Engineering Asset Management Review 2

Joe E. Amadi-Echendu · Kerry Brown
Roger Willett · Joseph Mathew *Editors*

Asset Condition, Information Systems and Decision Models

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Foreword

I commend this second issue of the Engineering Asset Management Review (EAMR volume 2) to you as we consolidate the establishment of a coherent and integrated body of knowledge to guide all elements of managing physical engineering assets. Each volume in the EAMR Series is a thematic collation of second-level, peer-reviewed collection of selected articles from our past World Congresses on Engineering Asset Management (WCEAM) (www.wceam.com) that began in Australia in 2006 and have since been held in the UK (2007), China (2008), Greece (2009), and Australia (2010) and in the USA in 2011.

Engineering asset management (EAM) is gaining acceptance as a term that encompasses all types of engineered assets, including built environment, infrastructure, and plant and equipment. By this definition, human, financial, and information and communication assets are emphasized only in terms of their relationship with the specific tasks of optimizing the service delivery potential of an engineered physical asset. While optimizing service delivery potential is the primary objective, it is important to note that EAM strives to achieve this in the broader context of maximizing value and minimizing risks and costs. Sustainability imperatives now also impact on EAM, broadening the optimization challenge to incorporate maximization of natural and social capital whilst concurrently minimizing ecological footprint – sometimes interpreted in terms of the corporate social responsibility themes of our asset-intensive organizations.

Within the growing field of EAM persists the longstanding belief that there should be separation between different types of assets in terms of how they are managed. For example, there is a view that civil infrastructure assets should be considered quite separately from manufacturing and process plant and equipment. Yet the asset register in many organizations typically reflects all of these assets, hence representing a need, from a systems perspective, to view all assets in a holistic and transdisciplinary manner.

The civil, mechanical and electrical components that comprise the engineered physical asset base of an organization do not function in isolation from each other. Civil infrastructure is usually constructed to support the operation of various plant and equipment, including mobile assets. For example, rail companies must manage both plant and equipment, such as locomotives and carriages, and rail infrastructure, such as tracks and bridges.

Many organizations utilize corporate enterprise resource planning (ERP) systems, which are gradually driving businesses to consider all types of assets in a strategic and integrated way for effective decisions at the highest levels of governance. The need to have an integrated view of EAM becomes imperative as a result – representing the next big challenge for this field.

I trust that the selected papers in this and future EAM Reviews will continue to add to our understanding and knowledge and assist in consolidating this integrated and holistic systems-orientated view of our developing transdisciplinary field of endeavour.

Australia, May 2012

Professor Joseph Mathew
Chair, Board of Directors
The International Society of
Engineering Asset Management

Preface

Engineering Asset Management Review (*EAMR*) Series is a publication of the International Society for Engineering Asset Management (ISEAM) dedicated to the dissemination of research by academics, professionals and practitioners in engineering asset management. *EAMR* complements other emerging publications and standards that embrace the wide ranging issues concerning the management of engineered physical assets.

The theme of Volume 2, *Asset Condition, Information Systems and Decision Models* focuses on the conversion of raw data into information that should guide managers into making valid decisions, especially regarding the operational condition of assets. The articles contained in EAMR Volume 2 highlight quality issues such as the appropriateness and integrity of data and information that describe the condition or 'health' of the asset. The articles further illustrate how multidisciplinary views of the asset influence, not only the acquisition and analyses of data and information but also, what models are used in making decisions regarding the asset.

The Editors wish to thank all the contributors for their effort and patience through the extended review process and the delays in publishing this EAMR Volume 2. To all readers, we invite your comments and further critique, so that we all may benefit from increased body of knowledge relevant to the management of engineered physical assets.

