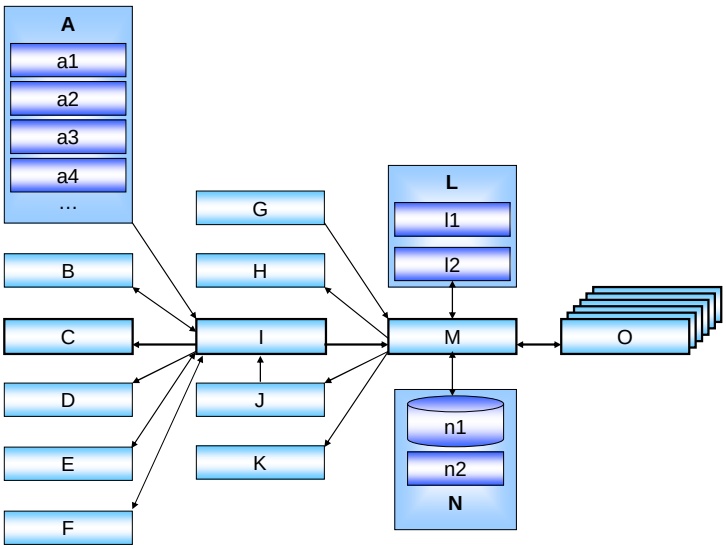


Figure 4.19: Information Flow (Case G)
Source: (developed by the author)

Furthermore, communication between information producers and information consumers should be established and information supply agreements may be used to ensure a certain level of information quality; one of the managers explained:

> *"Service level agreements mainly revolve around transit times and the expectation of getting the information. They are mostly void of the integrity of the information. I think the SLAs could be improved!"*
>
> IM Operations Manager (Case J)

Information should also be captured in real-time, and it should never be copied manually. Additionally, it is critical to have suitable configuration management processes in place as the following example illustrates:

> *"When we go and change the functionality of our data, we are subject to full configuration management processes to ensure that the integrity of our systems and the data aren't undermined by any changes that were made."*
>
> ILS Manager (Case G)

Furthermore, configuration audits can also play a part in information quality assessments.

> *"The configuration management process, and that's where configuration audits come in, means that we are constantly reviewing the physical product against all the baselines that are held in the systems. … Somebody goes down and eyeballs the asset, and then reviews the data that is stored in the databases themselves, against what should be there, and what the system says is there."*
>
> ILS Manager (Case G)

In addition, change control boards should be used to ensure that any changes to the information products or even the information systems do not create any further issues.

> *"We have a change process in place … people responsible for particular application are responsible for reviewing that and for approving the change prior going to production."*
>
> IM Operations Manager (Case J)

Strict controls for any table modifications were found to be in place in Case H. Also, any changes had to go through the data modeller and had to be approved by the change control board, which met every 2 weeks and looked at any potential impacts that the changes may introduce. Management Of Change (MOC) forms were being used for major changes, thus forcing the requestor to go through a checklist of potential implications. An enterprise architecture board was also in place and it dealt with any changes to the enterprise architecture.

In Case G, the configuration manager was responsible for maintaining the consistency of the configuration data between the systems, as well as validation, verification, and auditing of the elements of the configuration status account. Configuration management was mainly focused on the design data where a system was used to manage the full lifecycle of change management, from initiation of problem reports through to closure. All approved configuration changes, baselines, and deviations were recorded within the system. Consequently, configuration management processes ensured that any changes to documents could be tracked-back, or reversed, if needed. The configuration management department also performed regular data audits to make sure that what is in the database truly reflects the real world situation (i.e. to ensure that data integrity is not undermined by any changes made, or that any changes made can be tracked back). Technical manuals updated by Case G were managed by maintaining a history file of the changes to each individual manual. Changes to system's source code were managed using a configuration management tool, and Oracle database document vault system provided automatic revision control and check-in/check-out functionality for documents in Microsoft Word format.

Developing a taxonomy of information products is also one of the key information quality management maturity indicators. Any such taxonomy may organise information products in a hierarchical structure as well as identify relationships between information products, including, aggregations, compositions and associations.

In Case H, aggregate information was presented in corporate Business Objects reports, which were grouped in folders and were typically assigned a process owner and a process analyst, thus enforcing appropriate management and enforcing any accountability. Responsibilities were shifted to departments or groups, thus process owners had the responsibility for their reports. Furthermore, tools which allowed one to select a table and

then provide the list of all associated ETLs and tables were in place. Informatica was used for managing ETLs.

In Case G, one of the systems held all associations between the product structure, logistic, and maintenance documents data. The information system, through hyperlinks, associated planned and scheduled maintenance requests to each maintenance control record and permitted associations of documents to maintenance tasks. The system could also associate other information products. Technical and maintenance documents were held in the information system as unique components of text that were selected to construct a document of a specific context. Document elements and attributes were handled in the database so that common records were used in any number of documents that required the specified information. Style-sheets were used with DTDs to produce a result tree that was the basis of published technical documents.

With reference to Visualisation Management, making sure that all information products have a similar look-and-feel should greatly assist with improving the representational information quality dimensions. One BA explained:

> *"All forms look pretty much the same. Once you have seen one form, the rest look pretty much the same. The structure is almost the same. The layout is the same, the buttons are all in the same place."*
>
> Business Analyst (Case G)

In Case H, all corporate documents as well as GIS reports were based on a standard template, and Business Objects was used as the only standard reporting tool across the organisation. All major procedures and process guides also had associated templates.

Furthermore, any derived information products should be identified and comprehensively documented, including original information as well as derivation (analysis) rules. The enterprise information architect in one of the case study organisations explained:

> *"We are using a product called Rational Data Architect to map and keep the alignment between the derived data structures and the conceptual model. …It is a derived model, but the mapping is in tact, so if we make any changes to the enterprise logical model, we'll be able to tell the downstream impact on any physical repository, any service, data structure, any of those."*
>
> Enterprise Information Architect (Case J)

In Case H, most of the reporting tables were aggregate. All the rules were typically in the system design space, posted and available on shared servers. Corporate documents contained metadata providing additional information about the document.

Establishing a metadata registry is also one of the key maturity indicators.

> *"Our whole system is just metadata driven. Metadata is also used to drive reporting, and is also used in the rule engine."*
>
> Senior Manager (Case K)

However, many organisations struggle with that task of creating a metadata registry; as a CTO in one of the case study organisations explained:

> *"We have tried that for years and have recognised the need for that, but we do not have that in place. We spent millions of dollars on a metadata tool and it never came off the shelf, never was installed, it was never adopted. Some metadata may exist in pockets, but we do not have a data architecture with metadata."*
>
> CTO (Case I)

Another information quality manager supported this argument by stating:

> *"The biggest problem is that we don't have any metadata repository."*
>
> IQ Manager, DW (Case M)

And according to one data architect:

> *"We have never had a good business metadata strategy – an Excel sheet here, a Word document there – but now we need a better solution."*
>
> Data Architect (Case M)

What's more, metadata can directly be used to assist in any information quality management efforts as the following example shows:

> *"We have decided to flag some data, which are perhaps not correct. We also have a priority matrix telling us which data source has higher priority in comparison with the other one. And some data, which we cannot correct, we just flag. And then, nobody would go and clean up all these flags just proactively, but if you have a project in that area, and you have an opportunity to go to a manhole to have a look, then you go there and you clean up the data."*
>
> Solution Architect (Case M)

Case H had a project under way to evaluate their meta-data repositories. Their existing repository contained the logical model, all business rules, entities, physical data models, and diagrams (physical & logical). It was missing the Business Objects report information and ETL transformations. Case H was trying to bring everything together (objects and relationships) so that navigation between elements would be possible (i.e. it should be possible to find the information flow, and the original source of a particular piece of data in a Business Objects report).

Information Quality Needs Management



Before any information quality assessment or improvements efforts can be initiated, relevant information quality requirements first need to be identified. This includes the identification of the key information quality dimensions as well as the relevant business rules.

> *"We have developed information quality goals for 2007/2008, and we have identified the relevant IQ dimensions. We have discussed what we are expecting, how will the information quality improve if we are taking the measures."*
>
> Business Object Owner (Case M)

Any such requirements would have to be gathered from the key stakeholders, since they are the ones judging the quality of information; as the following statement illustrates:

> *"It's not just a data problem. It's a process and customer requirement problem."*
>
> ILS Manager (Case G)

Case L conducted an information quality project, whereby they surveyed all key stakeholders, asking them to compare the importance of all of the 16 Wang/Strong IQ dimensions with each other. They analysed the results and were able to rank the IQ dimensions based on their importance to stakeholders. As a result, it was then possible to set the information quality goals and objectives as well as the minimum desirable levels of information quality. On the other hand, one can consider zero information quality problems as the ultimate goal; a CTO in one of the case study organisations explained:

> *"The data quality standard is zero failure. When you are dealing with confidential records, data quality standard is zero failure."*
>
> CTO (Case I)

However, improving one information quality dimension can often lead to a quality drop in another dimension; for example:

> *"Timeliness is often a trade-off with accuracy, and accuracy and completeness are often a trade-off."*
>
> IAIDQ Member

Another manager illustrated that point with the following example:

> *"Coverage and accuracy somewhat conflict. So, we already have an inherent problem in that our clients expect high coverage, and then expect consistency in our data, and therefore accuracy is not always as high as it could be. So, we have to balance that very carefully."*
>
> Senior Manager (Case K)

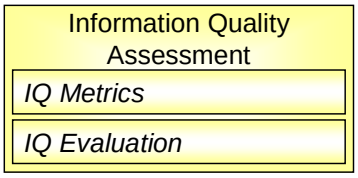
Information quality requirements were specified as more than 700 IQ rules in plain English in Case H. Additionally, Case H identified 6-9 key information quality dimensions with a

high visibility in the organisation, and mapped them to the relevant business goals and KPIs. The information quality rules were assigned appropriate information quality dimensions, priorities, and where possible the IQ rules were linked to associated business rules. No targets had been specified, since the goal was zero information quality problems; however, since this was not really possible, the ambition was to accomplish continuous improvement. Approximately every 18 months, surveys were conducted and asked employees about their satisfaction regarding information quality. Data management teams in the governance structure ensured that information quality requirements were understood and met, and information quality specifications existed for the most critical data, including, the content and presentation needs. In addition, core processes specifically addressed information quality requirements in the process guides and training plans.

In Case G, accuracy, timeliness, completeness, relevancy, and consistency were identified as critical information quality dimensions, and were mapped to corresponding business processes and information products. Business rules were also identified and documented in a High Level Use Case Definition document.

Finally, all information quality needs should also be regularly reviewed.

Information Quality Assessment



Before any information quality improvements can be attempted, it is critical to assess the current state of the information quality. In order to do that, qualitative and quantitative information quality metrics have to be developed and applied. Unfortunately, many organisations fail to implement those steps even for the most critical information in the organisation; one of the interviewees explained:

> *"I wouldn't say that we have any performance metrics for the financial data. We obviously are interested in the financial performance of the agency, but I don't think that we monitor the financial information itself."*
>
> CFO (Case I)

Not having confidence in information may cost organisations a lot of money. In Case H, early surveys indicated that on average up to 40% of staff time was wasted on searching for, reconciling, scrubbing, and reformatting poor quality information.

> *"Users don't trust the reports. Before they use any information, they make checks regarding the information quality, because they know how bad the data is. So, they loose a lot of time checking the information quality."*
>
> IQ Manager, DW (Case M)

Other organisations have developed numerous information quality KPIs, where each KPI may comprise of many individual rules; as one interviewee explained:

> *"Each of the KPIs has more then one rule associated with it. Each KPI would have between 10 and 20 rules."*
>
> Head of Data Management (Case M)

Some organisations have gone to great lengths, defining up to 1000 business rules, which can be used to assess information quality. A solution architect in one of the case study organisations explained:

> *"We have developed a rule base, a very thick book comprising of business rules which can be tested. We have a tester, which shows whether the rules are being followed. … We have 1000 or so rules. It is structured and the rules are in the form IF - THEN. So, IF in the source data you see that AND the situation is like this THEN do something."*
>
> Solution Architect (Case M)

However, senior management often do not have much time and thus may be interested in having even only one information quality metric. According to the head of data management in one of the case study organisations:

> *"The new manager has now asked us to provide him with only one data quality KPI. My suggestion is to take 10 most important systems and somehow make a KPI from those 10 systems."*
>
> Head of Data Management (Case M)

In addition, commercial profiling tools may be used to perform domain and type assessments; to calculate various statistics, including, minimum, maximum, and median values; to discover any dependencies within tables, or between tables; to identify any duplicates, and so on. However, it has to be noted that:

> *"Information profiling is the simplest form of assessment and it really does not help you identify anything other than 'you have a problem with the quality', but you have no way of really categorising what the nature is and what the impact is."*
>
> IAIDQ Member

Many organisations appear to start their information quality efforts with consistency checks. Such organisations often encounter problems due to the change in personnel (for instance staff retiring); one business analyst explained:

> *"You see consistency only because these people sit in these chairs for 10, 15 years. That's the only reason. It's not because it's documented, or because there is a process."*
>
> Business Analyst (Case G)

Another organisation also mainly focused on ensuring consistency between systems.

> *"We have technical data management team, who check consistency across some of the systems. We want to expand that consistency checking to all the relevant systems in order to improve synchronisation of the data."*

Business Object Owner (Case M)

What's more, the enterprise information architect in one of the case study organisations equated information integrity with consistency by stating:

> *"Integrity is – we get a file from here to here, is it the same file, did we loose anything?"*
>
> Enterprise Information Architect (Case J)

Assessments can also be periodically performed, thus, tracking the trends.

> *"Some of the information quality projects that we've done, have mostly been one off efforts. We are looking to productionalise those checks to continually run those in the future at some agreed upon frequency, weekly, monthly, quarterly, whatever."*
>
> IM Operations Manager (Case J)

Any trends may then be monitored through the use of statistical XmR control charts.

> *"Every time we get a package, we study the trends. And, any time there is a deviation in the quantity, we get alerts. We have also developed a website for monitoring. So, before data enters our systems, we want to check if there is a problem."*
>
> DBA (Case I)

Also, when performing periodic assessments, it is essential not to modify the KPIs on the fly; the head of data management in one of the case study organisations explained:

> *"We have generated several KPIs, which are measured on a monthly basis. We track the monthly trends and we also have targets, which we are trying to reach. … What we normally do is, we have a set of rules, which we use for a period, say 12 months, and perhaps in-between we see there are also other patterns which should be checked, so we make a new rule set for the next year. Then we check the same database with the old rules and the new ones, and we look at the differences. So, we do not make changes to the rules in-between, otherwise you wouldn't get a clear picture. At least, the trend is correct."*
>
> Head of Data Management (Case M)

Most inconsistency issues are caused by unmanaged redundant storage. As a result, some organisations have developed tools which ensure that systems are synchronised.

> *"There is still no consensus about where certain data elements should be mastered. … We have redundant systems working in parallel, with nightly consistency checks."*
>
> Enterprise Architect (Case M)

Additionally to performing consistency checks between systems, they can also be employed within one system, assessing the consistency based on historical information; an information quality manager explained:

> *"We have some data quality indicators, which we use to measure some values… Then we check consistency, based on historical values."*
>
> IQ Manager, DW (Case M)

However, it is not always possible to develop fully automated systems for consistency assessments, since once an inconsistency is found it is not always possible to automatically identify the correct information element.

> *"We have written cleansing applications, which look for inconsistencies, which a human then checks manually. It is not really possible to make an automated tool, because it is hard to guess which one is the correct one."*
>
> IT Product Manager (Case M)

According to another architect:

> *"We have special systems checking the quality, but also we are checking visually what an IT system cannot do."*
>
> Solution Architect (Case M)

Other organisations do not accept any automatic updates to their systems, but instead manually validate all information before any updates; according to one manager:

> *"One of the early rules we set was that we wouldn't accept any automatic updates to our system. It all has to be done manually, and we validate the data before the update."*
>
> ILS Product Manager (Case G)

Some organisations start off by performing manual spot checks, which are then later automated; one manager explained:

> *"We manually spot check the results to make sure it's performing within tolerances. Most recently, we have taken those on and are looking to automate those tolerances so that we can get electronically notified."*
>
> IM Operations Manager (Case J)

Further information quality assessments may include verification and validation; one enterprise information architect explained validation:

> *"Validation is, are the codes valid? And we have a lot of problems with that. We have fields in the data where we get nulls all the time, or the first feature that shows up because it is the easiest to hit, a combo-box, it's already pre-populated."*
>
> Enterprise Information Architect (Case J)

And about verification:

> *"Verification is even harder, because that's not only is it a valid code but is it right code. And that's really difficult to do without manual checks."*
>
> Enterprise Information Architect (Case J)

Verification is basically comparable to accuracy. Another organisation used statistical sampling to assess it; a senior manager explained:

> *"Accuracy, the way we look at it is our truth file. We have our truth file that has truth data in it, where we have had survey data in it. And so we compare our database to that. There is a program that does that for us, and then we have an analyst group that looks at it, and then they provide me with the results."*
>
> Senior Manager (Case K)

Further complications may arise since:

> *"The fact that [information] is not current does not necessarily mean that it wasn't accurate when it was developed."*
>
> ILS Manager (Case G)

It is also essential to integrate information quality management into the system development lifecycle; one manager explained:

> *"You know, we talk strategy, but we don't have anybody to proactively go, and at the very beginning of that project check the quality of the data, before we even start the development. We need to check information quality before we start developing. That's why we are reacting so often."*
>
> IQ Manager (Case J)

Furthermore, some organisations make use of external auditors for their information quality assessments. A CTO in one of the case study organisations explained:

> *"If you are closely associated with a system, and it's your baby, you tend not to see it as an ugly baby. So, I engage external quality assurance people and when they are in I ask 'What am I doing wrong? What is the vendor doing wrong? What are the people doing wrong?'"*
>
> CTO (Case I)

Another organisation was regularly getting audited by the government.

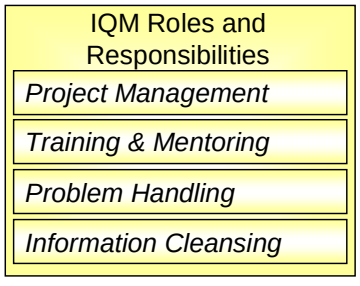
> *"The process that we have got, just to deal with the maintenance part of the logistics data, is sometimes the subject to a two or three day audit, from our Commonwealth auditors."*
>
> ILS Manager (Case G)

In Case H, the information quality rules, which were initially specified in plain English, were regularly being applied to the existing data. The information quality rules were related to the appropriate business rules, IQ dimensions, and data objects, and were updated regularly and reviewed weekly by each team and monthly by the CEO and the business vice-presidents. The information monitoring system, which was checking all data against more than 700 pre-defined IQ rules, was used to measure and report information quality levels, generating daily and weekly reports and automatically distributing them to the right personnel in each data management team. The information quality levels were stored in the data warehouse and reported via a business intelligence tool. Some databases also contained an information quality indicator attribute in some tables. A software tool, which was developed in-house, was being used for profiling when smaller (mainly Access) databases were being compiled into the corporate database. Initially subject matter experts would identify the necessary tables and columns; the software was then run on the full database and produced a report detailing all linked tables, data tables, columns, types, primary keys, min/max values, zeros, nulls, unique values, and row count. The software also provided a questionable characters report (e.g. parentheses, brackets, commas, etc.) as

well as a patterns report (i.e. number, capital letter, small letter, etc.). Pareto charts and histograms were used for final analysis. The preliminary report was then taken to the subject matter experts for verification. In addition, IBM's Information Analyser had been purchased with the intent to replace the existing profiling tool. Information quality assessments had also been incorporated into the system development lifecycle; so that IQ levels of any source systems were assessed before any ETLs were performed. No checking for accuracy was being undertaken since it was considered too labour intensive.

