TOWARDS A COMPREHENSIVE APPROACH FOR EVALUATING AND IMPROVING INFORMATION (QUALITY) MANAGEMENT CAPABILITY MATURITY: A CASE STUDY OF INTEGRATED LOGISTIC SUPPORT IN A LARGE AUSTRALIAN ENGINEERING ASSET MANAGEMENT ORGANISATION

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ABSTRACT

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. Nevertheless, many organisations still struggle to assess their Information (Quality) Management practices, and thus also find it difficult to develop potential improvement strategies. In this paper, we illustrate a comprehensive approach for evaluating Information (Quality) Management practices, with a case study of a large Australian Engineering Asset Management Organisation. We finally propose a range of strategies which may be utilised to ensure and enhance information quality in complex Engineering Asset Management Information Systems.

KEYWORDS

Data/Information Quality, Data/Information Management, Integrated Logistic Support, Engineering Asset Management, Case Study, Capability Maturity Assessment

INTRODUCTION

> "*British Gas officials stunned staff at an Oxford University college after sending them a £4.6m gas bill. Eric Bennett, the home bursar at Exeter College, and his staff were amazed when they saw the staggering bill for £4,679,601.32. The bill covered a period of 19 days in December [of 2006]*." [1]

Gartner Research has reported that through 2008, organisations that ignore Information Management (IM), will struggle to maintain their status in business environments [2]. Hence, an increasing number of contemporary organisations are beginning to realise the importance of IM and Information Quality (IQ) to effective decision making and successful business operations. However, contemporary enterprises have in recent times experienced significant change, most of which has been technologically driven, which has resulted in an overabundance of information [3]. Yet, such information abundance has not necessarily resulted in more informed organisations or more effective decision making. Consequently, enterprises are now managing more information than ever before and are gradually becoming more aware of resulting IQ issues.

Even though there has been growing awareness of IQ issues, many organisations find it difficult to assess their current Information Quality Management (IQM) capability. That is, many organisations are not sure about how well they manage their information, how confidently they can ensure information quality, and how their practices compare to other organisations' methods. For that reason, this paper illustrates the IQM Capability Maturity Model (IQM-CMM) and the associated appraisal instrument, which was applied in a case study to evaluate IM and IQM processes employed in a large Australian Engineering Asset Management Organisation (EAMO). Hence, this paper may be of interest to other EAMOs who may wish to assess and/or enhance their IQM competency.

BACKGROUND

In this section, we present a brief overview of the relevant parent theories, including Total Quality Management (TQM), Quality Management Maturity, and Information Quality Management literature.

Total Quality Management

Producing quality products and delivering quality services are considered fundamental for success and continued existence in contemporary competitive business environments [4]. Furthermore, it has been argued that quality is the single most important force in organisational success and growth in national and international markets [5]. This section presents a brief review of literature related to Quality Control (QC), Quality Assurance (QA), and Total Quality Management (TQM).

QC refers to the practice of measuring quality at the end of the production line. Thus, defective products can be found and may be removed or fixed prior to delivery. QA refers to the practice of building quality into processes, thus preventing defects from occurring in the first place. TQM refers to holistic, organisation wide efforts of QA, emphasising customer-driven quality management and continuous process improvements.

Walter Shewhart is considered by many to be the founder of the modern quality movement, having developed statistical control charts and Shewhart cycle for continual improvement. He argued that quality has two aspects; the objective aspect, relating to quality characteristics inherent to the product/service, and the subjective aspect, relating to subjective (user/customer defined) quality characteristics. According to Shewhart, although the objective aspects of quality are usually measured, subjective aspects of quality may be of greater commercial interest [6]. Philip Crosby defined quality as conformance to requirements [7], describing it as a difference between two states (preferred and actual states). For instance, customer expectations can be seen as the preferred state and the concrete product or service as the actual state. He also pioneered the idea of quality management maturity. Juran defined quality as "fitness for use" [8], and introduced the idea of quality trilogy: Quality Planning, Quality Control and Quality Improvement [9]. Quality Planning provides a system that is capable of meeting quality standards; quality control is used to determine when corrective action is required; and quality improvement corrects root causes of quality problems. W. Edwards Deming [10] defined quality as a predictable degree of uniformity and dependability. He is perhaps best known for his 14 points of quality, and for helping to lead the Japanese manufacturing sector out of the ruins after the Second World War. As a consequence the highest quality award in Japan, The Deming Prize, was named in his honour. He also slightly modified the Shewhart cycle to the contemporary Deming Cycle (Plan – Do – Study – Act). Furthermore, he argued that the customer is the most important part of the production line and that improvements in quality lead to improvements in productivity as well as competitive position [10]. Kaoru Ishikawa [11] is credited with developing the idea of company-wide quality control in Japan. He pioneered the use of quality circles and various other tools to understand the root causes of quality problems. He also developed one of those tools, the Cause-And-Effect-Diagram (also known as Ishikawa Diagram or the Fishbone Diagram).