Australia, New Zealand, May 2012

Joe Amadi-Echendu, Editor-in-Chief
Kerry Brown, Senior Editor
Roger Willet, Senior Editor
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Approaches to Information Quality Management: State of the Practice of UK Asset-Intensive Organisations

Philip Woodall, Ajith Kumar Parlikad and Lucas Lebrun

Abstract Maintaining good quality information is a difficult task, and many leading asset management (AM) organisations have difficulty planning and executing successful information quality management (IQM) practices. The aims of this work are, therefore, to understand how organisations approach IQM in the AM unit of their organisation, to highlight general trends in IQM, and to provide guidance on how organisations can improve IQM practices. Using the case study methodology, the current level of IQM maturity was benchmarked for ten organisations in the U.K. focussing on the AM unit of the organisation. By understanding how the most mature organisations approach the task of IQM, specific guidelines for how organisations with lower maturity levels can improve their IQM practices are presented. Five critical success factors from the IQM-CMM maturity model were identified as being significant for improving IQM maturity: information quality (IQ) management team and project management, IQ requirements analysis, IQ requirements management, information product visualisation and meta-information management.

Keywords Asset information quality, Asset information system, Asset management, Information quality management, Information quality practices, Information quality requirements, Information quality management maturity model

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1 Introduction

Making sound asset management (AM) decisions, such as whether to replace or maintain an ageing underground water pipe, are critical to ensuring that organisations maximise the performance of their assets. These decisions are only as good as the information which supports them, and basing decisions on poor-quality information may result in great economic losses [1]. Maintaining and providing good-quality information is a difficult task, and many leading AM organisations therefore require guidance on how to plan and execute successful information quality management (IQM) practices; typical practices include the identification of IQM key performance indicators and the application of suitable information security procedures. To develop such guidelines and ensure that they are geared towards the current maturity and needs of the organisations, an understanding of the current state of IQM performance (maturity) of AM organisations is required. The research question for this work is therefore: how do organisations approach IQM in the AM unit of their organisation?

To address this question, the Information Quality Management Maturity Model (IQM-CMM) [2], developed specifically within the domain of AM, was used to benchmark the current level of IQM performance in AM organisations. Organisations in the U.K. which have a significant portion of their expenditure and risk associated with the management of their assets were selected for this assessment. Asset managers from ten AM organisations were interviewed using questions developed from the critical success factors (CSFs) contained in the IQM-CMM model. Each organisation was placed in the model, and the maturity level was determined by the extent to which the organisation satisfied the CSFs.

By understanding how the most mature organisations approach IQM, five CSFs which were satisfied by only the higher-level organisations are highlighted; lower maturity organisations can focus on these CSFs to quickly improve their IQM practices.

This paper is organised as follows. Section 2 presents a brief background of asset management. Section 3 describes information quality (IQ) and IQM and reviews the different IQM-related maturity models available. The case study methodology is described in Section 4, and the results and analysis of the maturity benchmarking exercise are presented in Section 5. Section 6 analyses these results and describes the key CSFs which lower maturity level organisations should focus on. Finally, Section 7 presents the conclusions of the paper regarding the current state of IQM practices in AM-related organisations.

2 Assets and Asset Management

In this work, the term *asset* is used to describe physical engineering objects, and examples of assets for the rail and utilities industries include trains, junction boxes, rails, transformers, power cables and water pipelines. AM is defined as the

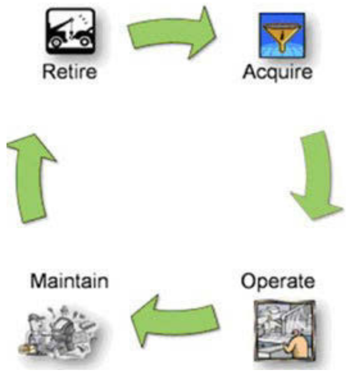

Figure 1 Asset Lifecycle [4]

"systematic and coordinated activities and practices through which an organisation optimally manages its assets, and their associated performance, risks and expenditures over their lifecycle for the purpose of achieving its organisational strategic plan" [3]. A strategic plan in this context is "the overall long-term plan for the organisation that is derived from and embodies its vision, mission, values, business policies, objectives and the management of its risks" [3]. Together, these definitions encompass the whole lifecycle aspect and the physical nature of the assets. For a thorough review of asset management definitions see [4].