In Case G, Document Type Definitions (DTDs) were used to validate and construct documents in the document production system, and all technical documentation, received from various manufacturers, was reviewed upon receipt. Maintenance requirement records were periodically reviewed to confirm that identified part numbers and other necessary supply support requirements were reflected against the various equipments lists, and regular audits of work orders, which were kept on file in paper form, were being performed. Maintenance feedback information as well as maintenance plans and procedures were regularly reviewed. No automatic updates were accepted into any systems; thus, all updates were performed manually and all data was validated before being entered. All proposed changes to maintenance tasks were reviewed before being implemented. Audit and verification processes were applied against the Configuration Status Account to ensure that the intended changes had been made correctly and were consistent with the documentation. Audits also ensured that physical items were consistent with their documentation. Any discrepancies discovered are auctioned through to closure.

Information Quality Management Roles and Responsibilities



Besides information quality assessments, various other relevant roles and responsibilities are of critical importance for effective information quality management efforts. Appropriate team and project management, training and mentoring, problem reporting and handling, as well as formalised information cleansing are all to be considered when developing a holistic information quality management strategy. Not having formalised procedures and utilising ad hoc processes is a clear sign of low maturity.

> *"We may not label any roles as being IQ. We have a quality group that's looking more at the organisational quality effort. We have DBAs who manage data integrity. We have security people who look at information security, but I do not have a title IQ. The closest that would come to an IQ role are the DBAs, but they would be doing it inherently, without applying the IQ term to it."*
>
> CTO (Case I)

Another organisation attempted to justify the lack of standardised processes and documentation with the following argument:

> *"We don't have any written down processes, we don't have any software systems that do that for us; there are so many variables in it that we would just spend the rest of our lives developing processes that check data quality. I guess the thing is that we do it, but I can't show you a piece of paper that says that."*
>
> ILS Product Manager (Case G)

Maintaining appropriate records of any information quality audits is also very important. One of the enterprise information architects provided the following example:

> *"We had an issue last year where some vendor out there on the Internet had somehow managed to get hold of a whole bunch of call details and made it available for purchase. Of course, that is illegal, that's private information, and the government cracked down and said 'If you cannot show that you didn't loose any information to this company, then we are gonna fine you.' And we were not being able to collect all of our audit information in time enough, so we got fined and our name was in the article in the newspaper, but 10 days after the article had been published we found out it wasn't us. So all that audit and history is all really important to information quality."*
>
> Enterprise Information Architect (Case J)

Formally managing information quality management efforts is critical for their success. In Case H, the "Manage Information / Data Quality" process ensured that best practices were used across the organisation. The process had a process owner and a strategic leadership team sponsor, who, among others, was setting business directions and committing resources. The "Process Steering Council" coordinated the activities and priorities of the process, and business information stewards were responsible for the approvals of logical data models as well as any information quality rules. Data management teams were focusing on process improvement and data cleansing. Furthermore, an information stewardship program was implemented as one of the enterprise architecture planning transition projects. Tactical stewards were accountable for the definition of the business data, while business information stewards were the custodians of data elements.

Additionally, increasing the awareness of the importance of information quality should also be a priority for organisations; as an information quality manager illustrated:

> *"Internally, people maybe don't recognise data quality problems as much. It's just a lot more tolerated. We don't hold ourselves to the same standard in general information management realm as we would for instance on the banking side."*
>
> IQ Manager (Case J)

In one of the case study organisations, the head of data management took the initiative with information quality management after completing a Masters thesis on a similar topic.

> *"We were not asked to do this. I did my Masters thesis a few years ago on developing a balanced scorecard for data management. That's perhaps why I took the initiative with information quality."*
>
> Head of Data Management (Case M)

In Case H, information quality skills and competencies requirements had been defined by job family. Two types of training existed. Data management team members were getting a lot of training and they had specific training curriculums. They had to understand the logical and physical data models, the business and information quality rules, applications used, and so on. Typically, one member would get trained and then teach his/her colleagues. Testing and certification processes were also in place. Tests included multiple choice questions, and some game show like activities (like millionaire, jeopardy, and the like). Furthermore, leading information quality consultants used to come in and provide training, however, in recent times, comprehensive training was being provided mainly by the IQM manager. There was also mandatory information quality training for new hires. In addition, the "Data Quality Principles" document provided all staff with a set of information quality principles designed to guide decisions about data management.

Also, having a standardised procedure for the reporting and handling of information quality problems is crucial for effective information quality management. Ad hoc problem reporting and handling may not be very effective; as one of the business analysts observed:

> *"These problems go round and round, and nobody documents them, so the topic comes up every six months. Same issues trying to be resolved all the time."*
>
> Business Analyst (Case G)

Some organisations rely entirely on problem reporting for their information quality management efforts as the following example illustrates:

> *"Right now, we are in a reactive mode. So, as we hear from our users that there may be potential issues in certain databases, then we go and research those issues."*
>
> IQ Manager (Case J)

Other organisations use a help desk to log information quality problem reports and track their resolution. An information management manager explained:

> *"We log help desk issue tickets to make sure we are tracking them until they are resolved. We are keeping those and prioritising those periodically."*
>
> IM Operations Manager (Case J)

Using a help-desk, business users may report any potential problems and request an information quality specialist to further investigate any issues. An information quality manager explained:

> *"I mostly analyse the problems that get reported to me by the business users. I then analyse the problem, make some change requests to fix the problem, and manage the whole process involved."*
>
> IQ Manager, DW (Case M)

In Case H, the data management teams were basically acting as the information quality help desk. Formal processes for calling the help-desk existed, but approximately 50% of the time people would call a member of the data management team to report any arising information quality issues. The team then communicated the issues to the IQM Manager. Case H expected each data management team to have a process for information quality problem reporting (it was not standardised across the organisation). The individual data management teams mainly managed information quality issues in Excel spreadsheets assigning local responsibilities, classifications (high, medium, low, etc.), and so forth. Data management teams also developed cleansing rules, which were then implemented by the IQM team, and fully tested before being used. Any cleansing requests also had to go through the Change Configuration Board, and process owner needed to provide final approval. Some enrichment from internal databases in case of missing values existed, and some competitor's publicly available data was being used. Some data was also being obtained from contractors, and GIS staff had an information quality process in place for imported GIS data.

In Case G, all change requirements were identified and reviewed by a competent authority and held in an auditable system. Case G operated a Help-Desk for the reporting of any information quality problems, and all calls were logged and tracked through to completion. Data changes were only made via the change control board. No scripted information cleansing was being performed; on occasion users would request specific data updates but all requests had to be approved by the change control board. Changes to the system would originate as problem reports and (if appropriate) a system change request would be raised. Change requests were then reviewed by the change control board, and if approved, would become included in a software release. The system also provided feedback on the progress and status of changes in progress.

Level 4: MANAGED

This section illustrates the relevance of each of the IQM-CMM Level 4 (MANAGED) maturity indicators to the explanatory case study organisations.

Information Quality Management Governance



Gartner Research defined information governance as "The specification of decision rights and an accountability framework to encourage desirable behaviour in the valuation, creation, storage, use, archival and deletion of information. It includes the processes, roles, standards and metrics that ensure the effective and efficient use of information in enabling an organization to achieve its goals." (Bell, Logan & Friedman 2008, p. 4). An enterprise information architect described governance as:

> *"The governance process is to resolve, and get everybody agreeing on what should be done."*
>
> Enterprise Information Architect (Case J)

However, it has also been argued that:

> *"Governance and stewardship are very abstract concepts, which typical system owners or department leads – non IT architects – wouldn't understand."*
>
> Enterprise Architect (Case M)

Information quality management governance should integrate organisation-wide IQM efforts and provide a centralised structure. The head of data management in one of the case study organisation explained:

> *"There are another two guys working on the same stuff in other departments, but I don't know what they are doing at the moment. I guess we have to get closer together."*
>
> Head of Data Management (Case M)

A data architect provided the following example:

> *"There are many data quality and data management teams. There will now be a reorganisation project, which will try to integrate all those different groups."*
>
> Data Architect (Case M)

Some organisations are working on establishing data governance boards to address some of those concerns; one data architect explained:

> *"I have to bring people together in the data governance board, so that they can understand the big picture… We need a central point that people can go to and get the guidelines."*
>
> Data Architect (Case M)

Furthermore, the rate at which an organisation matures with respect to information quality management is directly linked to upper management's understanding of their responsibilities and accountabilities; one interviewee explained:

> *"It does take time to mature through these levels, and the rate at which an organisation matures is based directly upon the degree at which upper management understands and acts upon their own responsibilities and accountabilities to make quality happen."*
>
> IAIDQ Member

The information quality management governance process area in IQM-CMM also addresses accountability and further encourages IQ based rewards and incentives. One interviewee provided the following example:

> *"We have created an error list with 10-15 criteria. That's being checked monthly and it gets linked to the people producing those failures."*
>
> Business Object Owner (Case M)

Information quality audit trails can also be used to enforce accountability.

> *"In fact, we have to address questions from users like, who deleted this data, and we have log analysers to find out any fraudulent activities."*
>
> DBA (Case I)

In Case H, a formal governance structure had been defined and was being used. Quarterly reviews for external information suppliers, with information quality expectations included in the review, were performed. Internal information suppliers were also accountable through the governance process. Additionally, some job performance evaluations included information quality expectations. For instance, the professional performance communication form (for hourly paid professional staff) included a section on information quality. This forced the supervisors to discuss information quality with every hourly employee. Knowledge workers and managers (salaried employees) also had information quality requirements associated with the staff performance communication forms. Furthermore, every job posting description included information quality expectations.

However, some organisations place greater emphasis on operational efficiency than they do on information quality. According to an enterprise information architect:

> *"Data producers are not being incented for data quality; they are being incented for efficiency."*
>
> Enterprise Information Architect (Case J)

Information quality should also be benchmarked internally, within the organisation, as well as externally, against industry leaders or international standards and regulations.

> *"We have a department called revenue assurance, and they asked us to show them how we measure data quality. We gave them the information and they benchmarked us against two other operators in Europe. They compared our data quality management practices and the error rates found. …If you know what the benchmark is then you know where you are, or where you could be."*
>
> Head of Data Management (Case M)

Benchmarking can also be performed informally, as the following example illustrates:

> *"We all use standard products, which we are trying to improve. We go to conferences of our suppliers, and we talk about the functionality, we give presentations, and we talk to people."*
>
> Solution Architect (Case M)

In Case H, an internal data quality maturity model was being used for internal as well as external benchmarking (other sibling companies). Further external benchmarking was based on leading research and practitioners' conferences.

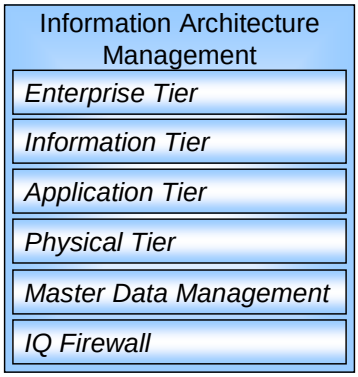
Case L employed a dashboard to visualise the levels of information quality and to communicate them to top management. Senior management were already familiar with the dashboard concept from business intelligence tools, which were used to monitor organisational KPIs.

Strategic information quality management should ensure that IQ is included in the corporate balanced scorecard and, consequently, that any information quality management efforts are aligned with organisational strategies and business goals. Likewise, information quality management should ensure the quality of organisational KPIs. However, some organisations even struggle with setting an organisational strategy and thus may have difficulties aligning their information quality management efforts with it. One enterprise architect provided the following example:

> *"In telecommunications, there is no corporate strategy; at least we haven't found the right McKinseys to tell us how the 5, 3, or even 2 years future will look like. And if there was somebody to tell us, the board still wouldn't believe in it. This is an industry problem that we cannot execute on a strategy more than three days in advance. If we are really in an industry where strategies don't work, do we need then architects, or data governance? How can you plan for an unstable environment?"*
>
> Enterprise Architect (Case M)

In Case H, information and process owners provided strategic direction for information quality management efforts. The process owners were asked to think about what they could do if they had optimal information quality, and then to set their strategic goals. Therefore, most major organisational strategic documents included information quality requirements and goals. Furthermore, information quality was in the corporate scorecard. It included all the automatic monthly IQ monitoring charts. An information quality scorecard was also being used.

Enterprise Information Architecture Management



Appropriately managing the information architecture of an organisation is essential when aiming to enhance the quality of their information. Appropriate information architecture should ensure that business process and workflow models have been aligned with the logical enterprise information model, thus combining any heterogeneous information sources under a single query interface. One of the enterprise architects described the goal of enterprise architectures as follows:

> *"To acquire all data that is of interest to the enterprise, to store it once and make it available to all persons, at locations."*
>
> Enterprise Architect (Case H)

Another enterprise architect describes his role in the organisation as follows:

> *"Creating a vision that the management buys into, and … then spreading it down to the IT organisation, and that everyone acts according to it."*
>
> Enterprise Architect (Case M)

An enterprise information architect described his role within the broader framework:

> *"I'm looking 3 years out, 5 years out … where we would like to be, where the company would like to be, what our vision is, and where we would like to take the company. Standards, policies, procedures… I am the information architect on the enterprise architecture board. So, we have other architects, who represent technology and application, but I'm the information architect."*
>
> Enterprise Information Architect (Case J)

The head of data governance in one of the case study organisations summed up the goal of enterprise information architecture management as follows:

> *"You have to look at the whole chain of the information flow… and we record it in a database. Then you have in the database all application that are relevant to the company, you have all the interfaces between the applications, and you have all the elements which are transferred…We have now added a hardware level to the model, so you can in fact identify what hardware each application is using. Now we are adding another layer describing the business activities that generate and use the data."*
>
> Head of Data Governance (Case M)

Information architecture should be as simple as possible and easy to understand.

> *"We'd be happy if we could produce any nice A4 picture or a PowerPoint slide that we could use to communicate our ideas. If we made it too structured, like most of those frameworks do, then the target audience, namely the managers, wouldn't understand it."*
>
> Enterprise Architect (Case M)

Furthermore, modelling the business processes and the workflow is also critical since process issues are at the centre of any information quality problems.

> *"Data quality is mainly a function of the business processes, so we tried not to hardcode any processes, but to allow certain degree of modularity. Of course, the process at the end had to ensure that when a technician changes something, that it is recorded in the system. It is always a process issue."*
>
> Enterprise Architect (Case M)

A business analyst in one of the case study organisations illustrated the importance of having standardised business processes as follows:

> *"To my surprise, there are still a lot of change requests in a piece of software that is 15 years old. It should be very stable. The business processes haven't changed that much, so why is it then that so many change requests are raised? Maybe because their business processes are not upheld 100%. They break the rules in business processes, so they want the software to break the rules as well."*
>
> Business Analyst (Case G)

In Case H, the enterprise architecture plan, which was based on the Zachman framework, identified 250 functions (indicating what activities were performed in the organisation), which described Case H's business at a high level. Subsequently a function-to-organisational group matrix, which identified opportunities for data and application sharing by groups performing matching functions, was developed. The Business Activity Model defined a complete picture of the major activities of the enterprise. Additionally, a number of modelling exercises grouping similar capabilities into applications were performed. As a result, more than 600 capabilities (business activities) were identified. These typically involved a verb and a noun (e.g. do something). Capabilities were independent of technology and they were related to the business model functions. An in-house developed application with an ORACLE backend and Access frontend – a repository for most of the

enterprise architecture modelling work – was used to group the capabilities into applications.

Additionally, horizontal integration should ensure inter-department interoperability and vertical integration should ensure that low level information can be aggregated into top-level reporting. One enterprise architect explained:

> *"For me, the important piece of a data model is the data model in my services. When we talk about connecting different domains, I don't care what data models they have, data models change over time, but what I need to standardise is the data model that is part of my service call."*
>
> Enterprise Architect (Case M)

Thus, integrating system interfaces is critical. According to another interviewee:

> *"There are two main reasons for information quality problems. One, the integration between the systems is not in place or is not working properly. And the second is failures in the processes – people are not working according to the rules. Process issues can be resolved relatively easily with training, but what's much harder to solve are the integration issues – it's quite expensive. We have had a lot of problems because we haven't done the integration properly, but it's very hard to argue with the business for the improvement of interfaces without additional 'WOW' business benefit."*
>
> Business Object Owner (Case M)

At the same time, ensuring interoperability through ETL transformations can be a sign of low maturity; one interviewee explained:

> *"If you have an organisation that is using ETL extensively, this is an indicator of poor maturity. That is not a characteristic associated with the maturing of an organisation with respect to information quality."*
>
> IAIDQ Member

Any such architecture should also aim to establish a single version of the truth.

> *"We had 13 data warehouses last year, and we had big problems with the 'single point of truth'. So the strategy now is to bring all those data warehouses together."*
>
> Data Architect (Case M)

Unfortunately, many organisations find it difficult to integrate systems and to establish a single version of the truth; one interviewee explained:

> *"We would ideally like to have one master table …, but we don't have that. What we have is a series of legacy systems which basically all stood up on their own, are functioning independently, and for the most part most of them don't wanna play well with each other."*
>
> Enterprise Services Administrator (Case I)

An enterprise architect explained why people may resist sharing or giving up the control of their systems:

> *"The biggest argument was 'I didn't invent this new system, so I am not going to play with it. It's not my toy, it's your toy, and I want to have my toys under my control.'"*
>
> Enterprise Architect (Case M)

As a consequence, the lack of integration can lead to major issues with accessibility.

> *"We have single islands in the IT landscape with different focus on IT services. Data is stored in different files, in different servers, and if you need some information you need to go to the right people and know who is responsible for this information, and you have to get the information on your own."*
>
> SLA Manager (Case M)

Nevertheless, the CTO from one of the case study organisations embraced the silo architecture, stating:

> *"People have been embracing enterprise architectures. I like my silo. I control my silo."*
>
> CTO (Case I)

Case H solved some of those issues by developing a data architecture (the corporate conceptual data model) and defining more than 50 major data objects or subject areas that supported organisation's business activities. The conceptual model also defined relationships between those objects. A logical data model had been developed and was used to physically design the data capture database as well as the data warehouse. Top-down modelling was utilised to elicit requirements from requirements gathering sessions, and bottom-up approach was applied for validation, using the findings from profiling of legacy systems. As a result, the enterprise logical information model provided common language and definitions, and was used to evaluate, configure and integrate purchased systems. Some of the most important sections of the Petrotechnical Open Standards Consortium (POSC) – a standard data model for oil industries – had also been reused.

Moreover, when attempting to establish a single version of the truth it is imperative to clarify the mastership of information. One of the enterprise information architects defined master data in the following way:

> *"To us, master data is the information that is shared across the enterprise, even though it's not duplicated. …If an application has some internal fields that are never shared outside of that application, than it's not master data."*
>
> Enterprise Information Architect (Case J)

Of course, most organisations have numerous applications, which redundantly store much of the information, and as such, any master data management efforts have to be strategically planned; one interviewee explained:

> *"Our long term goal is to have one system of record for every piece of data. … Long term we'd like to get it down to one, but until we get there we first have to synchronise the data that exists, then we have to turn off or redirect all the interfaces that allow you to change data in the place where it's not the system of record."*
>
> Enterprise Information Architect (Case J)

Therefore, organisations may:

> *"Not necessarily aim to consolidate, but to always have the ownership clearly laid out – who is the master."*
>
> Enterprise Architect (Case M)

Additionally, the logical information model should be mapped to the software layer, which in turn should be mapped to the hardware layer. In Case H, a function-to-data CRUD (create, read, update, delete) matrix formed the basis for the application architecture. The application architecture defined the major kinds of applications needed to manage Case H's data architecture and to support the business activities (business model) of the enterprise. Furthermore, Case H defined 90 projects, the theoretical number of "architected" systems needed to run the organisation. A matrix mapped applications to the business model functions. Furthermore, an information resources catalogue, documenting and describing existing systems and technologies used, had also been developed. Technology architecture defined the major kinds of technologies that provided the environment to support the software applications.

