BENCHMARKING INFORMATION QUALITY PERFORMANCE IN ASSET INTENSIVE ORGANISATIONS IN THE UK

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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 aim of this work is, therefore, to provide guidance on how organisations can improve IQM practices within the AM unit of the business. Using the case study methodology, the current level of IQM maturity was benchmarked for ten AM organisations in the UK by 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: IQ management team and project management, IQ requirements analysis, IQ requirements management, information product visualisation and meta-information management

Keywords: Information Quality, Information Quality Management, Information Quality Maturity, Benchmarking Information Quality, Asset Management, Information Quality Performance.

1. INTRODUCTION

Making sound asset management (AM) decisions, such as whether to replace or maintain an ageing underground water pipe, are critical to ensure 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 can potentially result in great economic losses [13]. 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 practices; typical practices include the identification of information quality management key performance indicators and the application of suitable information security procedures. In order 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 information quality management performance (IQ maturity) of AM organisations is required.

The Information Quality Management Maturity Model (IQM-CMM) [2], which has been developed specifically with the domain of asset management, was used to benchmark the current level of information quality management (IQM) performance in AM organisations. Organisations in the U.K. that have a significant portion of their expenditure and risk associated with the management of their assets were selected for this assessment. These companies were interviewed using questions that were 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, the CSFs which were satisfied by only the higher level organisations are presented as CSFs which lower maturity level organisations should focus on to improve their IQM practices.

This paper is organised as follows: section 2 presents a short background of asset management. Section 3 describes information quality, IQM and reviews the different IQM related maturity models available. The case study methodology is described in section 4 and the results of the maturity benchmarking exercise are presented in section 5. Section 6 analyses these results and describes the key CSFs which lower level maturity 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

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. Asset management is defined as the "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" [23]. 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" [23]. Together, these definitions encompass the whole lifecycle aspect and the physical nature of the assets. For a thorough review of asset management definitions see [22].

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 (see 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 asset management. Effective decision-making can be achieved through monitoring and capturing of information regarding key events and factors/constraints that impact on 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 [18], 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 is, therefore, of uttermost importance.

Figure 1: The Asset Lifecycle [22]

3. INFORMATION QUALITY

Numerous differing definitions have been used for IQ in the past 20 years [11]. Currently, the most widely accepted definition for IQ is Juran's definition "fitness for use" [16],[28],[27],[20]. This definition expresses the fact that IQ is something dependent on the context and high quality information for a purpose can be considered low quality for a different purpose. Moreover, the literature adds that IQ has to be seen from a consumer viewpoint [28],[9].

English [9] defines IQ as "consistently meeting knowledge worker and end-customer expectations", and that it is composed of two elements: inherent and pragmatic IQ. Inherent IQ refers to the correctness of the information while pragmatic IQ refers to the degree of usefulness of the information. Two similar categories are also used to define IQ as "conforms to specification" and "meets or exceeds customer expectations" [17].

While such definitions may capture the whole meaning of IQ, they appear impractical for direct measurement [17],[1]. Therefore, in order to measure IQ in a practical way, IQ is defined along different dimensions [24],[28],[17] such as accuracy, completeness, consistency, and timeliness as the most commonly used [4]. In order to maintain high quality information for all 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 [10]. Some definitions incorporate the area of knowledge management such as the work of Ge & Helfert [14] 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 in order to focus on the quality management, information management (see Figure 2). Moreover, no comprehensive framework has so far encompassed the three aforementioned approaches to IQM [14] and it is still unclear what IQM exactly encompasses [19]. Note that another important area in IQM relates to the importance of people and culture. Having conducted a study on business information quality in Lithuania, Ruževičius & Gedminaitė [25] observed that a change of attitude towards information is needed in order to succeed in IQM.

Figure 2: The Scope of this Research

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 (see Table 1). The Information Quality Management Capability Maturity Model (IQM-CMM) was developed and validated with asset management 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 critical success factors (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).

Table 1: Existing IQM maturity models

Model	Complexity	Method used for development	Usability
IQMMG [9]	6 categories (staged/continuous)	Built from QMMG	No assessment methodology
DGMM [7]	4 categories (staged/continuous)	Not explained	No assessment methodology
DQMMM [26]	Staged: 4 levels	Built from CMMI and authors experience	CEO interview
PAM [15]	28 categories (staged/continuous)	Built from BSI PAS55:2008	121 questions in an Excel tool
IQG [8]	2 axes, 4 quadrants	Not explained	17 criteria
IQMF [6]	Staged: 5 levels, 14 KPAs, 33 Activities, 74 Sub-activities	Built from CMMI and authors experience	190 questions split in 3 levels of depth
IQM-CMM [2]	Staged: 5 levels, 13 PAs, 48 CSFs	Inductively built from case studies	200 appraisal criteria

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 are 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.