As part of the coordinated activities to optimally manage assets, organisations must make decisions which affect the state of their assets for each of the lifecycle stages (Figure 1) while recognising that these decisions are not independent; for example, decisions to acquire new assets are often influenced by asset retirement decisions – hence the asset lifecycle. Coordinating these decisions and understanding the impact of one decision outcome on subsequent decisions is vital to efficient AM. Effective decision-making can be achieved through monitoring and capture of information regarding key events and factors/constraints which affect asset performance and, consequently, organisational performance. With the advent of the Internet, wireless sensing technologies, and the decreasing cost of data storage, it is possible to offer asset managers increasing amounts of information to support their decisions. However, more data does not necessarily mean better information or more effective decisions. This issue is highlighted by Koronios [5], who found that 70 % of generated data is never used by asset managers. Providing asset managers with good quality information and ensuring that effective IQM practices are in place are, therefore, of utmost importance.

3 Information Quality

Different definitions have been used for IQ in the past 20 years [6], and currently, the most widely accepted definition of IQ is "fitness for use" [7, 8, 9, 10]. This definition expresses the fact that IQ is something dependent on the context, and therefore, information considered to be of high quality for one purpose can be considered low quality for a different purpose. Various attempts have been made to refine this definition by incorporating aspects such as consumer viewpoints [8, 11]. English [9] refines the definition by considering IQ to be composed of inherent and pragmatic components, where inherent IQ refers to the correctness of the information, whereas pragmatic IQ refers to the degree of usefulness of the information. Furthermore, two similar categories are also used to define IQ as "conforms to specification" and "meets or exceeds customer expectations" [12].

While such definitions may capture the whole meaning of IQ, they appear impractical for direct measurement [12, 13]. Therefore, to measure IQ in a practical way, IQ is defined along different dimensions [14, 8, 12] such as accuracy, completeness, consistency and timeliness [15]. To maintain high-quality information for all relevant IQ dimensions, suitable IQM practices need to be in place and managed correctly in the organisation.

3.1 Information Quality Management

Information Quality Management can be defined as "the function that leads the organisation to improve information quality by implementing processes to measure, assess costs of, improve and control information quality, and by providing guidelines, policies, and education for information quality improvement" [9], and whose goal is to increase the organisation's effectiveness by eliminating the costs of poor information quality [16]. Some definitions incorporate knowledge management such as the work of Ge and Helfert [17], who defined three areas of research for IQM: quality management, information management and knowledge management. This work, however, excludes the complex area of knowledge management to focus on quality management and information management (Figure 2). Moreover, no comprehensive framework has so far encompassed the three aforementioned approaches to IQM [17], and it is still unclear exactly what IQM encompasses [18]. Note that another important area in IQM relates to the importance

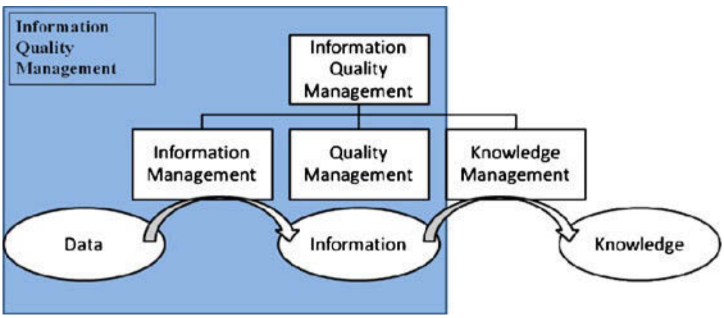

Figure 2 Scope of Research

of people and culture. Having conducted a study on business information quality in Lithuania, Ruževičius and Gedminaitė [19] observed that a change of attitude towards information is needed to succeed in IQM.

3.2 Information Quality Management Maturity Models

A number of IQM maturity models have been developed with different levels of complexity, methods of development and levels of usability (Table 1). The Information Quality Management Capability Maturity Model (IQM-CMM) was developed and validated with AM organisations and is, therefore, ideally suited to the focus of this study. Moreover, it also has a usable and extensive set of process areas (PAs) and CSFs which can be used as appraisal criteria for determining the level of maturity. These CSFs are defined for each of the maturity levels in the IQM-CMM model (optimising, managed, measuring, reactive and chaotic).

A high-level view of the model is shown in Figure 3, which illustrates the maturity levels with brief descriptions of the characteristics of each level. For each maturity level, PAs are defined, and these contain a set of CSFs. The mapping of all PAs to CSFs is shown in the results section in Table 3. Details of the meaning of the CSFs can be found in [2]. The aim of a maturity assessment using this model is therefore to determine the extent to which each CSF is satisfied within an organisation. The results for each CSF are then aggregated to determine the extent to which each PA is satisfied and then aggregated once again to determine whether a maturity level is satisfied.