However, there should ideally be a central focus on the information architecture rather then on the systems architecture; as one CTO explained:

> *"Here, it is not about the system, it is about the data, and if we can establish a data architecture then systems do not matter."*
>
> CTO (Case I)

Nevertheless, many architects encounter resistance when trying to develop a new architecture, or enforce an existing one; one architect observed:

> *"But then you are always facing the classical architect's dilemma, because …you are increasing the project cost, increasing the time to market, and you are the enemy of every project leader and every project sponsor. … At the end the architect always looses, because he cannot prove that doing it the other way saves more than the additional costs … I don't' have this business case, and if I were to create one, it would be so hypothetical that no one would believe it."*
>
> Enterprise Architect (Case M)

There may also exist other reasons why an organisation may not wish to develop, document, or enforce an enterprise architecture. For instance:

> *"Nobody would invest in the architecture, just to make it easier to expose the features to the competitors, because the regulations prescribe it."*
>
> Enterprise Architect (Case M)

Another problem is that even the best architectures tend to deteriorate over time:

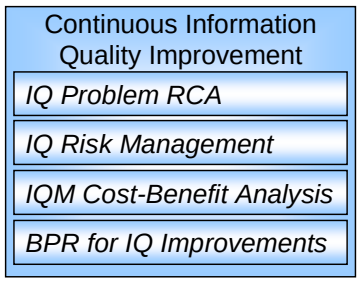
> *"If we build a new system according to our architecture, usually the system is nicely built and does exactly what it is supposed to do. But, over time, then it can evolve into something else. So, then it becomes hard to govern the ownership of master data."*
>
> Enterprise Architect (Case M)

Additionally, the idea of an "information quality firewall" emerged in one of the exploratory case study organisations (Case F). One of the prototype systems developed by Case F provided the functionality to dynamically generate statistics based on the historical values, and use those to provide warning messages when information entered appears to be unusual. No such functionality was found in any of the explanatory case study organisations. One interviewee explained:

> *"We do have some thresholds that we look at, but we don't necessarily have the tools in place where we can say, there is a new value that's shown up today that hasn't shown up in this batch for two years, is that a problem."*
>
> IQ Manager (Case J)

Case H was employing a multi-level "information quality firewall". Information quality rules were first enforced through human controls (supported by training), then through business processes controls, then through software application controls, and finally through the DBMS controls (constraints, triggers, and so on).

Continuous Information Quality Improvement



Improving the quality of information is the ultimate goal of any information quality management efforts. After information quality assessments have been performed, and after problems have been identified, organisations should aim to improve the quality of information. The initial step is to perform root cause analysis, thus identifying the root causes of any problems. Any such analyses may employ the use of Ishikawa diagrams and should consider human, process, and technological factors.

> *"We are going out there, first of all seeing how bad it is, we kind of take a look at it from an accuracy and completeness perspective first. Then we back into what are the reasons behind those problems."*
>
> IQ Manager (Case J)

Case H's system development lifecycle model included root-cause-analysis requirements for investigating information quality problems in the source systems. Ishikawa diagrams were used to analyse the root causes. Furthermore, the system development lifecycle also included respective templates, examples, and instruction manuals. Additionally, Case H had a standard root-cause problem solving class.

Another maturity indicator is information quality risk management. Information quality risk management does not only apply to IQ improvements, but also plays a larger role in information quality management efforts. Therefore, it is essential to appropriately identify the key information quality related risks and to develop corresponding response actions. One of the interviewees provided an example of where no structured approach was being followed:

> *"The information quality efforts are mainly based on gut feeling. I guess we'll have to undertake more structured risk management. We were asked by top management to show where the main risks lie."*
>
> Head of Data Management (Case M)

Another organisation had a more formalised process in place:

> *"We perform, every two years, a risk assessment for our department… and I would say that information quality risks are typically identified there. It's kind of a requirement."*
>
> CFO (Case I)

It is also critical to estimate the costs associated with any improvement initiatives as well as potential profits, or cost savings, following any improvements. One interviewee explained:

> *"The guess from the management was that we loose too much money due to poor information quality. Then the question is – 'Does it make sense to improve the information quality, or is the effort to improve going to cost more then you can save?'"*
>
> Head of Data Management (Case M)

Another manager provided the following example:

> *"You have to weigh the benefits of, what's really the importance of this field vs. the cost to get it filled in correctly."*
>
> IM Development Manager (Case J)

One of the interviewees even thought that her organisation had too high information quality:

> *"We have very high quality; we sometimes even think it's too high, because it costs too much effort to reach the quality on our side."*
>
> Solution Architect (Case M)

Another organisation chose not to utilise any information enrichment databases, because the costs associated with it outweighed any potential benefits:

> *"They are provided for a cost. Based on a cost-benefit-analysis we haven't so far been performing any data enrichment from external sources."*
>
> Enterprise Services Administrator (Case I)

Furthermore, quantifying the costs of poor information quality is also essential when building a business case for any information quality management projects; one architect explained:

> *"So we have to start measuring the quality and say 'Look here we can show you how much this is costing. May not be costing you anything, but you are costing us this much downstream.'"*
>
> Enterprise Architect (Case J)

Doing that, one can eventually aim to calculate the returns on information quality management investments.

> *"You find cost of poor quality, and cost of quality … and then you will measure the return on your investment of process improvements – given the improvement that you made, what is the reduction of the waste associated with that. So, you will be doing that and recovering the costs."*
>
> IAIDQ Member

Also, the rate at which an organisation matures with respect to information quality management is directly linked to any such cost-benefit analyses; one interviewee explained:

> *"The rate at which an organisation matures is going to depend on the executive management understanding of the reality of the economics of information quality management."*
>
> IAIDQ Member

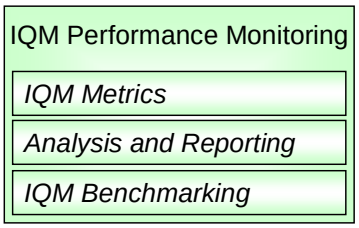
Case H periodically conducted surveys with their staff, asking them about examples of costs associated with poor information quality (e.g. time wasted due to poor information quality). The resulting "Value of Data Quality" document identified numerous costs associated with poor IQ.

With reference to BPR for IQ Improvements, any improvements should be appropriately planned and documented, and should preferably follow the PDCA cycle.

Level 5: OPTIMISING

This section illustrates the relevance of each of the IQM-CMM Level 5 (OPTIMISING) maturity indicators to the explanatory case study organisations.

Information Quality Management Performance Monitoring



The IQM performance monitoring process area deals with defining qualitative and quantitative information quality management metrics (IQM-KPIs) and using them to monitor the performance of organisational IQM efforts. Internal benchmarking is used to rank the information quality management practices within the organisation, and external benchmarking is used to compare organisational IQM practices against world leading organisations, best practices, and standards. No case study organisation had reached this level of maturity and, thus, the supporting evidence for this process area was very sparse. The performance of information quality management wasn't formally monitored in any of the organisations. Case M was the only organisation that had performed external benchmarking of their IQM practices.

> *"We have a department called revenue assurance, and they asked us to show them how we measure data quality. We gave them the information and they benchmarked us against two other operators in Europe. They compared our data quality management practices and the error rates found. … They now want to expand the number of operators benchmarked, to get a clearer picture."*
>
> Head of Data Management (Case M)

Case I, Case J, and Case K provided their staff with relevant postgraduate educations, thus, enhancing their existing capabilities. Other case study organisations relied on attending relevant conferences for the purpose of informal benchmarking. However, this research project provided all case study organisations with on opportunity to assess their practices against cutting-edge research in the field of information quality management.

Continuous Information Quality Management Improvement



Information quality management continuous improvement refers to the formal process that organisations use to enhance their IQM practices. The main idea is that any such improvements are appropriately planned and documented before any implementations, basically, that the PDCA cycle is followed. Most case study organisations addressed this process area to a large extent. This was expected because this is basically the same approach used for any process improvement. Thus, given the fact that all case study

organisations were very large and mature in their industries, it was expected that they would follow a formalised method for process improvement. However, given the lack of information quality management performance monitoring (the previous process area), most organisations were basing their improvements on ‘gut feeling’.

4.4.5 Theory Enhancements

The previous section described the results of the cross-case analysis, illustrating the relevance of each IQM-CMM maturity indicator to the explanatory case study organisations. This section takes those results into consideration and, as a result, derives further theory enhancements.

It is now clear that the Redundant Storage Management maturity indicator from the Storage Management process area in Level 2 should be merged with the Master Data Management maturity indicator from the Enterprise Information Architecture Management process area in Level 4. The initial model assumed that redundant storage requirements could be identified on Level 2, and that any such implementations could be suitably managed. However, after the explanatory case studies were conducted, it became apparent that most organisations struggle with redundant storage issues even long after they have commenced information quality management programs. This was in most part due to the use of numerous COTS autonomous applications, which had proprietary data models that often partially overlapped. As a result, it turned out that effectively implementing a master data management program requires quite a high level of information quality management capability maturity.

Some of the explanatory case study organisations, notably Case G, heavily relied on critical peer reviews for ensuring information quality. Consequently, the appraisal criteria for the Information Quality Evaluation maturity indicator from the Information Quality Assessment process area in Level 3 should be further extended to also take any critical peer reviews into consideration.

The Information Quality Firewall maturity indicator from the Enterprise Information Architecture Management process area in Level 4, which originated from the exploratory Case F, wasn’t implemented in any of the explanatory case study organisations. It is now apparent that any such functionality should be considered as extremely advanced. Further research is needed in order to decide whether this maturity indicator should be moved to a higher maturity level, or perhaps even removed from the model.

The Information Quality Management Optimisation maturity indicator from the Information Quality Management Continuous Improvement process area in Level 5 was largely addressed by most explanatory case study organisations. This was the case since this maturity indicator was heavily based on the PDCA cycle for process improvement. It turned out that following the PDCA cycle when improving any processes is a natural tendency, and that most organisations were familiar with it, and they were applying it to a large extent. Furthermore, this maturity indicator was also addressed by the Business Process Reengineering for Information Quality Improvements maturity indicator from the Continuous Information Quality Improvement process area in Level 4. As a result, the Information Quality Management Optimisation maturity indicator and the Information Quality Management Continuous Improvement process area may need to be altogether removed from Level 5.

Finally, an interesting approach to addressing information quality issues emerged from explanatory Case H. Case H, formally implemented a layered approach for information quality management, employing a multi-level "information quality firewall". Information quality was first enforced through human actions (e.g. supported by training), then through business processes controls, then through software application controls, and finally through the DBMS controls (e.g. constraints, triggers, and so on). Identifying, defining, and enforcing controls in such a layered fashion should be considered extremely advanced and as such should be included in IQM-CMM Level 5.

4.4.6 Discussion

Even though a rigorous assessment method (section 4.4.1) has been followed, no quantitative measures have been used in the explanatory phase of this research, and as such, the maturity ratings presented in section 4.4.3 are somewhat subjective. Similarly, the results presented in section 4.4.4 'Cross-Case Analysis' may also have been influenced by any biases of the researcher. In line with the interpretive research paradigm, all the results have been interpreted by the researcher and, as such, they reflect his personal beliefs and values. It is likely that a different researcher would have come up with somewhat different interpretations.

Interviewee selection may also have impacted the explanatory phase results. Even though, every effort was made to identify and interview the most relevant personnel, it is possible

that some key interviewees were not interviewed, especially when considering the fact that some of the explanatory case study organisations had many thousands of employees.

4.6 Conclusions

This chapter presented the analysis of the data collected in this doctoral research project. The first section of this chapter illustrated the results of the exploratory stage of the project, describing 45 candidate maturity indicators for effective information quality management. The candidate maturity indicators were identified through comprehensive literature review (see chapter 2) and six exploratory case studies. The second section of this chapter detailed the theory building stage of this research project, presenting the results of a four round Delphi study, which was used to validate the candidate maturity indicators and organise them within a staged evolutionary maturity model. The third section of this chapter presented the results of the theory testing and enhancing stage of this research project. This section included the IQM-CMM capability maturity ratings of the explanatory case study organisations, and explained the relevance of each of the IQM-CMM maturity indicators through cross-case analysis. The third section finally drew on the results of the cross-case analysis to propose further theory enhancements for IQM-CMM.

Chapter 5

Conclusions

"*Reasoning draws a conclusion, but does not make the conclusion certain, unless the mind discovers it by the path of experience.*"

—Roger Bacon

5.1 Introduction

The first chapter laid out the groundwork of this thesis by presenting a brief overview of the research background, the research problem, the research questions, and the justifications for the research, as well as the aims of the research. The second chapter critically reviewed the literature relevant to the research problem, and briefly explored the specific industry domain this research problem is being investigated in – engineering asset management. The third chapter outlined the research methodology employed in this doctoral research project and discussed the underlying philosophical research paradigms. The qualitative interpretive approach adopted in this research project was justified and the research design, comprising of three stages, was explained. The fourth chapter presented the analyses of the data gathered in this research project. The chapter was aligned with the research methodology and, as such, it comprised of three main parts: exploratory stage, theory building stage, and theory testing and enhancing stage. This chapter concludes this thesis by relating the findings to the research problem and the research questions. It further discusses the implications for theory and practice as well as the limitations of this research project. It concludes with a discussion on the direction of future research.

5.2 Conclusions about the Research Questions and Hypotheses

This section presents the conclusions about the research questions and the hypotheses. The research questions have been based on the problem of how information quality management capability maturity can be assessed and enhanced in engineering asset management organisations. In order to solve that problem, it was essential to identify the relevant information quality management maturity indicators and organise them into staged evolutionary levels. Furthermore, it was necessary to develop a diagnostic tool that can be used to evaluate all of the maturity indicators, so that organisations may be assessed against the model. This thesis also investigated how the Information Quality Management Capability Maturity Model (IQM-CMM) may provide for better utilisation and management of information relating to engineering asset management. The hypothesis proposed that the quality of engineering asset management information is enhanced as organisations move to a higher information quality management capability maturity level.

RQ1: How can information quality management capability maturity be assessed and enhanced in engineering asset management organisations?

Organisational capability maturity in information quality management may depend on a wide range of technological, organisational, and social maturity indicators – a view, which is based on the literature review and the data gathered from the exploratory case studies. Therefore, it was first necessary to identify what those maturity indicators were. The next sub-question addressed that problem.

RQ1.1: What are the information quality management maturity indicators?

This thesis has identified close to 50 organisational, technical, and social information quality management maturity indicators. Stage one of this doctoral research project identified a range of candidate maturity indicators through six exploratory case studies and a comprehensive literature review. The exploratory case studies were conducted in organisations dealing with transport services, telecommunications, building management, oil and gas exploration and production, water and wastewater services, and in one Defence organisation. The first stage also involved a comprehensive literature review of more than 200 articles, in the fields of total quality management (Shewhart 1925); quality awards, models and frameworks (Eskildsen, Kristensen & Juhl 2001; APO 2002; Porter & Tanner 2004; BNQP 2007; JUSE 2007a; JUSE 2007b; NQI 2007; SAI_GLOBAL 2007; SPRING 2007); standards and best practices (Paulk et al. 1993; ANSI/GEIA 2004; ISO/IEC 2004a; ISO 2005b; CMU/SEI 2006; ITGI 2007; OGC 2007a); data and information quality management (Wang & Strong 1996; Wang 1998); and maturity models (Chambless & Parker 1998; English 1999; Caballero, Gómez & Piattini 2004; Ryu, Park & Park 2006; Aiken et al. 2007). The complete literature review can be found in Chapter 2. Due to the Information Product analogy, it was found that a lot of the classic TQM critical success factors as well as various aspects of the quality models, frameworks, awards, standards and best practice approaches, could potentially also be applied to the domain of data/information quality. The literature review, together with the exploratory case studies resulted in a set of candidate information quality management maturity indicators (see section 4.2.2). Stage two of this doctoral research project included a two round Delphi Study, which was used to validate the candidate maturity indicators as well as identify a number of additional ones. All the maturity indicators, together with relevant justifications can be found in the 4.4.2 Cross-Case Analysis section of this thesis.

What maturity indicators may be found in an organisation will depend on that organisation's capability maturity in information quality management. Less mature organisations may only address a few basic indicators, whereas more mature organisations may address most of them. The next sub-question addressed that problem.

RQ1.2: How can the information quality management maturity indicators be organised into staged evolutionary levels?

This is a methodological question, which was addressed through the use of a Delphi study. A two round Delphi study was used to reach consensus within a panel of 20 information quality experts on how the maturity indicators should be grouped within a staged evolutionary capability maturity model (Figure 5.1) (see section 4.3.1). The names of the levels were based on the expert suggestions provided in the Delphi study (especially in the first round). Furthermore, the name of each level was chosen on the basis of its ability to succinctly summarise the information quality management capability of an organisation of such maturity.

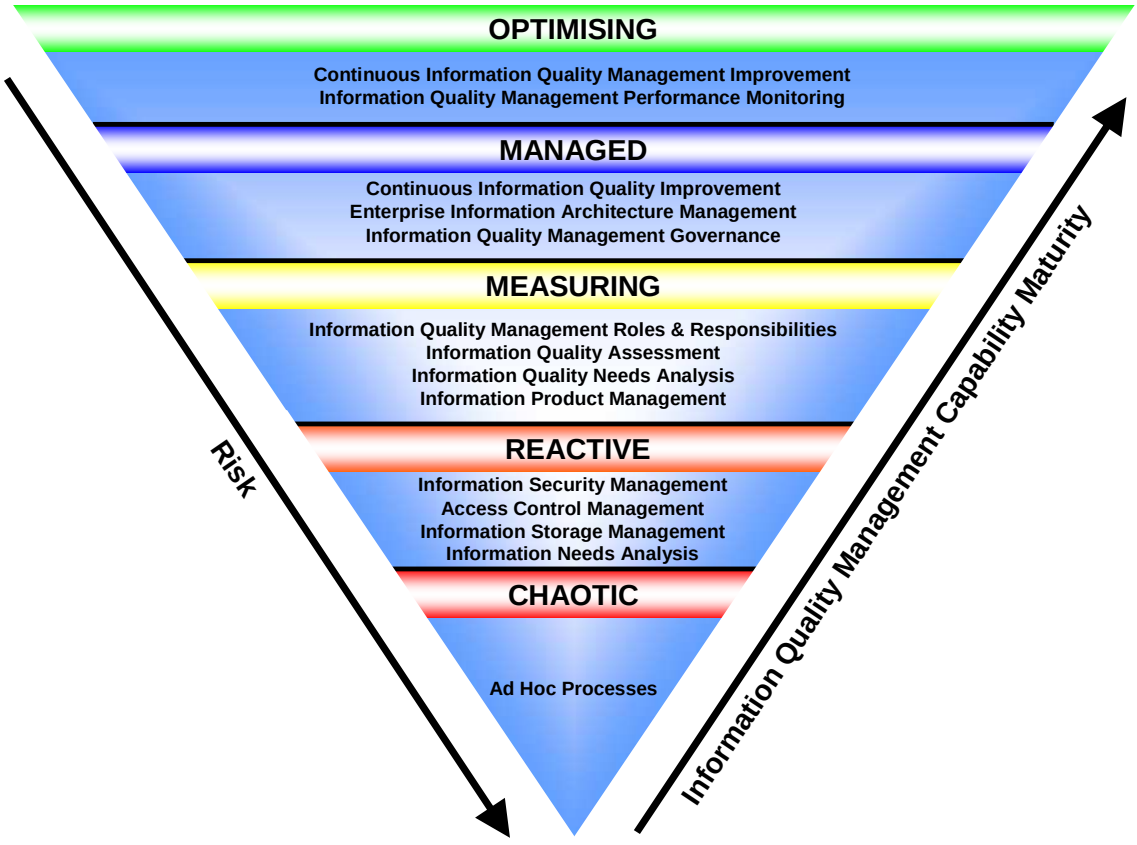


Figure 5.1: Information Quality Management Capability Maturity Model
Source: (developed by the author)

However, there was still a possibility that some of the maturity indicators were perhaps not very relevant, and as such may not need to be included in the model. The next sub-question addressed that problem.