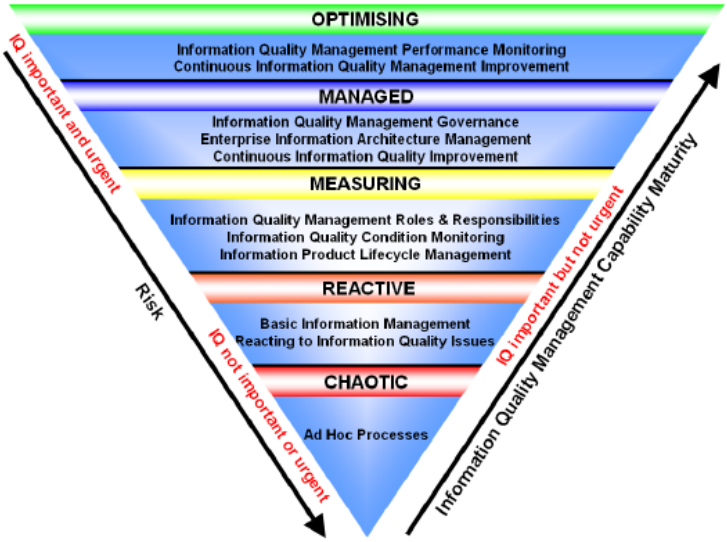

Figure 3: High-level view of the IQM-CMM Maturity Model [2]

4. METHODOLOGY USED TO UNDERSTAND WHAT APPROACHES ASSET MANAGEMENT ORGANISATIONS USE TO IMPROVE IQM

The case study methodology was used to determine the how organisations approach information quality management in the asset management unit of their organisation. Case studies are ideal in the following circumstances [5]:

1. The focus of the study is to answer how or why questions
2. It is not possible to manipulate the behaviour of those involved in the study
3. Contextual issues need to be covered
4. The boundaries are not clear between the phenomenon and the context

Each of these is relevant to the characteristics of this study. The question for this work ('how do organisations approach the task of improving information quality management in the asset management 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 part 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 is 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 asset management represents a core activity of their business were selected as the 'case organisations'. The unit of analysis within the case organisations is the practices related to the improvement and management of IQ in the AM part of the organisations. This encompasses the AM information systems, the procedures and people involved with asset management. 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 10 case study organisations were selected, the list of which is shown in Table 2. Confidentiality agreements were signed with the organisations, hence the names and identifying details of the organisations are not shown.

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

Case	Business Sector	Roles 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

Within the case study methodology, semi-structured interviews were used to determine the extent to which each organisation satisfies the CSFs of the IQM-CMM model. The interview consisted of 40 questions, 31 were developed from the IQM-CMM model CSFs and the remaining 5 questions focussed on asking about the organisation's future approach to IQM.

4.2. Selection of respondents

In order 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, nonetheless 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

In order to place each organisation in a particular maturity level, the answers to the 31 maturity interview questions were used to determine the extent to which each CSF is 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' represents partially satisfied and S represents 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 column shows the one of four different categories to which each CSF has been allocated. These four categories are Information Management (IM), Technical IQM (TIQM), Organisational IQM (OIQM), and People IQM (PIQM), and were established for the analysis of the different topics of IQM. This classification follows the TOP model adapted for the area of asset management [21] and includes the IM area due to the identification of the differences between IM and IQM [3].

Table 3: CSFs satisfied by the organisations ("-" = Not Satisfied, P = Partially Satisfied, S = Fully Satisfied)

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

		Information Product Visualisation	P	P	S	P	P	P	S	P	P	P
		Derived Information Products Management	S	P	S	-	P	-	-	S	-	-
		Meta Information Management	-	P	S	-	P	-	S	P	-	-
2	Information Security Management	Security Classification of Information Products	S	S	S	S	S	S	S	S	S	P
		Secure Transmission of Sensitive Information	S	S	S	S	S	S	S	S	S	S
		Sensitive Information Disposal Management	S	S	S	S	S	S	S	S	S	S
2	Access Control Management	Authentication	S	S	S	S	S	S	S	S	S	S
		Authorisation	S	S	S	S	S	S	S	S	S	S
		Audit Trail	S	S	S	P	S	-	P	P	S	S
2	Information Storage Management	Physical Storage	S	S	S	S	S	S	S	S	S	S
		Backup and Recovery	S	S	S	S	S	S	S	S	S	S
		Archival and Retrieval	S	S	S	S	S	S	S	S	S	S
		Information Destruction	S	S	S	S	S	S	S	S	S	S
2	Information Needs Analysis	Stakeholder Management	S	S	S	S	S	S	S	S	S	P
		Conceptual Modelling	S	S	S	S	S	S	S	S	P	P
		Logical Modelling	S	S	S	S	S	S	S	S	S	P
		Physical Modelling	S	S	S	S	S	S	S	S	S	P