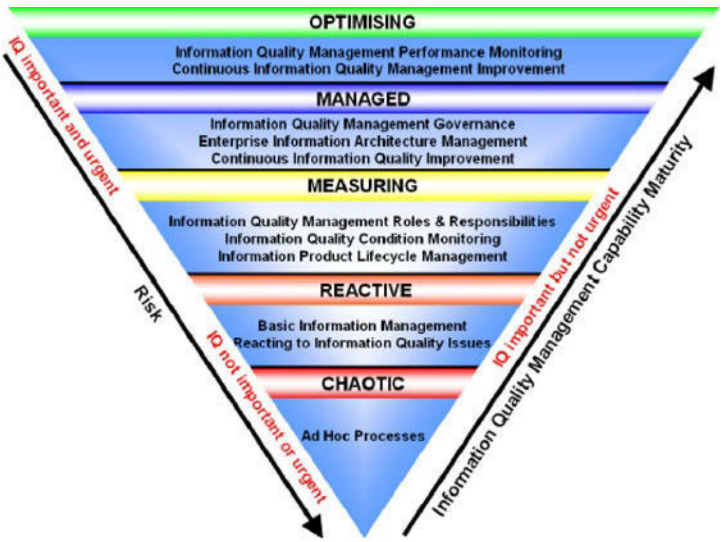

Figure 3 High-Level View of IQM–CMM Maturity Model [2]

Table 1 Existing IQM Maturity Models

Model	Complexity	Method used for development	Usability
IQMMG [11]	6 categories (staged/continuous)	Built from QMMG	No assessment methodology
DGMM [20]	4 categories (staged/continuous)	Not explained	No assessment methodology
DQMMM [21]	Staged: 4 levels	Built from CMMI and authors experience	CEO interview
PAM [22]	28 categories (staged/continuous)	Built from BSI PAS55:2008	121 questions in an Excel tool
IQG [23]	2 axes, 4 quadrants	Not explained	17 criteria
IQMF [24]	Staged: 5 levels, 14 KPAs, 33 activities, 74 Sub-activities	Built from CMMI and authors' experience	190 questions split into 3 levels of depth
IQM-CMM [2]	Staged: 5 levels, 13 PAs, 48 CSFs	Inductively built from case studies	200 appraisal criteria

4 Assessment Process

The case study methodology was used to assess the how organisations approach IQM in the AM unit of their organisation. Case studies are ideal in the following circumstances [25]:

1. The focus of the study is to answer 'how' or 'why' questions.
2. Study participants' behaviour cannot be manipulated.
3. Contextual issues need to be addressed.
4. Boundaries between phenomena and their context are not clear.

Each of these is relevant to the characteristics of this study. The question for this work ('how do organisations approach IQM in the AM unit of their organisation?') is a 'how'-style question and therefore meets the first requirement. In terms of manipulating the behaviour of the people involved with improving IQM, while it may be possible to influence what will be done, it is not possible to influence what has been done to reach the current state of IQM maturity. We also assert that IQM improvement in the AM unit of organisations must be related to the context because IQM improvement will depend on details such as the strategic direction of the organisation, the type of assets owned by the organisation (and hence the type of data/information required), and the type of regulations imposed on the organisation. Finally, the boundaries between the contextual details and IQM improvement are not clear because of the number of different contextual details and the current lack of understanding of the linkage between contextual details and IQM improvement.

4.1 Selection of Cases

Organisations where AM represents a core activity of business were selected as the 'case organisations'. Organisations from different business sectors were selected to ensure that the idiosyncrasies of a single business sector, such as the need to satisfy regulatory requirements, did not bias the understanding of how organisations approach IQM activities. The unit of analysis within the case organisations is the practices related to the improvement and management of IQ in the AM unit of the organisations. This encompasses the AM information systems and the procedures and people involved with AM. The spectrum of organisations chosen encompasses utility (suppliers of water, electricity and gas), transport, defence asset support (defence-related assets are managed via service contracts between organisations), and facility management. A total of ten case study organisations were selected (Table 2). Confidentiality agreements were signed with the organisations; hence the names and identifying details of the organisations are not shown.