RQ1.3: What is the relative significance of the information quality management maturity indicators?

Two additional rounds of the Delphi study were aimed at investigating the relative significance of each maturity indicator (see section 4.3.1). The participants were asked to rate the impact of each candidate maturity indicator on its level, where 1 indicated the lowest and 5 the highest impact. The results showed that all maturity indicators were deemed relevant, with all indicators being rated from 3 to 5. However, in order to determine the specific maturity indicators an organisation addresses, each indicator needs to be assessed against a set of relevant criteria. The next sub-question addressed that problem.

RQ1.4: How can the information quality management maturity indicators be assessed?

The appraisal criteria were identified and defined based on relevant literature, the exploratory case studies, and the results of the Delphi study (including the qualitative comments provided by the panellists). Figure 5.2 shows the hierarchical structure of IQM-CMM. The complete IQM-CMM Diagnostic Tool can be found in Appendix M. The Information Quality Management Capability Maturity Model (IQM-CMM) comprises of five staged levels, which represent an evolutionary path of increasingly structured and methodically more mature information quality management processes. Each level is dependent on a number of maturity indicators, which in turn depend on a number of appraisal criteria. The complete IQM-CMM includes 48 maturity indicators, and the diagnostic tool employs approximately five appraisal criteria per indicator, thus resulting in more than 200 appraisal criteria. The assessment method has been based on the appraisal requirements for CMMI (ARC, v1.2) (ARC 2006), and the standard CMMI appraisal method for process improvement –SCAMPI A, v 1.2 (SCAMPI 2006); please see section 4.4.1 for further details.

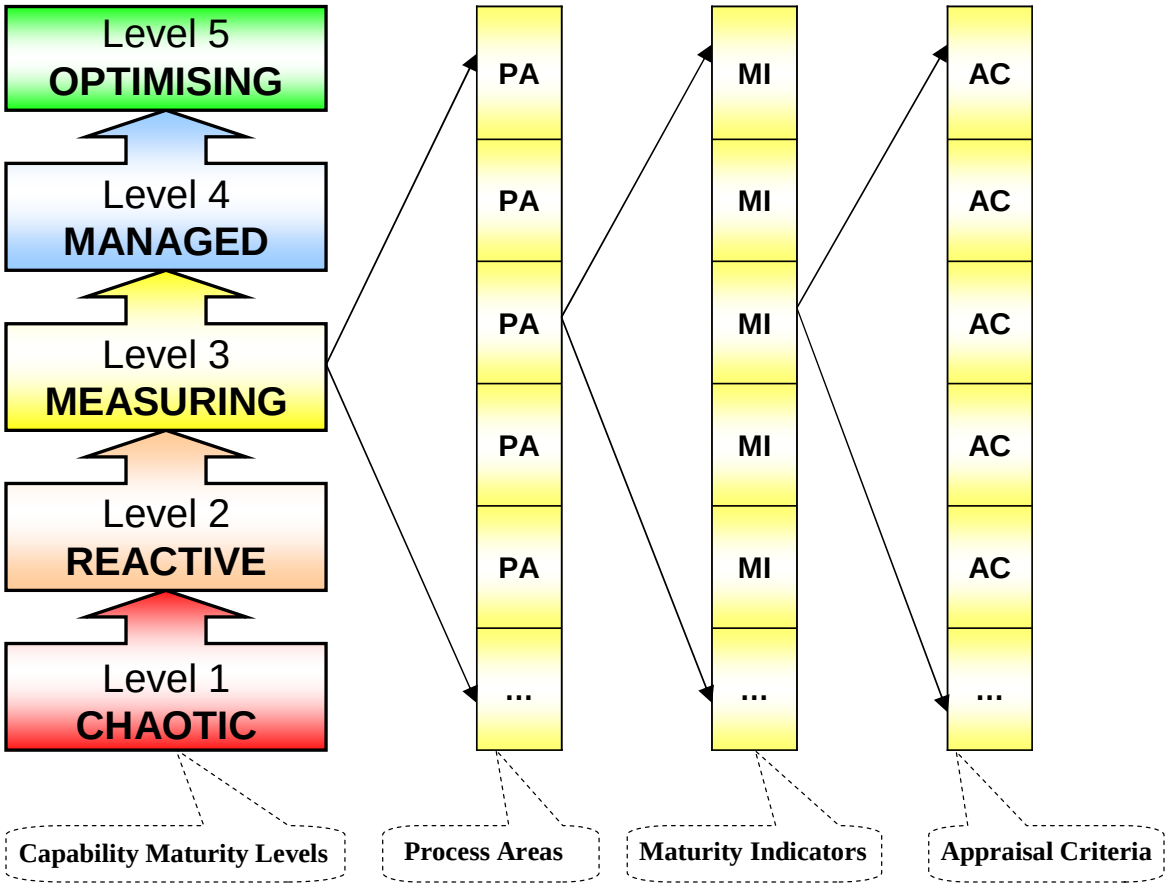


Figure 5.2: The Hierarchical Structure of IQM-CMM
Source: (developed by the author)

RQ2: How does the Information Quality Management Capability Maturity Model provide for better utilisation and management of information relating to engineering asset management?

The Information Quality Management Capability Maturity Model (IQM-CMM) addresses close to 50 organisational, technical, and social, information quality management maturity indicators. The diagnostic tool employs approximately five appraisal criteria per indicator, thus resulting in approximately 250 appraisal criteria. Assessing organisations against IQM-CMM may provide them with a maturity rating with respect to their information quality management capability, as well as identify any gaps in their existing capabilities. The gap analyses may then be used to guide any future developments of strategies for information quality management. Furthermore, the model may also be used as a benchmarking tool for tracking organisational maturity progression, or for comparing the capabilities of different organisations. The evolutionary model comprises of five levels, representing a 'best practice' maturity continuum for information quality management.

The first level, by definition, does not address any maturity indicators. Organisations that do not satisfy all the appraisal criteria from level two are classified as CHAOTIC. Such organisations may have some basic information management processes in place; however, they are not documented, standardised, or consistently implemented. Furthermore, CHAOTIC organisations do not attempt to assess or enhance the quality of information they manage; what's more, they may even be ignorant of any information quality problems or issues.

Organisations on level two are becoming more aware of any information quality issues that may exist; however, they are still only reacting to information quality problems as they occur. REACTIVE organisations have documented, standardised and consistently implemented basic information management processes in place, although they may not have any explicit information quality management initiatives. Such organisations have clearly identified their stakeholders' (information suppliers, stewards, owners, and users) information needs, and developed conceptual, logical, and physical data models. Storage management policies are used to ensure that critical information is backed-up and archived at regular intervals, and that information is regularly reviewed for destruction. Access control policies make sure that only authorised personnel interact with the information system, and audit trailing ensures that all user activities are being chronologically logged. In addition, security policies guarantee appropriate classification, transmission, and disposal of any sensitive information.

Organisations on level three begin to manage their information as a product throughout its lifecycle. Accordingly, such organisations have documented the information flow, and are appropriately managing the information supply chain. Furthermore, configuration management processes, which ensure that any changes are recorded and can be rolled back, are in place, and consistent representation is achieved by utilising the same 'look-and-feel' with all information products. Additionally, MEASURING organisations will have established a metadata registry, which means that metadata is managed separately from regular information. Relevant information quality dimensions will have been identified and information quality requirements will have been elicited from all the major stakeholders, resulting in qualitative and quantitative information quality metrics, and regular information quality assessments. Most importantly, a dedicated project manager is responsible for all information quality management efforts, with training programs making sure that all personnel have the necessary skills.

Organisations on level four have strict governance of information quality management roles and responsibilities, ensuring accountability, and providing rewards and incentives. MANAGED organisations benchmark information quality internally within the organisation, and externally against the leading organisations in their industry. Therefore, information quality is managed strategically, thus aligning information quality management efforts with organisational strategies and Key Performance Indicators (KPIs). Such organisations continuously enhance information quality by addressing the root causes of any problems through business process improvements. Moreover, MANAGED organisations have developed and documented their information architecture, which maximises information integration and interoperability.

Organisations on level five continuously monitor the performance of their information quality management efforts, through internal/external benchmarking, thus ensuring continuous information quality management improvement. OPTIMISING organisations are world-leaders in information quality management.

H_0: Quality of engineering asset management information is not changed as the organisation moves to a higher information quality management capability maturity level.

H_1: Quality of engineering asset management information is enhanced as the organisation moves to a higher information quality management capability maturity level.

The data gathered during the exploratory case studies provided evidence against the null hypothesis (H_0), and support for the alternative hypothesis (H_1). For instance, Case H and Case M, the two explanatory case study organisations with the most advanced implementations of information quality KPIs, were able to show substantial improvements in the quality of information, over time, resulting from the ongoing implementation of the IQM-CMM maturity indicators. Other explanatory case study organisations also experienced improvements in information quality due to their maturing with respect to information quality management. Section 4.4.4 Cross-Case Analysis of this thesis provides detailed explanations on how the implementations of each of the IQM-CMM maturity indicators may lead to enhancements in information quality.

5.3 Implications for Theory

This section discusses the contributions of this doctoral research project to the information quality management theory.

The concept of an information quality management capability maturity continuum is still an under-researched problem, and, as such, it is not sufficiently well understood in the research community. In other words, there is a gap in the literature on how organisations mature with respect to their information quality management capabilities, on what the different maturity stages are, on what the maturity indicators are, and most importantly, on what the best practices for information quality management are. This thesis has made significant theoretical contributions to fill those gaps in the literature.

This doctoral research project has extended the information quality management theory by identifying a wide range of organisational, technical, and social information management as well information quality management maturity indicators, and mapping them to a staged evolutionary capability maturity model. That is to say, this research project has identified close to 50 major factors, which, when not managed appropriately, may have detrimental effects on the quality of information used in contemporary organisations.

Another significant contribution is that the Information Quality Management Capability Maturity Model (IQM-CMM) has been developed inductively, as opposed to some deductively proposed models found in literature, and, as such, it is grounded in empirical data gathered from a wide range of information quality experts and practitioners. As a result, the model does not represent a limited view of one researcher, but aggregates a variety of different views. Additionally, the diagnostic tool, developed in this research project, provides a unique and comprehensive method for assessing organisational information quality management maturity, specifying close to 250 specific appraisal criteria.

Given that this research has identified such a large number of maturity indicators, the findings may also serve as a framework to guide any future research aimed toward advancing the theory of information quality management. Each of the maturity indicators warrants further, more in-depth, research efforts that could, for instance, investigate any correlations between the information quality dimensions and the maturity indicators identified in this thesis.

5.4 Implications for Practice

This section discusses the contributions of this doctoral research project to the information quality management practice.

Modern technology has made the collection and storage of information easier than ever. However, many organisations capture too much, or irrelevant, information, and are not confident about the quality of resulting information products. Furthermore, a wide range of technological, organisational, and social factors may have detrimental impacts on information quality, and many organisations do not know how to develop any information quality management strategies. Most importantly, 'best practice' frameworks for information quality management do not exist.

This doctoral research project can be classified as applied research, and the findings presented in this thesis may benefit organisations in several ways. IQM-CMM may be used as a tool for assessing the information quality management practices in organisations, and for developing capability gap-analyses, which may then guide the development of any improvement strategies. The diagnostic tool details close to 250 specific appraisal criteria, which can be used to assess organisations against close to 50 major organisational, technical, and social information management as well as information quality management factors. Any such assessments may result in maturity ratings, indicating what capabilities organisations have in place, and what capabilities are missing. The resulting findings may then be used to develop strategies for information quality improvements.

IQM-CMM may also be used as a benchmarking tool – benchmarking organisations against 'best practices' (IQM-CMM), or against other organisations that have undertaken similar assessments. In other words, IQM-CMM may allow organisations to find out where they are, where they could be, and how they compare to other organisations with respect to information quality management capabilities. Finally, it is expected that higher information quality management capability maturity may lead to enhanced information quality as well as relevant economic benefits; one of the interviewees summed it up as follows:

> *"You will be eliminating more and more of the cost of waste, as you get closer to the OPTIMISING level, and by the time you are at OPTIMISING the majority of your cost of quality is in the process improvement and in training, which is a fraction of the cost of poor quality which you had at LEVEL 2."*
>
> IAIDQ Member

5.5 Limitations

This section discusses the limitations of this doctoral research project.

George Box, the industrial statistician, famously stated that “all models are wrong but some are useful” (Box 1979, p. 202). Similarly, IQM-CMM represents a simplification of the real-world and as such it should not be regarded as the ultimate truth.

Several limitations concerning the qualitative research methodology have to be taken into consideration, including the inability to manipulate independent variables, the subjective interpretations, and the lack of randomisation (Kerlinger 1986). Potential limitations of case study research include the lack of controllability, deductibility, replicability, and generalisability (Lee 1989).

Furthermore, given the rapidly changing technology and business environments in contemporary organisations, IQM-CMM may not stay relevant for a very long time. Thus, it may need to be updated on a regular basis, since new issues and maturity indicators may emerge in the future.

In addition, IQM-CMM has placed a strong focus on the maturity assessment of organisations and as such it may not provide for adequate assessment of the individual capabilities, or maturity indicators. In other words, the model is currently in the staged representation, focusing mainly on the breadth of the maturity indicators, rather then on the depth of maturity indicators’ assessments.

Another limitation is that no quantitative IQM-CMM measures have been used or developed in this doctoral research project. Any assessments of the appraisal criteria are subjective in nature and have not so far been quantified. Also, even though this research project has addressed the issue of maturity indicators’ significance, no attempt has been made to quantitatively rank the impact of those indicators on IQM-CMM, or on information quality. Similarly, this doctoral research project has not investigated any relationships between the maturity indicators and the information quality dimensions. That is to say, at this stage, it is not clear which maturity indicators may affect which information quality dimensions. Moreover, even though, the case studies have shown evidence that increased IQM-CMM maturity may result in improvements in information quality, no quantitative empirical data supporting that argument has been collected in this doctoral research project.

5.6 Future Research

This section discusses the opportunities for future research following this doctoral research project.

Any future research could see the application of IQM-CMM in additional explanatory case study organisations for the purpose of further testing and enhancements. Such future research efforts may strengthen the generalisability of the model and could be aimed toward identifying additional maturity indicators, which may have been missed in this doctoral research project. What's more, given the rapidly changing technology and business environments in contemporary organisations, future research may even be necessary, since new issues (especially the technological ones) and maturity indicators are likely to emerge in the future.

Furthermore, IQM-CMM could also be adapted to accommodate the continuous representation, thus allowing for more comprehensive capability assessments of individual maturity indicators. That way, organisations could choose to only focus on improving the capability of a particular maturity indicator, rather than on conducting an organisation-wide maturity assessment. Additional research could also focus on developing quantitative measures for the appraisal criteria.

There is also a need to quantitatively rank the impact of the maturity indicators on IQM-CMM, and on information quality. That is to say, some maturity indicators may have a larger impact on any gains in information quality than other indicators. Additionally, further research may investigate the relationships between the maturity indicators and the information quality dimensions.

Additional proposals for future research may include quantitative investigations of any causal relationships between IQM-CMM levels and any gains in information quality, or even, any economic/productivity benefits to organisations.

Future research may also attempt to integrate IQM-CMM with various other relevant models found in the literature. Certain CMMI process areas may be applicable to information quality management, and, as such, it may be possible to integrate them within the IQM-CMM diagnostic tool. It may also be possible to integrate IQM-CMM with ISO/IEC 15504, which is a generic process assessment standard.

5.7 Conclusion

This chapter concluded this thesis by briefly summarising the whole research project, and presenting conclusions about the research questions and hypotheses. Furthermore, the chapter presented a comparison of IQM-CMM with other related maturity models, and discussed the implications of this research for theory as well as practice. The chapter concluded by discussing the limitations of this research project and by suggesting potential direction for future research.

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Appendix A: Glossary

AM	Asset Management
AQC	Australian Quality Council
ASQ	American Society for Quality
BPR	Business Process Reengineering
CIEAM	CRC for Integrated Engineering Asset Management
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CMMS	Computerised Maintenance Management Software
CMU	Carnegie Mellon University
CRC	Cooperative Research Centre
CRM	Customer Relationship Management
CSF	Critical Success Factors
DBMS	Database Management System
DC	Data Cleansing
DM	Data Management
DQ	Data Quality
DQM	Data Quality Management
EAM	Engineering Asset Management
EFQM	European Foundation for Quality Management
ERP	Enterprise Resource Planning
ILS	Integrated Logistic Support
IM	Information Management
IP	Information Product
IQ	Information Quality
IQM	Information Quality Management
IQM-CMM	Information Quality Management Capability Maturity Model
IS	Information System
ISO	International Organisation for Standardisation
ITIL	Information Technology and Infrastructure Library
JQA	Japan Quality Award
JUSE	Japanese Union of Scientists and Engineers
MBNQA	Malcolm Baldrige National Quality Award
MDM	Master Data Management
MIS	Management Information System
QA	Quality Assurance
QC	Quality Control
SAI	Standards Australia International
SEI	Software Engineering Institute
SPICE	Software Process Improvement and Capability dEtermination
SQA	Singapore Quality Award
TDQM	Total Data Quality Management
TQM	Total Quality Management
UniSA	University of South Australia

Appendix B: Definitions

Given the fact that the precise definition of core terms is critical in any research project (Perry 1998), this section presents the definitions relevant to this thesis.

Assessment Constraints. Restrictions placed on the use of the assessment outputs and on the assessment team's freedom of choice regarding the conduct of the assessment (ISO/IEC 2005a, p. 2).

Assessment Indicator. Sources of objective evidence used to support the assessors' judgement in rating process attributes (ISO/IEC 2005a, p. 2).

Assessment Instrument. A tool or set of tools that is used throughout an assessment to assist the assessor in evaluating the performance or capability of processes, in handling assessment data and in recording the assessment results (ISO/IEC 2005a, p. 2).

Assessment Output. All of the tangible results from an assessment (ISO/IEC 2005a, p. 2).

Assessment Record. An orderly, documented collection of information which is pertinent to the assessment and adds to the understanding and verification of the process profiles generated by the assessment (ISO/IEC 2005a, p. 2).

Capability. Ability of an organisation, system, or process to realise a product that will fulfil the requirements for that product (ISO 2006a, p. 8).