Numerous researchers have, over the years, proposed a wide range of Critical Success Factors (CSFs) for TQM [12-20]. Motwani [21] conducted a comparative analysis of six empirical studies on CSF for TQM [22-27], where he grouped similar constructs to arrive at seven primary factors: top management commitments, quality measurements and benchmarking, process management, product design, employee training and empowerment, supplier quality management, and customer involvement and satisfaction.

Quality Management Maturity

The idea of Quality Management Maturity originated with Philip Crosby in 1979 [7]. He proposed five levels of organisational quality management maturity: Uncertainty, Awakening, Enlightenment, Wisdom, and Certainty, which depend on various factors including, management understanding and attitude, problem handling, quality improvement actions, and so on. His ideas were then further developed by IBM and applied to the software engineering discipline in 1985 [28]. The Software Engineering Institute (SEI) at the Carnegie Mellon University (CMU) and the United States Department of Defense (US DOD) further developed the quality maturity idea, by developing the Capability Maturity Model (CMM), beginning in 1986 [29]. CMM has been extensively used by the US DOD to evaluate its software and system developers and the current CMM release, 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 comprises of five maturity levels, which represent an evolutionary path of increasingly structured and methodically more mature software engineering processes. Following the success of CMM and the Capability Maturity Model Integration (CMMI) [30], numerous maturity models have been developed for a wide range of diverse domains, including a number of IQM Maturity Models [31-34]. However, all existing IQM maturity models have been lacking a detailed assessment instrument, which is the gap in the literature that we aim fill with this paper.

Information Quality Management

According to Information Theory, which was largely developed at Bell Labs in the 1940s, information serves to reduce uncertainty [35-37]. Handscombe & Patterson [38] describe the quantity of information as "the ratio of the number of possible answers before and after receiving information" (p. 28). 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 [39, 40]. Consequently, organisations are coming to view quality information as one of their most important assets [41, 42].

Numerous researchers have attempted to define data quality and to characterise its dimensions, such as accuracy, completeness, timeliness, relevance and so on [41, 43-55]. What also makes defining IQ more difficult is the fact that 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 [56]. Thus, improving IQ still remains a difficult task, given the fact that 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) [49]. Subsequently, an IQ problem has been defined as any difficulty encountered along one or more quality dimensions that renders data completely or largely unfit for use [57].

The Total Data Quality Management (TDQM) framework adapted the Total Quality Management (TQM) principles to IQM, by drawing a correlation between traditional product manufacturing and the manufacturing of Information Products (IP) [58]. Therefore, the quality of resulting IPs may be directly affected by the quality of processes employed in the Information System (IS). Consequently, it is important to ensure that processes at each stage of information lifecycle do not have a negative impact on the quality of information they manipulate. The TDQM methodology has further adapted the quality improvement cycle from the manufacturing industry to IQ enhancement, by applying the "Plan, Do, Check, Act" cycle from Deming's (TQM) literature [10] to IP quality enhancements, thereby emphasising that IQ improvements depend on continuous feedback to the processes producing the IP.

METHDOLOGY

The IQM-CMM was developed in two stages. Stage one identified a range of IQM Capability Maturity indicators, through exploratory case studies and extensive literature review. The maturity indicators were examined from three perspectives: organisational, social, and technological. Stage two involved a two round Delphi Study, which was used to validate and group individual maturity indicators into staged levels. The first round of the Delphi study 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 (IQ) practitioners and academics. The second round was conducted online and additionally included members of the International Association for Information and Data Quality (IAIDQ). Finally the resulting model was applied in a large Australian EAMO in order to assess information (quality) management practices employed by its Integrated Logistic Support (ILS) department. This paper illustrates preliminary results of that case study. According to Yin [59] this case study can be classified as being explanatory in nature, since it is used to investigate casual relationships and to test prior theory. Explanatory case studies are characterised by "how and "why" research questions because they investigate the relationships that are proposed between different theory components [60]. Inconsistencies between a preliminary theory and the evidence are accommodated in an explanatory case study design by revising the preliminary theory [61]. Yin [60] defines 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). Thus, following recommendations from literature [60, 62], a range of documents were examined in the organisation, which provided us with great insights into business processes employed by the organisation as well as the overall design and use of the information system under investigation. Additionally, about dozen in-depth interviews were conducted with relevant personnel, including the ILS manager, logistic information systems manager, ILS systems support manager, as well as a number of business analysts and database administrators. Furthermore, personnel were observed while using the information system and the associated database. The assessment was carried out over a period of about six months.