Within the case study methodology, semi-structured interviews were used to determine the extent to which each organisation satisfied the CSFs of the IQM-CMM model. The interview consisted of 40 questions, 31 of which were developed from the IQM-CMM model CSFs; the remaining questions focussed on the organisation's future approach to IQM.

Table 2 Business Sectors and Roles of the Interview Respondents for Each Organisation

Case	Business sector	Role of interview respondents
A	Utility	Head of asset information department
		Manager of asset performance team
B	Utility	Business transformation manager, ex-manager of asset information team
C	Defence asset support	Information specialist from information exploitation team
D	Facility management	IT programme manager
E	Utility	Asset information manager
		Asset manager
		Asset manager
		IS development programme manager
F	Facility management	Head of facilities department
		Technical services manager
		Estates and buildings manager
G	Utility	Information delivery manager
		Data integrity team manager
H	Defence asset support	Supply policy manager
I	Defence asset support	Systems architect
J	Transport	Asset information manager

4.2 Selection of Respondents

To ensure suitable respondents were selected, a sample set of questions from the interview was sent to each organisation prior to each interview. Each interview was conducted either over the telephone (8 cases) or face-to-face (2 cases), and recorded with the help of a Dictaphone. Notes were also taken by the interviewer during the interview. The details of the full interview protocol are available on request from the authors. Most organisations had respondents who were asset information specialists, only one organisation, case G, had a dedicated IQ manager (see Table 2). Cases F and H did not have information specialists, and cases D and I had IT specialists. In some cases, the lack of dedicated positions related to IQM was due to resource constraints and business priorities for the two facility management organisations.

5 Maturity Assessment Results

To place each organisation on a particular maturity level, the answers to the 31 maturity interview questions were used to determine the extent to which each CSF was satisfied. The level of satisfaction was measured using an ordinal scale (not satisfied, partially satisfied and fully satisfied). The actual levels of satisfaction for each CSF for the ten organisations (labelled organisation A to J) is shown in Table 3, where '–' represents not satisfied, 'P' partially satisfied and 'S' fully satisfied. The table also shows the maturity level, process areas for each maturity level and the groups of CSFs belonging to each process area. Note that maturity level 1 is not shown in Table 3 because it is always satisfied. The final two columns show the frequencies of partially satisfied (cP) and fully satisfied (cF) across all the organisations.

The processes and systems being analysed were complex, and determining whether these processes and systems met the CSFs was not feasible beyond the scale used. Unfortunately, partially satisfied cannot be interpreted simply as 50 % because in some cases partially satisfied was less than 50 % and in other cases more than 50 %. This does mean that the intervals between these categories are not always equal. Therefore, calculating aggregate measures, such as the mean, using these values for a set of CSFs would violate the restrictions imposed by ordinal scales [26]. The following measures were therefore developed to aggregate the values for the CSFs in Table 3 into maturity levels which could then be used to determine the extent to which an organisation had satisfied each maturity level.

- F = Number of CSFs fully satisfied / Number of CSFs
- FP = Number of CSFs fully satisfied or partially satisfied / Number of CSFs

Table 4 shows the final maturity level of each organisation, and the values of 'F' and 'FP' for each maturity level are shown as percentages. For example, for organisation A no CSFs were fully satisfied for maturity level 4, but 3 out of 13 CSFs were fully or partially satisfied for maturity level 4, which is shown as 23 % in the FP column for organisation A. A maturity level was deemed satisfied when F > 50 and FP > 80; the final maturity levels of the organisations are shown in the bottom row.