Capability Maturity Model. A model that contains the essential elements of effective processes for one or more disciplines and describes an evolutionary improvement path from ad hoc, immature processes to disciplined, mature processes with improved quality and effectiveness (CMU/SEI 2006, p. 535).

Data Management. The disciplined processes and systems that plan for, acquire, and provide stewardship for business and technical data, consistent with data requirements, throughout the data lifecycle (CMU/SEI 2006, p. 538).

Maturity Level. Degree of process improvement across a predefined set of process areas in which all goals in the set are attained (CMU/SEI 2006, p. 543).

Objective Evidence. Data supporting the existence or verity of something (ISO/IEC 2005a, p. 4). Objective evidence may be obtained through observation, measurement, test, or other means (ISO 2005a).

Organisational Maturity. The extent to which an organisation has explicitly and consistently deployed processes that are documented, managed, measured, controlled, and continually improved. Organisational maturity may be measured via appraisals (CMU/SEI 2006, p. 545).

Process. Set of interrelated or interacting activities which transforms inputs into outputs (ISO/IEC 2005a, p. 4).

Process Area. A cluster of related practices in an area that, when implemented collectively, satisfy a set of goals considered important for making improvement in that area (CMU/SEI 2006, p. 548).

Process Capability. A characterisation of the ability of a process to meet current or projected business goals (ISO/IEC 2005a, p. 4).

Process Capability Determination. A systematic assessment and analysis of selected processes within an organisation against a target capability, carried out with the aim of identifying the strengths, weaknesses and risks associated with deploying the processes to meet a particular specified requirement (ISO/IEC 2005a, p. 5).

Quality. Degree to which a set of inherent characteristics fulfils requirements (ISO 2006a, p. 7).

Quality Assurance. A planned and systematic means for assuring management that the defined standards, practices, procedures, and methods of the process are applied (CMU/SEI 2006, p. 552).

Quality Control. The operational techniques and activities that are used to fulfil requirements for quality (CMU/SEI 2006, p. 552).

Appendix C: CobiT 4.0 Control Objectives Applicable to IQM

Table C.1: CobiT 4.0 Control Objectives Applicable to IQM

PO2.1 Enterprise Information Architecture Model
PO2.2 Enterprise Data Dictionary and Data Syntax Rules
PO2.3 Data Classification Scheme
PO2.4 Integrity Management
PO4.6 Roles and Responsibilities
PO4.9 Data and System Ownership
PO4.7 Responsibility for IT Quality Assurance
PO8.1 Quality Management System (QMS)
PO8.2 IT Standards and Quality Practices
PO8.3 Development and Acquisition Standards
PO8.4 Customer Focus
PO8.5 Continuous Improvement
PO8.6 Quality Measurement, Monitoring and Review
AC1 Data Preparation Procedures
AC2 Source Document Authorisation Procedures
AC3 Source Document Data Collection
AC4 Source Document Error Handling
AC5 Source Document Retention
AC6 Data Input Authorisation Procedures
AC7 Accuracy, Completeness and Authorisation Checks
AC8 Data Input Error Handling
AC9 Data Processing Integrity
AC10 Data Processing Validation and Editing
AC11 Data Processing Error Handling
AC12 Output Handling and Retention
AC13 Output Distribution
AC14 Output Balancing and Reconciliation
AC15 Output Review and Error Handling
AC16 Security Provision for Output Reports
AC17 Authenticity and Integrity
AC18 Protection of Sensitive Information During Transmission and Transport
DS4.9 Offsite Backup Storage
DS5.11 Exchange of Sensitive Data
DS11.2 Storage and Retention Arrangements
DS11.3 Media Library Management System
DS11.4 Disposal
DS11.5 Backup and Restoration
DS11.6 Security Requirements for Data Management

Source: developed from (ITGI 2005)

Appendix D: Definitions of Information Quality Dimensions

Table D.1: Definitions of Information Quality Dimensions

Absolute Reliability. When the database mirrors reality (Agmon & Ahituv 1987).
Accessibility. Accessible, retrievable, speed of access, and available (Wang & Strong 1996; Kahn, Strong & Wang 2002; Bovee, Srivastava & Mak 2003). Information can be obtain when needed (Miller 1996). Available (Wang & Strong 1996).
Accuracy. Agreement with a real-world entity, a value stored in another database, or the results of an arithmetic computation (Klein, Goodhue & Gordon 1997). Data are certified error-free, accurate, correct, flawless, reliable, and precise. Errors can be easily identified, and data has integrity (Wang & Strong 1996). It doesn't contain a substantial amount of bias (King & Epstein 1983). Measure of agreement with an identified source (Huh et al. 1990). Reflects the underlying reality (Miller 1996). The correctness of the output information (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985; Miller & Doyle 1987; Baroudi & Orlikowski 1988). The frequency of errors in the data (Halloran et al. 1978). The level of accuracy expected from the system (Robey 1979). The recorded value conforms to the real-world fact or value (Fisher & Kingma 2001). The recorded value is in conformity with the actual value (Ballou & Pazer 1985). The extent that data from the system requires correction (Franz & Robey 1986). Accurate, believable (Zmud 1978).
Appropriate Amount of Information. The extent to which the volume of information is appropriate for the task at hand (Kahn, Strong & Wang 2002).
Arrangement. Orderly, precise (Zmud 1978).
Believable. Complete, consistent, credible source, and accurate (Wang & Strong 1996; Kahn, Strong & Wang 2002).
Coherence. How well the information hangs together and is consistent (Miller 1996).
Compatibility. Information can be combined with other information and delivered to customer (Miller 1996).
Completeness. No missing IS states (Wand & Wang 1996). Breadth, depth, and scope of information contained in the data (Wang & Strong 1996). All values for a certain variable are recorded (Ballou & Pazer 1985). The degree to which values are present in the data collection (Fisher & Kingma 2001). The set contains all relevant data (Huh et al. 1990). Complete (Miller 1996). The comprehensiveness of the output information (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985; Miller & Doyle 1987; Baroudi & Orlikowski 1988). It is not sufficient alone (King & Epstein 1983). Complete, enough (Gallagher 1974).
Concise. Well-presented, concise, compactly represented, well-organised, aesthetically pleasing form of presentation, well-formatted, format of the data (Wang & Strong 1996; Kahn, Strong & Wang 2002).
Consistency. It is noticeably impaired as to comparability (King & Epstein 1983). The recorded value is the same in all cases (Fisher & Kingma 2001). The representation of the data value is the same in all cases (Ballou & Pazer 1985). Two sets of data do not conflict with each other (Huh et al. 1990).
Consistent Representation. Data are consistently represented in the same format, consistently represented, consistently formatted, and data are compatible with previous data (Wang & Strong 1996; Kahn, Strong & Wang 2002).
Correct. No multiple states mapped to the same IS states (Wand & Wang 1996).
Currency. Data are up to date (Huh et al. 1990). The age of the output information (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985; Miller & Doyle 1987).
Ease of Manipulation. The extent to which information is easy to manipulate and apply to different tasks (Kahn, Strong & Wang 2002).
Ease of Operation. Easily joined, changed, updated, downloaded, or uploaded. Data can be used for multiple purposes, manipulable, aggregated, reproduced, data can be integrated, and customised (Wang & Strong 1996).
Ease of Understanding. Easily understood, clear, readable (Wang & Strong 1996).
Factual. Factual, true (Zmud 1978).

Flexibility. Adaptable, flexible, extendable, and expandable (Wang & Strong 1996).
Format. How the information is presented to the customer (Miller 1996). The material design of the layout and display of the output contents (Bailey & Pearson 1983). Information if presented in the useful format and is clear (Doll & Torkzadeh 1988). The medium, ordering, and graphic design of the report (Ahituv 1980). Readable, orderly, logical, clear, simple (Gallagher 1974). The amount of complex recalculations or adjustments necessary in order to use the information presented to complete a specific decision (Larcker & Lessig 1980; Blaylock & Rees 1984).
Free of Error. The extent to which information is correct and reliable (Kahn, Strong & Wang 2002).
Importance and Useableness. Sufficient, the portion of information essential for completing a specific decision (Blaylock & Rees 1984; Klein, Goodhue & Gordon 1997).
Integrity. Accurate, complete, consistent, and existent (Bovee, Srivastava & Mak 2003).
Interpretability. The extent to which information is in appropriate languages, symbols, and units, and the definitions are clear (Wang & Strong 1996; Kahn, Strong & Wang 2002; Bovee, Srivastava & Mak 2003).
Meaningful. No map to a wrong state (Wand & Wang 1996).
Objectivity. Unbiased, unprejudiced, and impartial (Wang & Strong 1996; Kahn, Strong & Wang 2002).
Precision. The variability of the output information from that which it purports to measure (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985; Baroudi & Orlikowski 1988).
Quantitativeness. It is primarily quantitative (King & Epstein 1983).
Quantity. Complete, effective, material, sufficient (Zmud 1978).
Readable. Clear, convenient, readable, simple (Zmud 1978).
Reasonable. Logical, sensible (Zmud 1978).
Relevancy. The extent to which the information is applicable and helpful to the task at hand (Kahn, Strong & Wang 2002; Bovee, Srivastava & Mak 2003).
Reliability. The consistency and dependability of the output information (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985; Baroudi & Orlikowski 1988). Accurate, reliable, valid, true (Gallagher 1974).
Reliable. Valid (Zmud 1978).
Reputation. The extent to which information is highly regarded in terms of its source or content (Kahn, Strong & Wang 2002).
Security. Appropriate restrictions to maintain security (Kahn, Strong & Wang 2002).
Similarity. Accuracy of the reported data (Ahituv 1980).
Timeliness. The age of the data (Wang & Strong 1996). The recorded value is not out of date (Ballou & Pazer 1985; Fisher & Kingma 2001). Currency. Refers to the age of the primitive data units used to produce the information products (Ballou et al. 1998). Current (Gallagher 1974; Zmud 1978; Miller 1996; Cappiello, Francalanci & Pernici 2003-4). Up-to-date information (Doll & Torkzadeh 1988). The availability of the output information at a time suitable for its use (Bailey & Pearson 1983; Ives, Olson & Baroudi 1983; Barki & Huff 1985). The extent to which the information is sufficiently up-to-date for the task at hand (Kahn, Strong & Wang 2002).
Unambiguous. No map to meaningless IS state (Wand & Wang 1996).
Understandability. It is understandable (King & Epstein 1983).
Validity. It can be verified as being true and satisfying appropriate standards related to other dimensions (Miller 1996).
Value Added. The extent to which information is beneficial and provides advantages from its use (Kahn, Strong & Wang 2002).
Volatility. How long an item remains valid (Ballou et al. 1998).

Source: developed from (Nelson, Todd & Wixom 2005, pp. 227-229)

Appendix E: Research Information Sheet

UniSA

Research Information Sheet

Research Project: Information Quality Management Capability Maturity Model
Research Institution: School of Computer and Information Science
University of South Australia
Researcher: Sasa Baskarada
Ph: +61 8 830 23785
E-mail: sasa.baskarada@unisa.edu.au
Principal Supervisor: Professor Andy Koronios
Ph: +61 8 830 23352
E-mail: andy.koronios@unisa.edu.au
Associate Supervisor: Dr. Jing Gao
Ph: +61 8 830 23082
E-mail: jing.gao@unisa.edu.au

This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, Tel: 8302 3118; Email: Vicki.allen@unisa.edu.au

Approximate interview duration: 60 minutes

Research Purpose
This doctoral research project aims to develop an information quality management capability maturity model for engineering asset management information systems. The model is intended to act as a tool to assess information quality management capability maturity in engineering asset management organisations. It is also intended to assist in the enhancement of the collection, storage and use of data; and it is thought that it will most likely improve organisational asset management related learning and decision making by enhancing the quality of data.

Research Hypotheses
H_0: Quality of engineering asset management information is not changed as the organisation moves to a higher information quality management capability maturity level.
H_A: Quality of engineering asset management information is enhanced as the organisation moves to a higher information quality management capability maturity level.

Research Approach
The proposed methodology for this project is case research with some face-to-face semi-structured interviews. The interviews will be seen as 'open' as not all the questions to be used during the interview will be decided beforehand. Instead the researcher has a list of topics that will be covered during the interview.

Role of Participants
The research will involve you as a member of the general public who works for an asset management organisation in a face-to-face interview with the researcher. Participation in this interview process is voluntary and you may withdraw from the study at any time without prejudice. These interviews will be used to explore the research hypotheses outlined above. The results will be collated and analysed only by the researcher.

Confidentiality
The primary medium for data recording will be written notes taken by the researcher. Audiotapes of interviews will be used to provide backup to the written notes. Where this is to occur, participants will be specifically advised of this prior to the interview commencing. All identifying demographics, such as name, age, gender, etc. will be removed from the collected interview transcripts and will not be used in any part of the final report. Data obtained from the research will be stored for 7 years as both hard copy and on CD-ROM in a secure location of the Information Systems Doctoral School. This storage will be as per the University's guidelines for the storage of research data.

Appendix F: Consent Form

Project Title: Information Quality Management Capability Maturity Model

Researcher: Sasa Baskarada
Principal Supervisor: Professor Andy Koronios
Associate Supervisor: Dr. Jing Gao

- I have read the Participant Information Sheet, and the nature and the purpose of the research project has been explained to me. I understand and agree to take part.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can withdraw from the study at any stage and that this will not affect my status now or in the future.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- I confirm that I am over 18 years of age.
- I understand that I will be audio-taped during the study.
- I understand that the tape will be stored for 7 years in a secure location in the School of Computer and Information Science.

Name of participant: ……

Signed: …….

Dated: …….

I have explained the study to subject and consider that he/she understands what is involved.

Researcher's Signature and Date: ……

Appendix G: Research Invitation Letter for Exploratory Case Studies

University of South Australia
Division of Information Technology, Engineering and the Environment
School of Computer and Information Science
Strategic Information Management (SIM) Lab
sim.unisa.edu.au

Research Invitation

An increasing number of contemporary organisations are coming to realise the importance of quality information to effective decision making. Many organisations however do not fully understand their existing capability in Information Quality Management (IQM), nor do they know how they compare to other organisations. We are currently investigating the factors influencing organisational IQM capability maturity. More specifically:

- What are the different IQM capability maturity levels/stages?
- What are the maturity indicators that influence (or determine) organisational IQM capability maturity?

Thus, this research aims to help asset management organisations with benchmarking their IQM practices against other organisations and industry standards. Moreover, we aim to develop guidelines for IQM improvements and thus better decision making, resulting in lower cost asset management.

We are seeking access to Engineering Asset Management organisations for the purpose of conducting interviews which will help us gain further insights into the research questions. We seek to interview 3-6 people per organisation, totalling about 6 interviews (45-60min per interview). Some examples of potential interviewees are shown in the table below.

Organisational Level	**Staff Titles/Functions/Roles**
Strategic	CIO, CEO
Tactical	Asset Managers, Senior Engineers, System Administrators
Operational	Maintenance Staff, Field Workers, Technicians

Any data collected will be treated in a confidential manner and anonymity of the organisation's name will be assured. Any findings will be summarised in journal/conference papers and a PhD thesis.

Sample questions that may be asked during interviews:

- What is your perception of the quality of information you are using/producing?
- What are the main types of IQ problems you organisation is experiencing?
- What IQM processes are used in you organisation?
- What IQM processes do you think should be implemented in the future?
- What impact has poor IQ had on your organisation in the past?
- …

A copy of the summary of the findings of this survey will be sent to any organisation participating in this aspect of the research. The summary will provide an insight as to the position of your organisation relative to the others that have also participated in terms of IQM Capability Maturity. No identifying information will be shown except the position of your organisation.

CIEAM Cooperative Research Centre for
Integrated Engineering Asset Management

Appendix H: Candidate Maturity Indicators

Table H.1: Maturity Indicators Pertaining to Information Capture

Real-time information capture.
It is critical that information is entered only once into the system, as close to the point of creation as possible, and never manually copied.
Correction and resubmission of erroneously entered information.
This could apply to real-time information entry or to subsequent corrections and updates. Nevertheless, standard procedures should be defined and followed.
Erroneous transactions are identified dynamically without being processed.
This maturity indicator refers to functionality beyond the simple DBMS constraints or input validation. Erroneous transactions could potentially be identified based on dynamically generated rules, which could be based on historical information and heuristics. The Case F organisation illustrated this functionality with an example of a prototype application being developed by a subject matter expert. The application mined the database for historical information and provided real-time feedback to the user about the quality of the input values. The prototype system warned the user if an unusual set of values had been entered.

Source: (developed by the author from literature and exploratory case studies)

Table H.2: Maturity Indicators Pertaining to Information Analysis

Scripted (SQL based) data cleansing.
Any scripted information cleansing must be appropriately managed and documented. Such activities should only be infrequently carried out, should be officially authorised, and should be thoroughly analysed and tested before execution.
Information product classification.
Considering the assess security dimension, it is vital to establish a classification scheme for information products that applies throughout the enterprise. Such a classification scheme should be based on the criticality and sensitivity of information (e.g. public, restricted, and confidential), and may include details about information ownership, definition of appropriate security levels and protection controls, and a description of information retention and destruction requirements. This may be used as the basis for applying access controls, archiving, or encryption.
Management of derived information products.
Following the information product analogy, reports, tables, forms, and so on, are all composed of numerous individual pieces of information. As such, it is essential to document how such information products are composed and where the individual data elements are coming from. Another example is a derived data element (e.g. mean value), which gets calculated from other data elements. Any such occurrences also should be comprehensively documented.

Source: (developed by the author from literature and exploratory case studies)

Table H.3: Maturity Indicators Pertaining to Information Access

Presentation templates for information products.
Several information quality dimensions in the Wang and Strong (1996) framework refer to the presentation of information products. Thus, information should be presented in a consistent fashion, preferably using pre-defined templates.
Access control.
Only authorised personnel should be performing information input and updates. This could be ensured through the use of various authentication mechanisms. Furthermore, the principle of least authority, which states that users should have the least set of privileges they need, should be observed.
Critical review, identification and handling of errors contained in the output.
All information used should be critically reviewed at all times, and when any information quality problems are found, standard procedures should be followed in order to provide corrections.

Source: (developed by the author from literature and exploratory case studies)

Table H.4: Maturity Indicators Pertaining to Information Disposal

Disposal management.
Access to deleted sensitive information from equipment or media should be prevented. Thus, deleted sensitive information should not be retrievable. This refers to soft-copy as well as hard-copy information products.