INFORMATION (QUALITY) MANAGEMENT CAPABILITY MATURITY ASSESSMENT

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 criteria. Partial IQM-CMM is shown in the table below. The complete IQM-CMM includes 50+ criteria, and the assessment instrument employs approximately five appraisal measures per criteria, thus resulting in approximately 250 appraisal measures.

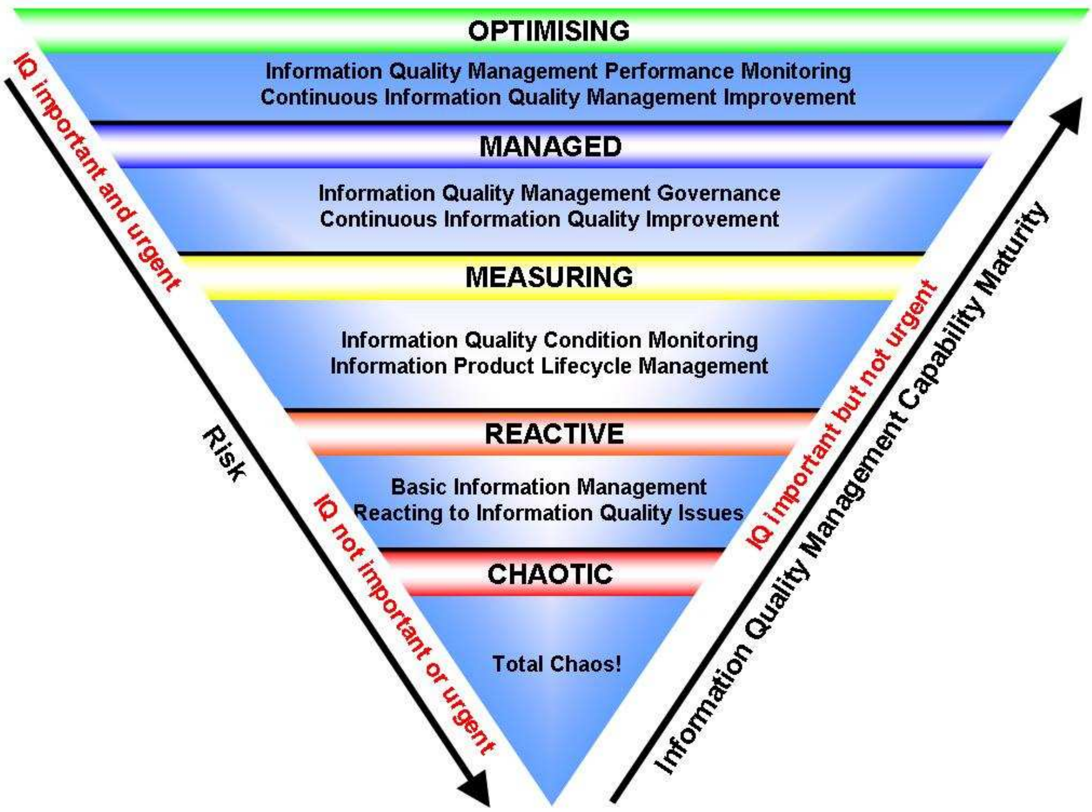

Figure 1 Information Quality Management Capability Maturity Model

Table 1 Partial Information Quality Management Capability Maturity Model (IQM-CMM), developed by the authors