Table 3 CSFs Satisfied by the Organisations (– = Not Satisfied, P = Partially Satisfied, S = Fully Satisfied)

Maturity Level	Process Area	CSF	Organisation A	B	C	D	E	F	G	H	I	J	cP	cF
5	IQ Firewall	IQ Firewall	–	–	–	–	–	–	–	–	–	–	0	0
5	IQ Management Performance 'Monitoring'	IQ Management Metrics	–	–	–	–	–	–	–	–	–	–	0	0
		Analysis and Reporting	–	–	–	–	–	–	–	–	–	–	0	0
		IQ Management Benchmarking	–	–	P	–	–	–	P	–	–	–	2	0
4	Continuous IQ Improvement	IQ Problem Root–Cause–Analysis	–	P	S	–	–	–	–	–	–	–	1	1
		IQ Risk Management and Impact Assessment	P	–	–	P	–	–	S	P	P	–	4	1
		IQ Management Cost–Benefit Analysis	–	–	S	–	P	–	–	S	–	–	1	2
		Business Process Reengineering for IQ Improvements	–	–	S	P	–	–	–	P	–	–	2	1
4	Enterprise Information Architecture Management	Enterprise Tier Management	P	P	S	P	P	P	S	S	P	P	7	3
		Information Tier Management	–	P	P	–	–	–	P	–	P	P	5	0
		Application Tier Management	–	S	S	P	P	–	P	P	P	–	5	2
		Physical Tier Management	P	P	S	P	P	P	P	–	S	P	7	2
		Master Data Management/Redundant Storage	–	P	P	–	–	–	P	–	–	–	3	0
4	IQM Governance	IQM Accountability, Rewards & Incentives: IQ is Everyone's Responsibility	–	–	P	P	–	–	–	P	–	–	3	0
		IQ Benchmarking	–	P	P	–	–	–	–	–	–	–	2	0
		Strategic IQ	–	–	P	–	P	–	P	–	–	–	3	0
		IQ Audit Trail	–	P	S	–	P	–	–	–	P	–	3	1
3	IQ Management Roles and Responsibilities	IQ Management Team and Project Management	P	P	S	–	P	–	S	–	–	P	4	2
		IQ Management, Education, Training and Mentoring	–	–	P	–	–	–	P	–	–	–	2	0
		IQ Problem Reporting and Handling	–	–	P	–	–	–	P	–	P	–	3	0
		Scripted information Cleansing	–	–	S	S	P	–	–	–	–	S	1	3
3	IQ Assessment	IQ Metrics	–	–	P	–	–	–	P	P	–	–	3	0
		IQ Evaluation	–	P	P	P	–	–	P	P	P	–	6	0

Table 3 (*continued*)

Maturity Level	Process Area	CSF	Organisation A	B	C	D	E	F	G	H	I	J	cP	cF
3	IQ Needs Analysis	Requirements Elicitation	P	P	S	P	P	P	P	S	P	P	8	2
		Requirements Analysis	–	P	S	–	–	–	S	P	–	–	2	2
		Requirements Management	–	–	S	–	–	–	S	P	–	–	1	2
3	Information Product Management	Information Supply Chain Management	–	P	S	P	–	–	S	S	P	P	4	3
		Information Product Configuration Management	–	S	S	S	S	–	S	S	S	S	0	8
		Information Product Taxonomy	P	S	S	S	P	P	S	S	P	P	5	5
		Information Product Visualisation	P	P	S	P	P	P	S	P	P	P	8	2
		Derived Information Products Management	S	P	S	–	P	–	–	S	–	–	2	3
		Meta-information Management	–	P	S	–	P	–	S	P	–	–	3	2
2	Information Security Management	Security Classification of Information Products	S	S	S	S	S	S	S	S	S	P	1	9
		Secure Transmission of Sensitive Information	S	S	S	S	S	S	S	S	S	S	0	10
		Sensitive Information Disposal Management	S	S	S	S	S	S	S	S	S	S	0	10
2	Access Control Management	Authentication	S	S	S	S	S	S	S	S	S	S	0	10
		Authorisation	S	S	S	S	S	S	S	S	S	S	0	10
		Audit Trail	S	S	S	P	S	–	P	P	S	S	3	6
2	Information Storage Management	Physical Storage	S	S	S	S	S	S	S	S	S	S	0	10
		Backup and Recovery	S	S	S	S	S	S	S	S	S	S	0	10
		Archival and Retrieval	S	S	S	S	S	S	S	S	S	S	0	10
		Information Destruction	S	S	S	S	S	S	S	S	S	S	0	10
2	Information Needs Analysis	Stakeholder Management	S	S	S	S	S	S	S	S	S	P	1	9
		Conceptual Modelling	S	S	S	S	S	S	S	S	P	P	2	8
		Logical Modelling	S	S	S	S	S	S	S	S	S	P	1	9
		Physical Modelling	S	S	S	S	S	S	S	S	S	P	1	9