Source: (developed by the author from literature and exploratory case studies)

Table H.5: Maturity Indicators Pertaining to Information Storage/Update

Conceptual data modelling.
Given that "fitness for use" defines information quality, data modelling was quickly identified as a key information quality management maturity indicator. Even though data modelling is actually an information management process, it may have a huge impact on the quality of information in organisations. Conceptual data modelling refers to the process of identifying high-level business concepts and their relationships. These concepts are based on business requirements and as such emerge out of the business processes.
Logical data modelling.
Logical modelling takes the conceptual data model as input and further identifies concept attributes and primary and foreign keys. This model is usually normalised to the third normal form, and it forms a graphical representation of the business requirements. Identifying the right attributes is a crucial step in logical data modelling. Normalising the data model to at least the third normal form is also critical. A normalised data model minimises redundancy and ensures that referential integrity is enforced. Case F provided an example on how a non-normalised data model may create data quality problems. The lack of normalisation allowed for duplication of unique items, created referential integrity problems, and resulted in various update anomalies.
Physical data modelling.
Physical data modelling refers to the process of implementing the logical data model (or part thereof) in a Database Management System (DBMS). The physical model may additionally create indexes, define constraints, link or partition tables or clusters, and the like. Thus, it is imperative to carefully choose the right DBMS, because different DBMS have different requirements and capabilities, resulting in different implementations of the physical data model. For that reason, an organisation has to carefully consider the different options and choose the DBMS best suited to its needs.
DBMS constraints.
Information should be validated and edited as close to the point of creation as possible. Any such checks may be based on business rules and could be built into a DBMS as various constraints. Case F illustrated how a lack of input validation can result in poor information quality. The database in use by the Case F organisation didn't include any rules or constraints, and as such it allowed for mismatched data types, out-of-range values, undesired null values, and the like.
Storage and archival.
Defining and implementing procedures for information storage and archival was also identified as one of the information quality management maturity indicators. Any such procedures should consider the physical storage environment, retrieval issues, and security requirements. This maturity indicator addresses the accessibility dimensions.
Backup of critical information.
Given that accessibility is one of the information quality dimensions, all critical information should be backed up and stored offsite. Offsite facilities should be periodically assessed for content, environmental protection and security. Procedures for backup and restoration of information should also be defined.
Redundant storage management.
Redundant storage has been identified as one of the major causes of information quality problems. Nevertheless, some redundancy may be necessary, for example, to ensure reliability or accessibility. Any such redundant storage should be identified, documented, and appropriately managed. The ultimate goal should be to utilise as little redundancy as possible.
Single point of truth.
Redundant storage may lead to inconsistencies and thus to multiple points of truth. Therefore, it is essential to define end establish master systems, which should act as the single point of truth.
Extract Transform Load.
A lot of extract-transform-load activities in an organisation may be a sign of low information management maturity. Such processes should be thoroughly documented and communicated throughout the organisation, as to prevent unforseen problems from changes to data models and the like.

Source: (developed by the author from literature and exploratory case studies)

Table H.6: Maturity Indicators Pertaining to the whole of Information Lifecycle

Stakeholder management.
Identifying all the main information system stakeholders is the first step to obtaining business and information quality requirements. The stakeholder list should also be periodically reviewed and updated because stakeholders may change over time.
Information management roles and responsibilities.
Defining and communicating information management roles and responsibilities for all personnel in the organisation is a prerequisite for information quality. Role descriptions, which should be updated regularly, should outline authorities and responsibilities, and include definitions of skills and experience needed in the relevant positions. Some organisations may represent this graphically.
Stewardship and ownership.
Following on from the information management roles and responsibilities, it is essential to manage information stewardship responsibilities, to implement a formal stewardship program, and to address the responsibilities for ownership of data and information systems. According to Gartner, "stewards should be considered data subject-matter experts for their respective business functions and processes" (Friedman 2007a, p. 3).
Security requirements management.
Given that access security is one of the information quality dimensions in the Wang and Strong (1996) framework, security requirements applicable to the receipt, processing, physical storage, and output of sensitive information should be identified and documented.
Education, training, and mentoring.
Staff dealing with information at any stage of the information management lifecycle should be appropriately trained and mentored. Standardised policies and procedures should be in place and they should be followed. Furthermore, staff should be educated about information quality management and about the importance of producing quality information.
Secure transmission of classified information.
Sensitive information should be exchanged only over a trusted path or medium, or information should be encrypted before being transmitted over a public channel. This maturity indicator addresses the access security dimension.
Information product configuration management.
Selected information products may need to be managed within a configuration management system. Such system would track any changes and would provide functionality to revert to any previous versions.
Meta-information management.
Meta-information can be used to enhance information quality by providing additional information about various information products. Not all information needs to be meta-tagged; only the critical information products may need to have this option. Meta-information may describe various properties such as, ownership, security, edit history and so on.
Enterprise information architecture.
Establishing and maintaining an enterprise information model, to enable applications development and decision-supporting activities, is a vital factor for effective information quality management. An enterprise logical information model may facilitate the optimal creation, use, and sharing of information. On the other hand, some organisations may find that their "information architectures have become fragmented and have excessive redundancy — this leads to an inability to discover the single version of the truth" (Bell, Logan & Friedman 2008, p. 5).
Information integration management.
Various information quality related problems can occur during the process of information integration. Thus, standardised policies and processes should be in place to ensure that any information integration does not create further problems. Less mature organisations integrate systems on a more ad hoc basis.
Audit trail.
Information creation, access, and edits should be logged, as to allow for reconstruction of events. This may be of use when enforcing information quality accountabilities and security policies.

Source: (developed by the author from literature and exploratory case studies)

Table H.7: Maturity Indicators Pertaining to Information Quality Management

Information quality management team and project management.
IQM efforts need to be formally managed if they are to produce any lasting results. A sample project proposal provided by Case E detailed business requirements, key roles for the project, project approach, the scope of the work that is required, the deliverables of the project, business/technical aspects of the project, business acceptance criteria, and the business case – estimated project costs and benefits.
Information quality requirements management.
Before any IQM programs can be started, relevant quality requirements first have to be identified. Given that IQ is defined by the users, key stakeholders should be surveyed for their expectations. Also, not all information is equally important, and not all information requires quality levels of 100%. Accordingly, any such issues should be identified and appropriately documented.
Information quality management policies management.
Organisational or departmental IQM policies may raise the visibility and demonstrate the significance of IQ. Any such policies may provide a framework for IQM, set IQ standards, and describe best practices. They should also be reviewed and updated on a regular basis.
Information quality is everyone's responsibility.
Deming argued long time ago that quality should be everyone's responsibility. The aim is to embed IQM into the culture of the organisation so that everyone plays a part in it.
Information quality management roles and responsibilities.
Even though IQ should be everyone's responsibility, IQM roles and responsibilities should be clearly defined, documented, and effectively communicated to all stakeholders. Roles descriptions should be updated regularly and should outline authorities and responsibilities.
Best practices for IQM have been identified and are used.
It is critical that organisations keep up-to-date with the industry best practices as well as cutting-edge academic research on IQM. Best practices should be documented (potentially integrated within IQM policies) and communicated within organisation.
Information quality risk management and impact assessment.
Critical information products and relevant IQ dimensions should be identified. Also, consequences and probabilities of IQ problems should be estimated and acceptable levels of risk should be evaluated.
Information quality metrics and assessments.
Metrics for relevant IQ dimensions should be developed and assessments should be performed on a regular basis. Due to government regulations, some organisations are also audited by external parties.
Information profiling.
Information profiling may be used to uncover information anomalies by inspecting the content, structures and relationships of information sources. It may also be used to analyse information values in order to find areas that are incomplete or inaccurate.
Information enhancement.
Information enhancement (sometimes called augmentation) may be used to append additional information to the existing one. This information may come from internal (the same organisation) or external (third-party database, CD, DVD, and the like) sources.
Continuous improvement (Kaizen).
IQM should be a continuous, never-ending, process. It should become a part of the company culture, which always seeks new ways for eliminating waste. This should be based on the PDCA cycle.
Information quality root-cause-analysis.
Continuous improvement should be based on root-cause-analysis. When IQ problems are found, all potential causes should be investigated, and the root cause should be corrected. That way an organisation may prevent the recurrent occurrence of identical IQ problems.
Information quality management cost-benefit analysis.
Before any root cause issues can be addressed, a cost-benefit analysis should be performed. If it is found that the correction is not economically viable, then an organisation may choose to accept the IQ problems.
Information quality management alignment with ICT and organisational strategies.
IQM strategies should be aligned with organisational and ICT strategies. As such, continuous improvement should be forward looking, and not only be based on current requirements. IQM strategies may be linked to organisational or ICT balanced score cards.
Information quality accountability.
Every person should be accountable for the quality of his or her work and should not send poor quality information to the next person in the process. Rewards and incentives may also lead to higher IQ.

Source: (developed by the author from literature and exploratory case studies)

Appendix I: Delphi Questionnaire (round 1)

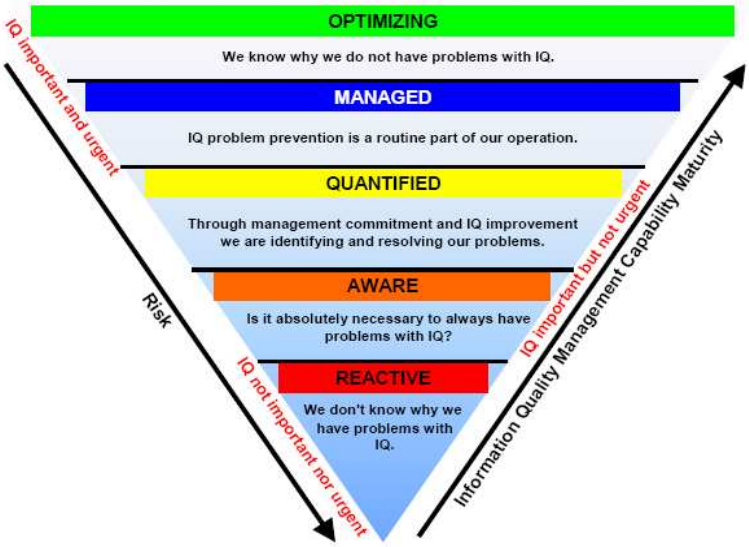
Information Quality Management Capability Maturity Questionnaire (Session 6B)

(Please direct any comments to: sasa.baskarada@unisa.edu.au)

Dear Colleague,

By completing this questionnaire, you are making a valuable contribution my PhD research. We sincerely appreciate your expert input and thank you for sharing your experiences and thoughts. This questionnaire should only take approximately 10 minutes to complete.

This doctoral research project aims to develop an Information Quality Management Capability Maturity Model. The model comprises five Maturity Levels that represent an evolutionary path of increasingly structured and methodically more mature IM & IQM processes. The Maturity Levels shown on the right have been adopted from Crosby's Quality Maturity Grid. Please provide any additional comments for each Level in the table below, and suggest any potentially more suitable names on the dotted lines. Furthermore, a list of "Maturity Indicators" is provided at the back of this page. For each "Maturity Indicator" please tick the "lowest" Maturity Level, in which you believe it should be present. For example, by ticking "QUANTIFIED", you are saying that the "Maturity Indicator" is only present in levels "QUANTIFIED" and above. Please also include any other "Maturity Indicators" you believe should be considered.



Maturity Level Please suggest any potentially more suitable names	Please provide any additional comments for each Capability Maturity Level
Level 5: OPTIMIZING (.....)	
Level 4: MANAGED (.....)	
Level 3: QUANTIFIED (.....)	
Level 2: AWARE (.....)	
Level 1: REACTIVE (.....)	

We would be most grateful if you provided your name and email address so that you can help us further develop and validate this model through a Delphi study. **In return for your cooperation we will provide you with the final results of the study!**

Name: _____ **email:** _____

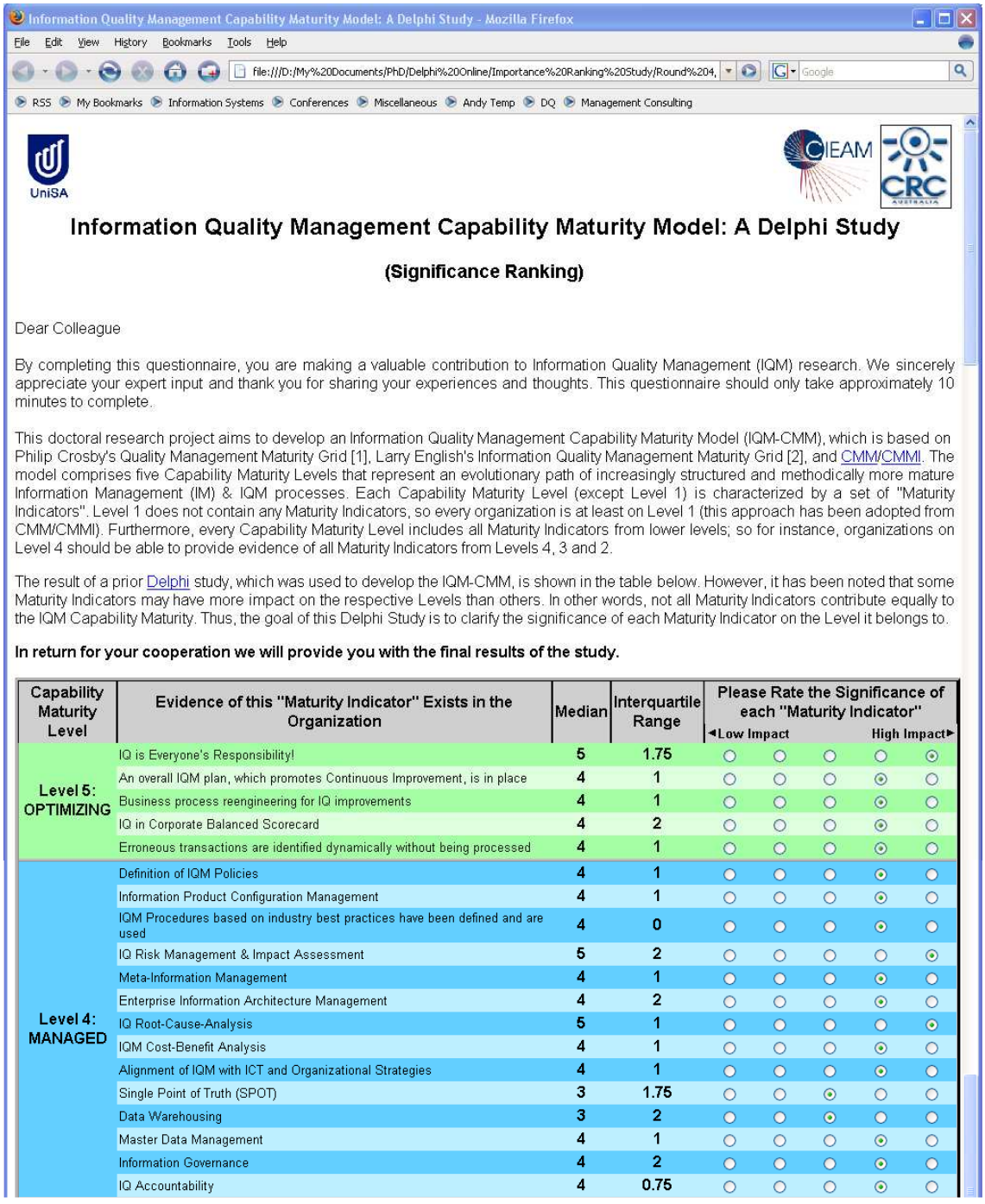
PLEASE TURN PAGE OVER

For each "Maturity Indicator", please tick the lowest Maturity Level in which you believe it should be present.

	Evidence of this "Maturity Indicator" exists in the organization	REACTIVE	AWARE	QUANTIFIED	MANAGED	OPTIMIZING
1	Conceptual Data Modeling (concepts & relationships)					
2	Logical Data Modeling (attributes, primary/foreign keys, normalization)					
3	Physical Data Modeling (implementation in a DBMS, any physical considerations)					
4	Templates for presentation of Information Products					
5	Information Product Classification (e.g. public, restricted, confidential)					
6	Information System Stakeholder Identification					
7	IM Roles and Responsibilities					
8	Information Stewardship and Ownership					
9	DBMS Constraints (business rules, referential constraints, etc.)					
10	Information storage and archival procedures					
11	Specification of Derived Information Products					
12	Security Requirements (for receipt, processing, storage & output)					
13	IQM Team & Project Management					
14	IQ Requirements Specification					
15	IQM Policies					
16	IQM Education, Training & Mentoring					
17	IQ is Everyone's Responsibility!					
18	IQM Roles & Responsibilities					
19	(Offsite) Backup of any critical Information					
20	Secure transmission of any classified information					
21	Access Control for input/access/edits					
22	Procedures for correction and resubmission of erroneously entered information					
23	Scripted (SQL Based) Data Cleansing					
24	Information Product Configuration Management					
25	Disposal Management (of sensitive information)					
26	IQM Procedures based on industry best practices have been defined and are used					
27	IQ Risk Management & Impact Assessment					
28	IQ Metrics and IQ Assessment					
29	Redundant Storage Management (some information may need to be stored redundantly)					
30	Meta-Information Management					
31	Real-Time Information Capture (information is entered only once; no manual copying)					
32	Erroneous transactions are identified dynamically without being processed					
33	Information Profiling					
34	Information Enhancement (from external sources)					
35	Enterprise Architecture has been developed and documented					
36	Procedures for critical review, identification and handling of errors contained in the output					
37	An overall IQM plan, which promotes Continuous Improvement, is in place					
38	IQ Root-Cause-Analysis					
39	IQM Cost-Benefit Analysis					
40	IQM alignment with ICT and organizational strategies					
41	IQ Accountability					
42	Information Integration Management					
43	Single Point of Truth (Data Warehousing)					
44	Audit Trail (information creation/access/edits are logged)					
45	Extract Transform Load (ETL)					
46						
47						
48						
49						
50						
51						
52						
53						

Please suggest any additional "Maturity Indicators" in the blank lines above.

Appendix J: Delphi Questionnaire (round 4)



Information Quality Management Capability Maturity Model: A Delphi Study - Mozilla Firefox

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UniSA

CIEAM CRC AUSTRALIA

Information Quality Management Capability Maturity Model: A Delphi Study

(Significance Ranking)

Dear Colleague

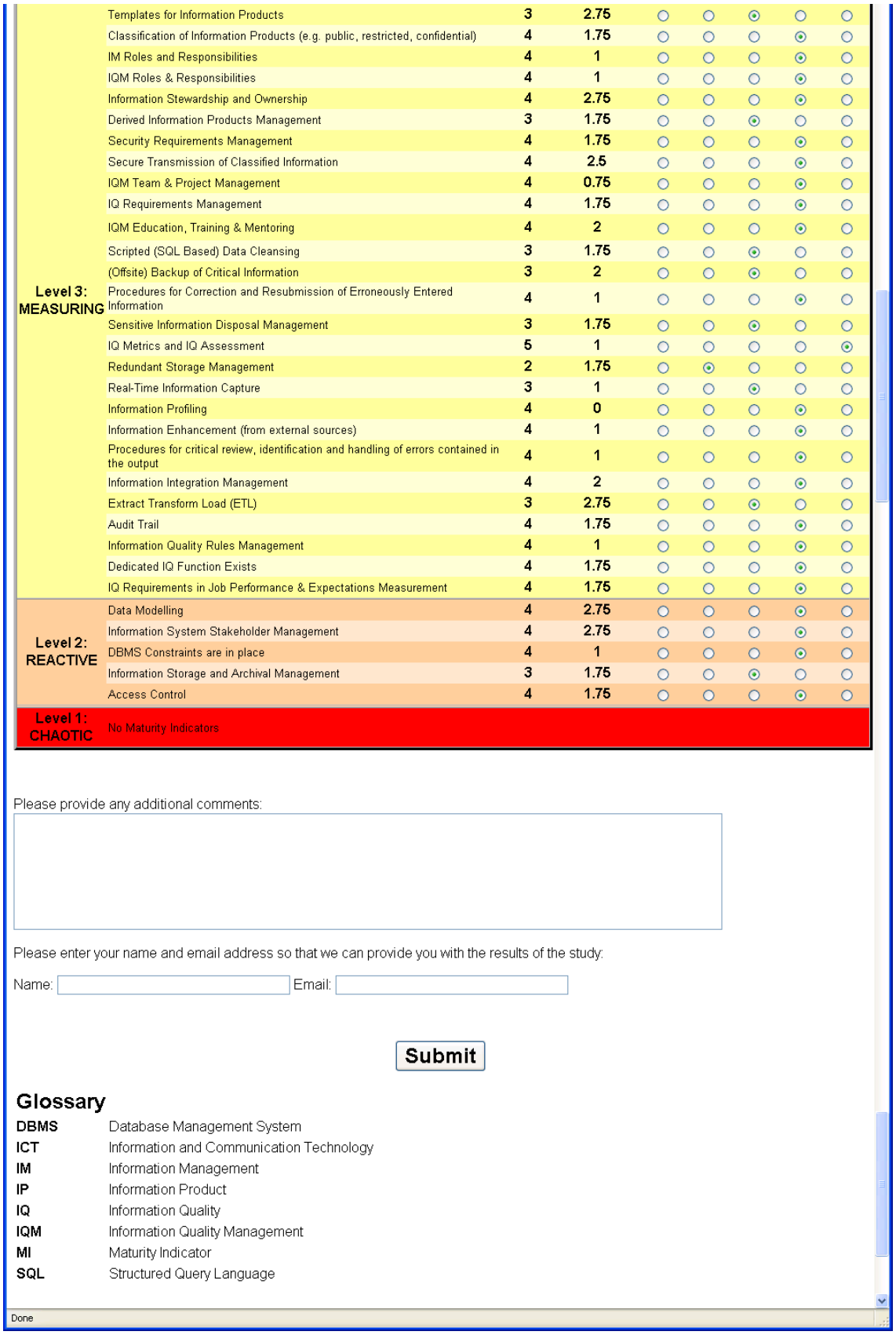
By completing this questionnaire, you are making a valuable contribution to Information Quality Management (IQM) research. We sincerely appreciate your expert input and thank you for sharing your experiences and thoughts. This questionnaire should only take approximately 10 minutes to complete.