Maturity Level	Maturity Indicator	Criteria
Level 5 OPTIMISING	Continuous IQM Improvement	IQ in Corporate Balanced Scorecard
		PDCA Cycle for IQ Improvement
Level 4 MANAGED	Single Point of Truth	Information Integration
		Data Warehousing
	IQM Governance	IQ Accountability
		IQ Risk Management & Impact Assessment
Level 3 MEASURING	Information Product Management	Information Product Supply Management
		Information Product Templates
	IQM Roles & Responsibilities	Information Profiling & Enrichment
		IQ Metrics and IQ Assessment
	Security Management	Secure Transmission of Information Products
		Sensitive Information Disposal Management
Level 2 REACTIVE	Information Modelling Management	Conceptual Information Modelling
		Physical Information Modelling
	Information Storage Management	Backup & Recovery
		Redundant Storage Management
	Access Control Management	Authentication
		Audit Trail
Level 1 CHAOTIC	No Maturity Indicators	

Information Quality

Organisational Background

XYZ was the principal contractor for the design, and construction of several large and complex engineering assets. XYZ has also been awarded a multi-billion dollar contract for the through-life support of those assets initially over 15 years, with the responsibility for the design, maintenance and enhancement until the end of their operational lives. XYZ's Integrated Logistic Support (ILS) Department manages and controls the integrated logistic support activities for these assets. A simplified XYZ-ILS department structure is shown in the figure below.

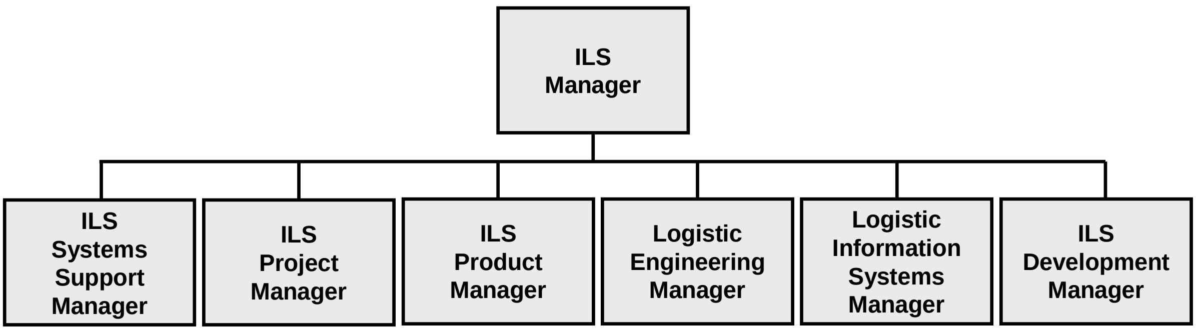

Figure 2 XYZ-ILS (simplified department structure), developed by the authors

XYZ-ILS mainly deals with two types of asset data: design data (e.g. design specifications and reports which represent various base lines), and logistic data (e.g. maintenance procedures, technical manuals and provisioning technical documentation). XYZ-ILS maintains three major computer systems. System A contains all the data and technical documentation required to support the operation and maintenance of the assets. It was developed by XYZ in the early 1990s and it provides a management capability for the logistic support, including configuration management, maintenance management, documentation management, safety management, and so on. System A was originally developed by XYZ for the purpose of supporting the build of the assets, and it then evolved into supporting through-life-support (i.e. ILS) activities. Thus, the system has been evolving over the years and now has a web-enabled user interface. It includes a very large database, which contains approximately 220 technical manuals, 25000 maintenance procedures, and 500000 hyperlinks. System A interfaces with System B to receive a range of ILS information products. The main functions of System B are management of the Logistic Configuration Baseline (LCB), maintenance analyses, supply support, and documentation and training requirements. Thus, System B is used to develop required ILS products, including creation of maintenance procedures from source data from various vendors and suppliers, or conversion of source data into a consistent format for use within System A. As a result, all ILS Information Products used in System A were originally developed in System B. Furthermore, System B ensures configuration management and validation against the LCB of all ILS information products. System C is used to store and process data relating to system and equipment failure analysis and system reliability and availability analysis.

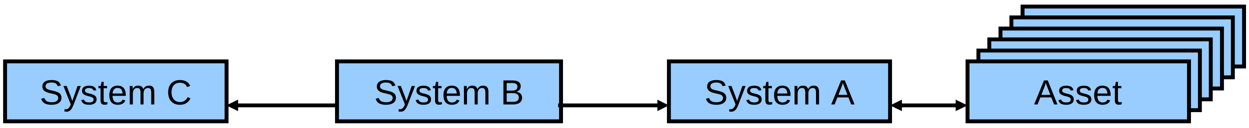

Figure 3 Simplified representation of XYZ-ILS information system, developed by the authors

Assessment Method

Given the fact that the IQM-CMM comprises of more than 50 criteria, we only present a partial assessment summary in this paper, illustrating partial evaluation of six Maturity Indicator Criteria: Information Profiling & Enrichment, IQ Metrics & IQ Assessment, Redundant Storage Management, Backup & Recovery, Authentication, and Audit Trail. We used three quality ratings for each appraisal measure: not-satisfied, partially-satisfied, and fully-satisfied.