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, assigning values of 0 to not satisfied, 0.5 to partially satisfied, and 1 to fully satisfied, and calculating the mean of these for a set of CSFs would violate the restrictions imposed by ordinal scales [12]. The following measures were, therefore, developed to aggregate the values for the CSFs in Table 3 into maturity levels which, although more complicated than a single value, adhere to the restrictions imposed by ordinal scales:

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

These two measures were chosen insofar as they represent lower and upper boundaries of the actual satisfaction of the CSFs. By analysing both, a good evaluation of the actual extent of satisfaction of the CSFs is obtained.

Table 4: The final maturity level of each organisation with percentage values of F and FP for each maturity level

Maturity Level	Organisations																			
	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	

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 percent 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.

6. GUIDELINES FOR IMPROVING INFORMATION QUALITY MANAGEMENT PRACTICES

There are five CSFs which have been fully satisfied by the highest level maturity organisations that have not been fully satisfied by any of the lower level (level 2) organisations. The higher level organisations have therefore demonstrated the feasibility to fully implement these CSFs and obtain higher maturity levels (level 3 for case G and level 4 for case C). These five CSFs (shown in Table 5) are therefore ideal candidates for the level 2 organisations to focus on in order to improve their IQM practices.

The ‘IQ management team and project management’ CSF requires the formal management of all IQM practices. This includes allocating the key roles for the project, determining the scope of the work that is required, deliverables of the project, business/technical aspects of the project, and estimating the project costs and benefits [2].

In the process area of ‘IQ needs analysis’ the CSFs ‘requirements analysis’ and ‘requirements management’ have received very little attention from lower maturity level organisations. The precursor to these CSFs is ‘requirements elicitation’ which, in general, involves speaking to stakeholders to determine what the current IQ problems are and then defining them. Interestingly, all of the organisations have attempted some aspect of ‘requirements elicitation’, but these organisation should now focus on prioritising these IQ problems, mapping them to specific systems, and determining the desirable levels of IQ as part of the ‘requirements analysis’ CSF. Furthermore, changes to the problems and effective communication of the analysis should be managed, and regular reviews of quality should be established for the ‘requirements management’ CSF.

The key aspect for satisfying the ‘information product visualisation’ CSF is to ensure that the same information, in multiple systems, is represented consistently. The maturity level 2 organisations partially satisfy this CSF by using the predefined forms which exist with the various information systems used in the AM unit of the organisation, but in order to take the next step, organisations need to find ways to ensure that these are as consistent as possible across different systems.

Meta data is the data describing the data in the AM related information systems and comprises properties such as edit history, ownership, and security level. The establishment of a meta data registry is required for the ‘meta information management’ CSF to be satisfied, which means that meta data is stored and managed separately from standard AM related data.

Table 5: Candidate CSFs for improving IQM practices for organisations in maturity level 2

			Organisations									
			High		**Maturity Level 2**							
Maturity Level	**Process Area**	**CSF**	**C**	**G**	**A**	**D**	**E**	**F**	**B**	**H**	**I**	**J**
3	IQ Management Roles and Responsibilities	IQ Management Team and Project Management	S	S	P	-	P	-	P	-	-	P
3	IQ Needs Analysis	Requirements Analysis	S	S	-	-	-	-	P	P	-	-
3	IQ Needs Analysis	Requirements Management	S	S	-	-	-	-	-	P	-	-
3	Information Product Management	Information Product Visualisation	S	S	P	P	P	P	P	P	P	P
3	Information Product Management	Meta Information Management	S	S	-	-	P	-	P	P	-	-

7. CONCLUSION

The IQM maturity of the AM unit of ten organisations was benchmarked in order to understand how organisations approach IQM. Most of the organisations find IQM a challenge to improve and need guidance on how to advance from their current level of maturity. No organisation is currently at the top level of the maturity model and so there is scope for improvement in all of the organisations surveyed. An analysis of how the critical success factors (CSFs) in the IQM-CMM maturity model were satisfied showed that five CSFs were fully satisfied by the two higher maturity level organisations and these were never fully satisfied by any of the lower maturity organisations. These five CSFs are therefore candidates for the lower maturity organisations to focus on in order to quickly improve their IQM practices. The CSFs concern: IQ Management Team and Project Management, Requirements Analysis, Requirements Management, Information Product Visualisation, and Meta Information Management. Further work is required to validate this recommendation with other organisations.

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9. ACKNOWLEDGMENTS

We would like to thank all the respondents for committing the time and effort to take part in this study, their help is very much appreciated. We also thank Alex Borek for help with proof reading this work and EPSRC for supporting this research.