This doctoral research project aims to develop an Information Quality Management Capability Maturity Model (IQM-CMM), which is based on Philip Crosby's Quality Management Maturity Grid [1], Larry English's Information Quality Management Maturity Grid [2], and CMM/CMMI. The model comprises five Capability Maturity Levels that represent an evolutionary path of increasingly structured and methodically more mature Information Management (IM) & IQM processes. Each Capability Maturity Level (except Level 1) is characterized by a set of "Maturity Indicators". Level 1 does not contain any Maturity Indicators, so every organization is at least on Level 1 (this approach has been adopted from CMM/CMMI). Furthermore, every Capability Maturity Level includes all Maturity Indicators from lower levels; so for instance, organizations on Level 4 should be able to provide evidence of all Maturity Indicators from Levels 4, 3 and 2.

The result of a prior Delphi study, which was used to develop the IQM-CMM, is shown in the table below. However, it has been noted that some Maturity Indicators may have more impact on the respective Levels than others. In other words, not all Maturity Indicators contribute equally to the IQM Capability Maturity. Thus, the goal of this Delphi Study is to clarify the significance of each Maturity Indicator on the Level it belongs to.

In return for your cooperation we will provide you with the final results of the study.

Capability Maturity Level	Evidence of this "Maturity Indicator" Exists in the Organization	Median	Interquartile Range	Please Rate the Significance of each "Maturity Indicator" ◄Low Impact High Impact►
Level 5: OPTIMIZING	IQ is Everyone's Responsibility!	5	1.75	○ ○ ○ ○ ◉
	An overall IQM plan, which promotes Continuous Improvement, is in place	4	1	○ ○ ○ ◉ ○
	Business process reengineering for IQ improvements	4	1	○ ○ ○ ◉ ○
	IQ in Corporate Balanced Scorecard	4	2	○ ○ ○ ◉ ○
	Erroneous transactions are identified dynamically without being processed	4	1	○ ○ ○ ◉ ○
Level 4: MANAGED	Definition of IQM Policies	4	1	○ ○ ○ ◉ ○
	Information Product Configuration Management	4	1	○ ○ ○ ◉ ○
	IQM Procedures based on industry best practices have been defined and are used	4	0	○ ○ ○ ◉ ○
	IQ Risk Management & Impact Assessment	5	2	○ ○ ○ ○ ◉
	Meta-Information Management	4	1	○ ○ ○ ◉ ○
	Enterprise Information Architecture Management	4	2	○ ○ ○ ◉ ○
	IQ Root-Cause-Analysis	5	1	○ ○ ○ ○ ◉
	IQM Cost-Benefit Analysis	4	1	○ ○ ○ ◉ ○
	Alignment of IQM with ICT and Organizational Strategies	4	1	○ ○ ○ ◉ ○
	Single Point of Truth (SPOT)	3	1.75	○ ○ ◉ ○ ○
	Data Warehousing	3	2	○ ○ ◉ ○ ○
	Master Data Management	4	1	○ ○ ○ ◉ ○
	Information Governance	4	2	○ ○ ○ ◉ ○
	IQ Accountability	4	0.75	○ ○ ○ ◉ ○



	Templates for Information Products	3	2.75	○	○	◉	○	○
	Classification of Information Products (e.g. public, restricted, confidential)	4	1.75	○	○	○	◉	○
	IM Roles and Responsibilities	4	1	○	○	○	◉	○
	IQM Roles & Responsibilities	4	1	○	○	○	◉	○
	Information Stewardship and Ownership	4	2.75	○	○	○	◉	○
	Derived Information Products Management	3	1.75	○	○	◉	○	○
	Security Requirements Management	4	1.75	○	○	○	◉	○
	Secure Transmission of Classified Information	4	2.5	○	○	○	◉	○
	IQM Team & Project Management	4	0.75	○	○	○	◉	○
	IQ Requirements Management	4	1.75	○	○	○	◉	○
	IQM Education, Training & Mentoring	4	2	○	○	○	◉	○
	Scripted (SQL Based) Data Cleansing	3	1.75	○	○	◉	○	○
	(Offsite) Backup of Critical Information	3	2	○	○	◉	○	○
Level 3: MEASURING	Procedures for Correction and Resubmission of Erroneously Entered Information	4	1	○	○	○	◉	○
	Sensitive Information Disposal Management	3	1.75	○	○	◉	○	○
	IQ Metrics and IQ Assessment	5	1	○	○	○	○	◉
	Redundant Storage Management	2	1.75	○	◉	○	○	○
	Real-Time Information Capture	3	1	○	○	◉	○	○
	Information Profiling	4	0	○	○	○	◉	○
	Information Enhancement (from external sources)	4	1	○	○	○	◉	○
	Procedures for critical review, identification and handling of errors contained in the output	4	1	○	○	○	◉	○
	Information Integration Management	4	2	○	○	○	◉	○
	Extract Transform Load (ETL)	3	2.75	○	○	◉	○	○
	Audit Trail	4	1.75	○	○	○	◉	○
	Information Quality Rules Management	4	1	○	○	○	◉	○
	Dedicated IQ Function Exists	4	1.75	○	○	○	◉	○
	IQ Requirements in Job Performance & Expectations Measurement	4	1.75	○	○	○	◉	○
	Data Modelling	4	2.75	○	○	○	◉	○
	Information System Stakeholder Management	4	2.75	○	○	○	◉	○
Level 2: REACTIVE	DBMS Constraints are in place	4	1	○	○	○	◉	○
	Information Storage and Archival Management	3	1.75	○	○	◉	○	○
	Access Control	4	1.75	○	○	○	◉	○
Level 1: CHAOTIC	No Maturity Indicators							

Please provide any additional comments:

Please enter your name and email address so that we can provide you with the results of the study:

Name: Email:

Submit

Glossary

DBMS	Database Management System
ICT	Information and Communication Technology
IM	Information Management
IP	Information Product
IQ	Information Quality
IQM	Information Quality Management
MI	Maturity Indicator
SQL	Structured Query Language

Done

Appendix K: Delphi Study Results

Capability Maturity Level	Evidence of this Maturity Indicator Exists in the Organisation	Round 1*				Round 2*				Round 3**				Round 4**			
		Mean	SD of Mean	Median	Interquartile Range	Mean	SD of Mean	Median	Interquartile Range	Mean	SD of Mean	Median	Interquartile Range	Mean	SD of Mean	Median	Interquartile Range
Level 5 (median 5)	Information quality is everyone's responsibility	4.12	1.33	**5**	1	4.36	1.33	**5**	0	4.28	1.02	**5**	1.75	4.73	0.46	**5**	0.5
	Continuous improvement (Kaizen)	4.32	0.82	**5**	1	4.77	0.69	**5**	0	4.06	1	**4**	1	4.73	0.46	**5**	0.5
	Business process reengineering for IQ improvement	4.5	0.71	**4.5**	0.5	4.77	0.69	**5**	0	4.33	0.69	**4**	1	4.13	0.35	**4**	0
	Information quality is in the corporate balanced scorecard	4.5	0.71	**4.5**	0.5	4.68	0.89	**5**	0	4	1.03	**4**	2	4.07	0.7	**4**	0
	Erroneous transactions are identified dynamically	4.10	1.10	**5**	2	4.36	1.33	**5**	0	3.56	1.29	**4**	1	3.67	0.49	**4**	1
Level 4 (median 4)	Information quality management policies management	3.63	1.06	**4**	1	3.64	0.79	**4**	0	4	1.24	**4**	1	4.27	0.46	**4**	0.5
	Information product configuration management	3.53	0.77	**4**	1	3.73	0.7	**4**	0	3.56	1.04	**3.5**	1	3.93	0.59	**4**	0
	Identification and use of best practices for IQM	3.79	1.03	**4**	0.5	3.95	0.21	**4**	0	4.11	0.58	**4**	0	4.13	0.35	**4**	0
	Information quality risk management and impact assessment	3.67	0.95	**4**	1	3.64	0.73	**4**	0.75	4	1.14	**4.5**	2	4.67	0.62	**5**	0.5
	Meta-information management	3.32	0.89	**4**	1.5	3.5	0.86	**4**	1	3.56	1.2	**4**	1	3.93	0.46	**4**	0
	Enterprise information architecture management	3.47	1.07	**4**	1	3.59	0.91	**4**	0	3.78	1.11	**4**	2	4	0.53	**4**	0
	Information quality root-cause-analysis	3.47	0.96	**4**	1	3.64	0.85	**4**	1	4.28	0.96	**4.5**	1	4.8	0.41	**5**	0
	Information quality management cost-benefit-analysis	3.47	0.90	**4**	1	3.64	0.73	**4**	0	3.72	0.89	**4**	1	3.87	0.52	**4**	0
	Alignment of IQM with ICT and Organisational Strategies	4.05	1.03	**4**	1.5	3.68	0.72	**4**	0	3.89	0.76	**4**	1	4.2	0.41	**4**	0
	Single Point of Truth (SPOT)	3.42	0.90	**4**	1	3.59	0.8	**4**	0.75	2.78	1.26	**3**	1.75	3.53	0.74	**4**	1
	Data warehousing	3.42	0.90	**4**	1	3.59	0.85	**4**	1	2.44	1.42	**2.5**	2	3.33	0.62	**3**	0.5
	Master Data Management (MDM)	4	0	**4**	0	3.77	0.97	**4**	0	3.67	0.84	**4**	1	4.07	0.59	**4**	0
	Information governance	4.5	0.71	**4**	0.5	3.77	0.97	**4**	0.75	3.78	1.11	**4**	2	4.2	0.56	**4**	0.5
	Information quality accountability	3.79	0.79	**4**	1	3.68	0.89	**4**	0	4.11	0.76	**4**	0.75	4.67	0.49	**5**	1
	Presentation templates for information products	2.84	0.76	**3**	0.5	2.77	0.53	**3**	0	3.28	1.32	**3**	2.75	3.2	0.56	**3**	0.5
	Information product classification	2.66	0.77	**3**	1	2.73	0.55	**3**	0	3.5	1.04	**4**	1.75	3.93	0.46	**4**	0
	Information management roles and responsibilities	3.12	0.74	**3**	1	2.73	0.46	**3**	0.75	4.11	0.96	**4**	1	4.13	0.35	**4**	0
	Information quality management roles and responsibilities	3.11	1.05	**3**	1.5	2.77	0.43	**3**	0	4.17	0.79	**4**	1	4.13	0.35	**4**	0
	Information stewardship and ownership	2.94	0.90	**3**	2	2.68	0.65	**3**	1	3.61	1.24	**4**	2.75	3.8	0.56	**4**	0.5

Level 3 (median 3)	Management of derived information products	2.95	0.91	**3**	0.5	2.86	0.47	**3**	0	2.83	0.99	**3**	1.75	3.47	0.52	**3**	1
	Security requirements management	2.56	1.17	**3**	1	2.95	0.21	**3**	0	3.56	1.15	**3.5**	1.75	4	0.38	**4**	0
	Secure transmission of classified information	2.79	1.40	**3**	2	2.82	0.59	**3**	0	3.61	1.29	**4**	2.5	4	0.53	**4**	0
	IQM team and project management	3.11	0.81	**3**	1	2.95	0.38	**3**	0	3.83	0.62	**4**	0.75	4.13	0.35	**4**	0
	Information quality requirements management	3.21	0.98	**3**	1	2.73	0.46	**3**	0.75	4	1.03	**4**	1.75	4.2	0.41	**4**	0
	Education, training, and mentoring	3.12	1.04	**3**	1.75	2.82	0.8	**3**	0	3.94	0.94	**4**	2	4	0.53	**4**	0
	Scripted (SQL based) data cleansing	2.68	1.06	**3**	1	2.64	0.73	**3**	0	3.17	1.1	**3**	1.75	3.13	0.64	**3**	0.5
	Backup of critical information	2.47	0.96	**3**	1	2.73	0.88	**3**	1	2.89	1.32	**2.5**	2	2.93	0.46	**3**	0
	Correction and resubmission of erroneously entered data	2.84	0.96	**3**	0	2.77	0.53	**3**	0.75	3.56	1.04	**4**	1	3.8	0.41	**4**	0
	Sensitive information disposal management	3.11	1.10	**3**	1	2.91	0.29	**3**	0	3.28	1.02	**3**	1.75	3.27	0.46	**3**	0.5
	Information quality metrics and assessments	3.26	0.93	**3**	1	2.73	0.63	**3**	0.75	4.22	0.94	**4.5**	1	5	0	**5**	0
	Redundant storage management	2.63	1.07	**3**	1	2.68	0.48	**3**	1	2.67	1.28	**2**	1.75	2.67	0.72	**3**	1
	Real-time information capture	2.89	1.05	**3**	1	2.82	0.39	**3**	0	3.22	0.88	**3**	1	2.93	0.59	**3**	0
	Information profiling	3.05	1.08	**3**	2	2.77	0.69	**3**	1	4.06	0.73	**4**	0	4	0.53	**4**	0
	Information enhancement	2.53	1.17	**3**	1.5	2.73	0.55	**3**	0	3.44	1.04	**4**	1	3.73	0.46	**4**	0.5
	Identification and handling of errors contained in the output	2.95	0.85	**3**	1	2.64	0.58	**3**	1	3.44	1.2	**4**	1	4.27	0.46	**4**	0.5
	Information integration management	3.12	0.81	**3**	1	2.77	0.43	**3**	0	3.72	1.13	**4**	2	4.47	0.52	**4**	1
	Extract Transform Load (ETL)	2.65	1.06	**3**	1	2.64	0.49	**3**	1	3.22	1.44	**3**	2.75	3.27	0.46	**3**	0.5
	Audit trail	2.74	0.99	**3**	1	2.86	0.56	**3**	0	3.56	1.15	**3.5**	1.75	4	0.38	**4**	0
	Semantic modelling	3	1.41	**3**	1	2.91	0.43	**3**	0	3.61	1.09	**4**	1	3.93	0.46	**4**	0
	Information quality rules management	3.5	0.71	**3.5**	0.5	2.73	0.46	**3**	0.75	3.94	1.16	**4**	1.75	4.27	0.46	**4**	0.5
	Dedicated information quality function exists	4	1.41	**4**	1	2.82	0.39	**3**	0	4	0.91	**4**	1.75	3.87	0.52	**4**	0
	IQ requirements in job performance measurements	3.5	0.71	**3.5**	0.5	2.68	0.65	**3**	0	3.72	1.36	**4**	2.75	4.2	0.41	**4**	0
Level 2 (median 2)	Data modelling	1.83	0.92	**2**	1	2.09	0.53	**2**	0	3.33	1.5	**4**	2.75	3.93	0.46	**4**	0
	Stakeholder management	2.53	0.70	**2**	1	2.14	0.35	**2**	0	3.72	0.75	**4**	1	4.2	0.41	**4**	0
	DBMS constraints management	2.32	1.20	**2**	0.5	2.09	0.53	**2**	0	3.5	1.15	**3**	1.75	3.47	0.74	**3**	1
	Storage and archival management	1.95	1.18	**2**	2	2.09	0.68	**2**	0	3.67	1.14	**4**	1.75	3.8	0.41	**4**	0
	Access control management	2.05	1.08	**2**	1.5	1.86	0.47	**2**	0	4.28	1.02	**5**	1.75	4.73	0.46	**5**	0.5
Level 1 (median 1)	No maturity indicators																

*** used to group the candidate maturity indicators into staged levels.**

**** used to verify the significance of each candidate maturity indicators.**

Appendix L: High-Level Interview Protocol

1. Introduction
2. Can you please explain your role in the organisation?
3. What types of information does your organisation/department mainly deal with?
4. Are you aware of any potential IQ problems in your organisation/department (in terms of accuracy, completeness, timeliness, etc.)?
    a. If so, can you please elaborate? **OR**
    b. If there are no problems, how do you ensure high IQ (in terms of accuracy, completeness, timeliness, etc.)?
5. IQM-CMM based evaluation:
    a. <discussion of the IQM-CMM themes>
6. Are there any other issues that I could have raised?
7. If I need to clarify any points, may I please get back to you?
8. Thank you sincerely for your generous input! I look forward to sharing some results with you.

Appendix M: IQM-CMM Diagnostic Tool

Maturity Level	Process Area	Maturity Indicators	Appraisal Criteria
Level 5 OPTIMISING	Information Quality Management Continuous Improvement	Information Quality Management Optimisation	Evidence of the following exists in the Information Quality Management Optimisation Policy document (or equivalent):
			Changes aimed at Information Quality Management improvement are planed and documented.
			Implementations of any changes are documented.
			It is monitored whether the small scale or experimental changes are achieving desired results.
			Organisation acts to implement changes on a larger scale if the experiment is successful.
	Information Quality Management Performance Monitoring	Information Quality Management Metrics	Qualitative and Quantitative Information Quality Management Key Performance Indicators (IQM-KPIs) have been defined and documented.
			IQM-KPIs have been named.
			IQM-KPIs have been described.
			Measurement procedures describe how each IQM-KPI is calculated.
			Measurement frequencies for each IQM-KPI have been specified.
			Target values have been specified for each IQM-KPI.
			Units of measurement have been specified for each IQM-KPI.
		Analysis and Reporting	Statistical Process Control (SPC) methods are used to control Information Quality Management processes.
			Information Quality Management Balanced Scorecard is in place.
		Information Quality Management Benchmarking	Information Quality Management Dashboard for top management indicates:
			Strategic Benchmarking: Benchmarking against Information Quality Management best practices or standards.
			Internal Benchmarking: Benchmarking against Information Quality Management practices within the organisation.
Level 4 MANAGED	Continuous Information Quality Improvement	Information Quality Problem Root-Cause-Analysis	Evidence of the following exists in the Information Quality Improvement Policy document (or equivalent):
			Root causes of Information Quality problems are being identified (what, how, why).
			Causal factor charts describe the events leading up to IQ problems and the conditions surrounding these events, including,
			Human factors
			Process/Organisational factors
			Technological factors
			Cause and effect charts (Ishikawa diagrams) are used to analyse the problems.
			Links between the root causes and Information Quality problems are documented and backed up by clear evidence.