Table 4 Final Maturity Level of Each Organisation with Percentage Values of F and FP for each Maturity Level

Maturity Level	Organisation A		B		C		D		E		F		G		H		I		J	
	F	FP	F	FP	F	FP	F	FP	F	FP	F	FP	F	FP	F	FP	F	FP	F	FP
5 – Optimising	0	0	0	0	0	25	0	0	0	0	0	0	0	25	0	0	0	0	0	0
4 – Managed	0	23	8	62	54	92	0	46	0	46	0	15	15	54	15	46	8	46	0	23
3 – Measuring	7	33	13	67	73	100	20	47	7	53	0	20	53	87	33	73	7	47	13	47
2 – Reactive	100	100	100	100	100	100	93	100	100	100	93	93	93	100	93	100	93	100	64	100
1 – Chaotic	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Final Maturity Level	2		2		4		2		2		2		3		2		2		2	

5.1 General Trends in Implementing Information Quality Management Practices

Figure 4 illustrates the aggregated (for all organisations) level of satisfaction for each CSF. The actual values (cP and cF) for this figure are shown in the rightmost columns of Table 3, where these values are represented as percentages. For ex-

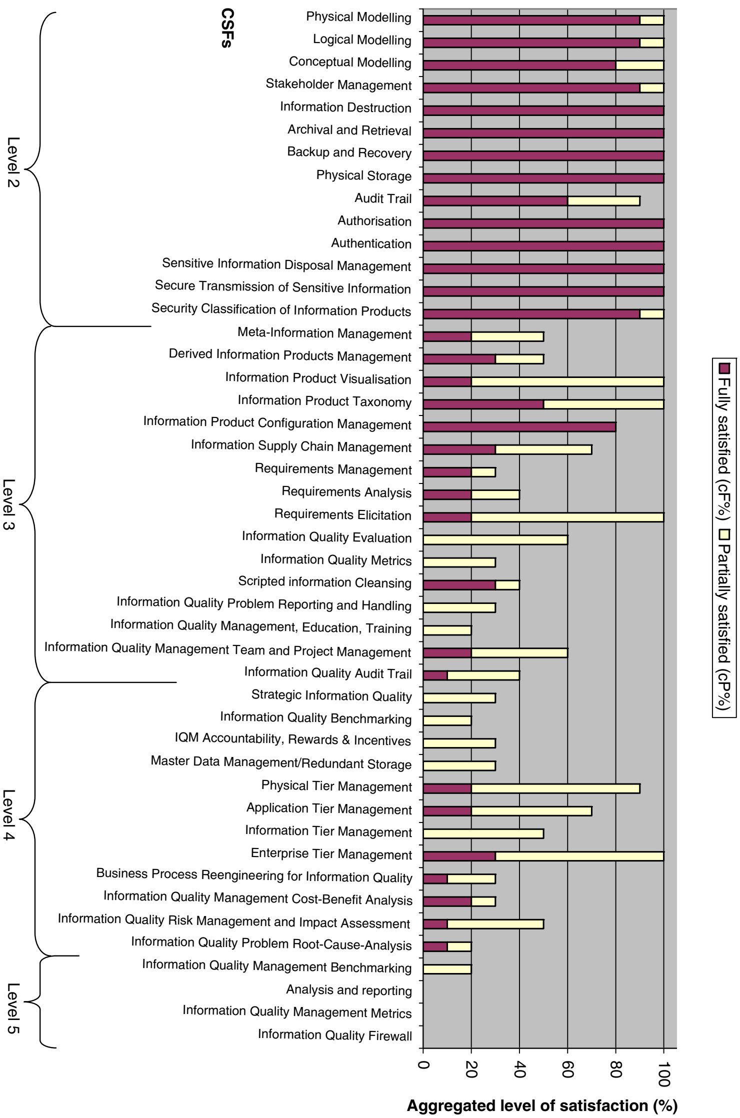

Figure 4 Aggregated Level of Satisfaction of CSFs for All Organisations