Table 2 Quality Ratings

Rating	Description
not-satisfied	There is no documentation and there is limited or no evidence to confirm the implementation.
partially-satisfied	Some documentation exists, however there is inconsistent implementation through ad-hoc processes.
fully-satisfied	Entirely documented, consistently implemented, effective and efficient, with above expectations results, utilising industry best practices.

Table 3 Partial IQM-CMM assessment summary illustrating the assessment of six Maturity Indicator Criteria (the complete assessment addresses 50+ criteria) , developed by the authors

Capability Maturity Level	Maturity Indicators	Criteria	Appraisal Measures	Rating not-satisfied, partially-satisfied, fully-satisfied
Level 3 MEASURING	IQM Roles & Responsibilities	Information Profiling & Enrichment	Evidence of the following exists in the Information Quality Management Policy (or equivalent):	
			Data cleansing tools are used for pattern verification.	**fully-satisfied**
			Incomplete information is identified and enriched from external sources.	**fully-satisfied**
		IQ Metrics & IQ Assessment	IQ metrics, for relevant IQ dimensions, have been developed and documented.	**partially-satisfied**
			Surveys are used to assess information consumers' subjective perceptions of IQ.	**partially-satisfied**
			Statistical valid samples of information are being assessed based on the IQ metrics.	**partially-satisfied**
			The quality of information products is assessed by aggregating individual IQ values.	**partially-satisfied**
			Assessments of IQ based on business rule violations.	**partially-satisfied**
Level 2 REACTIVE	Storage Management	Redundant Storage Management	Evidence of the following exists in the Information Storage Policy (or equivalent):	
			Requirements for replication of information have been identified and documented.	**fully-satisfied**
			The information that is replicated has been clearly identified and documented.	**fully-satisfied**
			Synchronisation frequency and schedule have been documented.	**fully-satisfied**
			Processes are in place to identify and resolve any update anomalies.	**fully-satisfied**
		Backup & Recovery	Critical information is being backed-up at regular intervals.	**fully-satisfied**
			Backups are stored off-site.	**fully-satisfied**
			Physical security of the backups is appropriately maintained.	**fully-satisfied**
			Backups are periodically restored to a test machine.	**partially-satisfied**
			Backups are appropriately labelled (e.g. date of backup, sensitivity level, etc.).	**fully-satisfied**
			Backups are encrypted whenever possible.	**partially-satisfied**
	Access Control Management	Authentication	Evidence of the following exists in the Access Control Policy (or equivalent):	
			User account management.	**fully-satisfied**
			Information System verifies the identity of every user.	**fully-satisfied**
			Session time out (users are logged off) after a certain period of inactivity.	**fully-satisfied**
			User accounts are being regularly reviewed.	**fully-satisfied**
		Audit Trail	Users' activities are being chronologically recorded/logged.	**fully-satisfied**
			Audit trail logs are being regularly analysed.	**fully-satisfied**

CONCLUSION

Contemporary Engineering Asset Management Organisations (EAMOs) are dealing with more information than ever before. Consequently, assessing and ensuring information quality has become a major concern. This paper has demonstrated partial results of a case study, where we applied the Information Quality Management Capability Maturity Model (IQM-CMM) assessment instrument to evaluate IM and IQM practices employed in a large Australian EAMO. The complete IQM-CMM assessment addresses more than 50 criteria with over 250 appraisal measures, covering a wide range of IM and IQM practices. The preliminary results of the case study indicate quite a high level of IQM Capability Maturity in the organisation under investigation. There was clear evidence of very well documented and meticulously implemented IM processes; however, some IQM processes were implemented in an implicit manner.

FUTURE WORK

We plan to finalise the assessment report within the next few months and to deliver it to senior management in XYZ. We also plan to apply IQM-CMM in other EAMOs, which will enable us to perform cross-organisational comparisons and to further validate and improve the assessment instrument.

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