		Information Quality Risk Management and Impact Assessment	Information Quality related risks to business goals have been identified and documented:
			Information Quality related risks have been categorised.
			Information Quality related risks have been prioritised.
			Risk response actions have been developed (such as acceptance, transfer, avoidance, or mitigation).
		Information Quality Management Cost-Benefit Analysis	Cost impacts of poor Information Quality have been estimated and documented:
			The cost of improvement initiatives has been estimated.
			The benefits of the improvement initiatives have been estimated.
		Business Process Reengineering for Information Quality Improvements	The changes aimed at Information Quality improvements are planed.
			Implementations of any changes are documented.
			It is monitored whether the small scale or experimental changes are achieving the desired result.
			Organisation acts to implement changes on a larger scale if the experiment is successful.
	Enterprise Information Architecture Management	Enterprise Tier Management	Evidence of the following exists in the Enterprise Information Architecture Policy document (or equivalent):
			An Enterprise Business Process Model has been developed.
			An Enterprise Workflow Model has been developed.
		Information Tier Management	A Logical Enterprise Information Model has been developed.
			Any heterogeneous information sources have been combined under a single query interface:
			Horizontal Integration enables inter-departmental integration.
			Vertical Integration allows for drill-down functionality (operational, tactical, and strategic).
			Single Version of Truth (SVOT) has been established.
			The Logical Enterprise Information Model has been mapped to the Enterprise Tier.
		Application Tier Management	The Software Architecture provides the necessary support for the Information/Enterprise tiers.
			The Software Architecture has been mapped to the Information/Enterprise Tiers.
		Physical Tier Management	The Hardware Architecture provides the necessary support for the Software/Information/Enterprise Tiers.
			The Hardware Architecture has been mapped to the Software/Information/Enterprise Tiers.
		Master Data Management	Master information has been centrally consolidated, stored and managed.
			Master information is interrelated and hierarchical.
			Referential integrity is validated.
			Master information reflects business model hierarchies and historical changes.
			Master information is stored separately from transaction information.
			Master information is transferable, in whole or in part, to a data warehouse.
		Information Quality Firewall	Dynamic generation of Information Quality Rules.
			The Information Quality firewall proactively monitors the quality of incoming information.

	IQM Governance	IQM Accountability, Rewards & Incentives: IQ is Everyone's Responsibility	Evidence of the following exists in the Information Quality Management Governance Policy document (or equivalent):
			Information Quality Management roles and responsibilities have been transparently cascaded down throughout the governance hierarchy.
			Disciplinary process for security breaches are in place.
			Information suppliers are accountable for the information they produce.
			Information Quality related rewards and incentives are in place.
			Information Quality is in the job performance review.
		Information Quality Benchmarking	Information Quality Dashboard for top management indicates:
			Internal Focus: Benchmarking Information Quality within the organisation.
			External Focus: Benchmarking Information Quality against world's leading organisations and/or international standards.
		Strategic Information Quality Management	Information Quality Management has been aligned with organisational strategies (business goals).
			Information Quality is in the corporate Balanced Scorecard.
			Information Quality Management ensures the quality of organisational Key Performance Indicators (KPIs).
		Information Quality Audit Trail	Information capture, modification, and destruction are being recorded/logged.
			The Information Quality audit trail enables the reconstruction of events, and ensures accountability.
			Information Quality audit trail logs are being regularly analysed.
Level 3 MEASURING	Information Quality Management Roles and Responsibilities	Information Quality Management Team and Project Management	Evidence of the following exists in the Information Quality Management Policy document (or equivalent):
			A dedicated project manager (Information Quality Champion) is responsible for the Information Quality Management efforts.
			The project scope has been defined.
			Project constraints have been identified.
			Roles, responsibilities, and authorities have been defined and documented.
			Roles, responsibilities, and authorities have been communicated and are enforced.
			The state of Information Quality is being regularly reported to all stakeholders.
			Information Quality Management resources are being effectively managed.
		Information Quality Management Education, Training and Mentoring	All training needs have been identified and documented.
			Regular training workshops are conducted.
			Mentoring programs are in place.
			Security related training programs are conducted.
			Information quality Helpdesk is in place.
			The effectiveness of training initiatives is being regularly reviewed.

		Information Quality Problem Reporting and Handling	Procedures for correction and resubmission of erroneously entered information are in place.
			Standard procedures for Information Quality problem reporting are in place.
			Information Quality problem reports are tracked through to closure.
			Standardised procedures are in place for Information Quality problem reports collection.
			Standardised procedures are in place for Information Quality problem classification.
			Standardised procedures are in place for Information Quality problem resolution.
			Standardised procedures are in place for Information Quality problem feedback.
		Scripted information Cleansing	Scripts are appropriately tested before use.
			Scripts are approved by the change control board before use.
			Incomplete information is identified and enriched from external sources.
	Information Quality Assessment	Information Quality Metrics	Evidence of the following exists in the Information Quality Assessment document (or equivalent):
			Qualitatibe and Quantitative Information Quality Key Performance Indicators (IQ-KPIs) have been defined and documented:
			IQ-KPIs have been named.
			IQ-KPIs have been described.
			Measurement procedures describe how each IQ-KPIs is calculated.
			Measurement frequencies for each IQ-KPI have been specified.
			Target values have been specified for each IQ-KPI.
			Units of measurement have been specified for each IQ-KPI.
		Information Quality Evaluation	Surveys are used to assess information consumers' subjective perceptions of information quality.
			Statistically valid samples of information are being assessed based on the IQ-KPI.
			The quality of information products is assessed (e.g. by aggregating IQ results of each component).
			Information Quality assessments based on business rule violations are in place.
			Dedicated data profiling software tools are used to perform:
			Type verification.
			Range verification.
			Pattern verification.
			Attribute interdependencies verification.
			Table interdependencies verification.
			Duplicate analysis.
			Missing values analysis.

	Information Quality Needs Analysis	Requirements Elicitation	Evidence of the following exists in the Information Quality Needs Analysis Plan document (or equivalent):
			Information Quality dimensions have been clearly defined, documented, and communicated to all stakeholders.
			Information Quality requirements have been collected from a statistically valid representative sample of the critical stakeholders.
			Business rule oriented Information Quality requirements have been identified and documented.
		Requirements Analysis	Information Quality dimensions have been prioritised based on their criticality.
			Information Quality dimensions have been mapped to the corresponding entities in the information model.
			Information Quality dimensions have been mapped to the corresponding business goals and KPIs.
			Information Quality objectives/goals have been specified.
			Minimum and desirable levels of information quality have been specified.
			Information Quality requirements have been verified and validated.
			Stakeholder agreement (win-win) has been reached.
		Requirements Management	Evolving requirements are being appropriately managed (adding, deleting, modifying).
			Information Quality Rules have been documented and are being managed.
			Information Quality requirements are effectively communicated to all stakeholders.
			Information Quality needs are being regularly reviewed.
	Information Product Management	Information Supply Chain Management	Evidence of the following exists in the Information Product Management Plan document (or equivalent):
			Internal information suppliers have been identified and documented.
			External information suppliers have been identified and documented.
			The information flow has been documented.
			Communication between information suppliers and users has been established.
			Information supply agreements have been established.
			Real-Time Information Capture is in place.
			Information is never copied manually.
		Information Product Configuration Management	Configuration Items (CI) have been defined (identified & named).
			Configuration Baselines (CB) have been established.
			A Change Control Board (CCB) is in place.
			Change requests (problem reports) are initiated, reviewed, approved & tracked to closure.
			Configuration Status Accounting (CSA) is in place.
			Formal audits are regularly performed to assess compliance with the CM plan.

		Information Product Taxonomy	Information product hierarchy has been developed and documented.
			Information Product relationships have been identified and documented:
			Dependencies between Information Products.
			Aggregations between Information Products.
			Compositions between Information Products.
			Associations between Information Products.
		Information Product Visualisation	All information products have the same look-and-feel.
			Templates for information products have been categorised and catalogued.
			Templates have been mapped to individual information products.
		Derived Information Products Management	Derived Information Products have been identified and categorised.
			Derivation (analysis) rules have been documented.
			Information products used as inputs for analysis have been identified and documented.
			Derivation rules are regularly reviewed.
		Meta-Information Management	Metadata Registry has been established
			Metadata are stored and managed separately from normal data.
			Metadata taxonomy has been developed and documented.
Level 2 REACTIVE	Information Security Management	Security Classification of Information Products	Evidence of the following exists in the Security Policy document (or equivalent):
			Information product classification guidelines have been developed/documented and are followed.
			Information products containing any intellectual property have been identified and appropriately classified.
			Information products containing any Commercial-In-Confidence information have been identified and appropriately classified.
			Security policies are being regularly reviewed.
			Information Product classifications are regularly reviewed.
			All classified information products have been appropriately labelled.
			Security classification related roles and responsibilities have been defined and documented.
			There is a process in place for reporting of security incidents.
		Secure Transmission of Sensitive Information	All sensitive information is encrypted before it is transmitted over an unsecured channel.
			All non-encrypted sensitive information is transmitted over an encrypted channel.
			All sensitive information transmitted on portable devices (e.g. laptops & PDAs) is encrypted.
			All sensitive hard-copy information products are transported in secure containers.
			Confidentiality agreements are used when sensitive information is communicated to an external party.

		Sensitive Information Disposal Management	Clean desk policy is in place.
			Hardcopy information products are shredded to a level that prevents reconstruction of information, or burnt.
			Optical media (CDs or DVDs) are shredded to a level that prevents reconstruction of information, or burnt.
			Sensitive information on hard drives is deleted by means of dedicated software algorithms that prevent reconstruction.
	Access Control Management	Authentication	Evidence of the following exists in the Access Control Policy document (or equivalent):
			User account management.
			Information System verifies the identity of every user.
			Session time out (users are logged off) after a certain period of inactivity.
			User accounts are being regularly reviewed.
		Authorisation	Information System verifies the privileges of every user (for data access & system functions).
			Every user has the least set of privileges s/he needs (Principle of Least Authority).
			Separations of duty access rules ensure there are no conflicts of interest.
			User privileges are being regularly reviewed.
		Audit Trail	Users' activities are being chronologically recorded/logged.
			The audit trail enables the reconstruction of events.
			Audit trail logs are being regularly analysed.
	Information Storage Management	Physical Storage	Evidence of the following exists in the Information Storage Policy document (or equivalent):
			Information is stored in dedicated areas.
			Physical access control procedures are in place.
			Storage areas are environmentally appropriate.
			The environmental conditions are being continuously monitored/inspected.
			Disaster management plans are in place for all storage facilities.
		Backup and Recovery	Critical information is being backed-up at regular intervals.
			Backups are stored off-site.
			Physical security of the backups is appropriately maintained.
			Backups are periodically restored to a test machine.
			Backups are appropriately labelled (date of backup, backup level, sensitivity level, etc.).
		Redundant Storage	Requirements for replication of information have been identified and documented.
			The information that is replicated has been clearly identified and documented.
			Synchronisation frequency and schedule have been specified and documented.
			Processes are in place to identify and resolve any update anomalies.

		Archival and Retrieval	The requirements for information archival have been documented.
			Archived information has been clearly identified and catalogued.
			The media used for archiving has appropriate longevity.
			The format used for archiving has appropriate longevity.
		Information Destruction	Information is destroyed at regular intervals.
			Information is destroyed only by authorised personnel.
			Information disposal rules have need defined and documented.
	Information Needs Analysis	Stakeholder Management	Evidence of the following exists in the Information Needs Analysis document (or equivalent):
			All stakeholders have been identified and documented.
			Stakeholder taxonomy has been developed.
			Stakeholders' roles and responsibilities have been identified/defined and documented/communicated:
			Information Suppliers (creating or collecting information).
			Information Manufacturers/Stewards (designing, developing, or maintaining the information).
			Information Consumers (using information).
			Information Managers/Owners (managing information).
			Stakeholders have been prioritised.
			Relationships between stakeholders have been identified.
			Relationships between stakeholders and the Information System have been identified.
		Conceptual Modelling	The schema has been documented using a conceptual data modelling notation (e.g. ERM, or UML).
			All entities and relationships have been documented.
			The conceptual schema has been mapped to explicit business requirements.
			Information needs are being regularly reviewed.
		Logical Modelling	All attributes for each entity have been specified.
			The primary key for each entity has been specified.
			Foreign keys for each entity have been specified.
			The schema has been normalised.
			The information dictionary has been created.
		Physical Modelling	Internal DBMS schema has been specified and documented (depicting tables, columns & relationships).
			DBMS integrity constraints have been specified and documented:
			Not null constraints.
			Check constraints.
			Referential integrity constraints.
			Unique constraints.

Level 1 CHAOTIC	

Source: developed from (Simon; Codd 1970; Codd 1972; Kent 1973; Chen 1976; Fagin 1977; DeMarco 1978; Codd 1979; Crosby 1979; Fagin 1979; Ling, Tampa & Kameda 1981; Deming 1982; Kent 1983; Freeman 1984; IEEE 1988; Juran & Gryna 1988; Codd 1990; IEEE 1990; Baskerville 1993; Guha, Kettinger & Teng 1993; Cotterell & Hughes 1995; Guynes & Vanecek 1996; Kaplan & Norton 1996; Sandhu & Samarati 1996; Wang & Strong 1996; IEEE 1997; Mitchell, Agle & Wood 1997; Pouloudi & Whitley 1997; Rhodes 1997; Checkland & Holwell 1998; Gardner 1998; IEEE 1998a; IEEE 1998b; Koh & Watson 1998; Kuny 1998; Wang 1998; English 1999; BS 2000; NAONZ 2000; NZG 2000; Genero, Piattini & Calero 2001; GOSA 2001; NAOA 2001; ASISO 2002; CCSDS 2002; CMMI 2002; NAOA 2002; Pfleeger & Pfleeger 2002; deVries & Verheul 2003; Ferraiolo, Kuhn & Chandramouli 2003; Gobbels & Jonker 2003; GOSA 2003; ISO 2003b; ISO 2003d; ISO 2003a; ISO 2003c; ISO/IEC 2003a; ISO/IEC 2003b; Kankanhalli et al. 2003; McQuaide 2003; Moody & Shanks 2003; Müller & Freytag 2003; Seborg, Edgar & Mellichamp 2003; ANSI/GEIA 2004; Connolly & Begg 2004; Friedman 2004; IEEE 2004; ISO 2004; ISO/IEC 2004c; ISO/IEC 2004d; Luján-Mora & Trujillo 2004; Vanamali 2004; Bassett et al. 2005; ISO 2005e; ISO 2005f; ISO 2005b; ISO 2005a; ISO 2005c; ISO 2005d; ISO/IEC 2005c; ISO/IEC 2005d; ISO/IEC 2005e; ISO/IEC 2005f; ISO/IEC 2005g; ISO/IEC 2005h; ITGI 2005; Moss, Abai & Adelman 2005; NLOA 2005; Pauls 2005; Thomas et al. 2005; Axelrod 2006; Gallegos & Smith 2006; Hu, Ferraiolo & Kuhn 2006; ISO 2006c; ISO 2006d; Lenz, Koppen & Muller 2006; NIST 2006; Rasche & Esser 2006; Soundararajan, Amza & Goel 2006; Zhu, Wu & Chen 2006; GOBC 2007; ISO 2007)

Appendix N: Comparison of IQM-CMM with Related Maturity Models

This appendix presents a comparison between IQM-CMM and several other related maturity models found in literature.

Model:	IQM-CMM
Representation:	Staged
Advantages:	A very detailed inductively developed model, comprising of approximately 50 maturity indicators for effective information quality management, addressing organisational, technical, and social factors. A detailed diagnostic tool, comprising of approximately 250 appraisal criteria, can be used in conjunction with a SCAMPI-like assessment methodology to develop gap-analysis and determine maturity ratings. The research methodology used for model development and testing has been extensively documented.
Disadvantages:	The model is currently only in the 'Staged' representation, and thus, it is currently mainly useful for determining organisational maturity in information quality management. The model could be further extended, so that a 'Continuous' representation could be used to assess the capability of individual maturity indicators.
Model:	Gartner's Data Quality Maturity Model (Bitterer 2007)
Representation:	Staged
Advantages:	Easy to understand and thus could be useful for conveying the notion of data quality management evolution to senior management.
Disadvantages:	The model is very high-level, deductively proposed, and it does not identify explicit maturity indicators for effective information quality management. The model lacks a detailed assessment instrument and methodology. Furthermore, the research methodology used to develop the model is not publicly available.
Model:	Data Management Maturity Model (Chambless & Parker 1998)
Representation:	Staged
Advantages:	Entirely based on the CMM, which has been widely and successfully used in industry. As such, any experienced CMM assessor should be able to perform the assessment.
Disadvantages:	Chambless & Parker proposed the application of CMM key process areas to the domain of data management. However, there are certain issues that have to be considered with this approach. For instance, the domain of data management is very different from the domain of software engineering, and thus, the process areas may not be so easily transferable. Also, software engineering processes are repeatable and the CMM aimed to ensure the repeatability of software development project successes. However, data management is a continuous process, without a clear start and finish.
Model:	The Information Quality Management Maturity Grid (English 1999)
Representation:	Staged / Continuous
Advantages:	Entirely based on Crosby's quality management maturity grid, which has been the inspiration for all subsequent maturity models.
Disadvantages:	The model is very high-level and it does not identify explicit information quality management maturity indicators. Furthermore, the model applies Crosby's ideas, which were aimed at quality management for manufacturing in 1970s to contemporary information quality management problems. The model also lacks a detailed assessment instrument and methodology.

Model:	CALDEA / EVAMECAL (Caballero et al. 2005)
Representation:	Staged
Advantages:	Caballero et al. employed a concept of an Information Management Process (IMP) and considered an Information System (IS) as a set of interrelated IMPs. They proposed a model for data and information quality management (CALDEA) and an assessment and improvement methodology (EVAMECAL) which uses CALDEA as a reference. The model identifies explicit information quality management maturity indicators.
Disadvantages:	CALDEA is based on maturity levels proposed by CMMI and the maturity indicators are based on CMMI's Key Process Areas and authors' experiences. The model has a strong focus on the process of information quality management and it does not really identify factors (organisational, technical, and social) which may negatively affect the quality of information.
Model:	Data Quality Management Maturity Model (Ryu, Park & Park 2006)
Representation:	Staged
Advantages:	Ryu, Park & Park proposed a number of maturity stages relating to information management, showing that higher information management maturity may result in improved information quality. On level 1, data is maintained by the physical attribute definition and reference integrity of tables. Level 2 manages the database based on the logical database model. In level 3, the standardisation of metadata is defined and centrally controlled, and level 4 deals with the management of the standard data architecture.
Disadvantages:	The model was deductively proposed by the researchers and is mainly focused on data management issues, without addressing the information quality management process (e.g. IQ metrics and assessments).
Model:	Data Management Practice Maturity Model (Aiken et al. 2007)
Representation:	Staged / Continuous
Advantages:	Easy to understand and thus could be useful for conveying the idea of data management evolution to senior management.
Disadvantages:	The model was deductively proposed by the researchers (the maturity levels are based on CMMI) and is very high-level, addressing five data management processes (data program coordination, enterprise data integration, data stewardship, data development, and data support organisations).
Model:	Generic Maturity Attribute Table CobiT 4.1 (ITGI 2007)
Representation:	Staged / Continuous
Advantages:	A generic maturity model addressing six high-level attributes, which may be used to assess the maturity of any IT process.
Disadvantages:	This is a generic maturity model, without any specific focus on information management or information quality.