TOWARDS A CAPABILITY MATURITY MODEL FOR INFORMATION QUALITY MANAGEMENT: A TDQM APPROACH

(Research-in-Progress)

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Abstract: An increasing number of contemporary organizations are coming to realize the importance of Information Quality (IQ) to effective decision making. However, assessing and enhancing the quality of information can still be a daunting task. Consequently, we propose a TDQM based Capability Maturity Model (CMM) for Information Quality Management (IQM). It is believed that the maturity model may assist organizations in assessing and enhancing their IQM capability, by addressing a wide range of Information Management (IM) and IQM process areas and organizing those process areas into staged levels.

Key Words: Information Quality Management, TDQM, Capability Maturity Model, Process Area

INTRODUCTION

Contemporary enterprises have in recent times experienced significant change, most of which has been technologically driven. The result of these gales of change has been an overabundance of information [17]. Yet such information abundance has not necessarily resulted in a more informed organization nor more effective decision making. Enterprises are now managing more information than ever before and are becoming aware of the information quality issues that exist in their enterprises. Consequently, IQ problems abound and IQM is becoming ever more important. Many organizations recognize that they are having problems with the quality of information in their Information Systems (IS) however they often find it difficult to assess their current IQM capability. For that reason, we propose an IQM Maturity Model as a tool for assessing and enhancing organizational IQM Capability.

Maturity models have been very successfully used in many different disciplines, including the Capability Maturity Model (CMM) [20] and Capability Maturity Model Integration (CMMI) [5], which are heavily used in Software Engineering. Borrowing from the idea of CMMI, a similar maturity model is proposed in this paper comprising five levels, with each level representing an evolutionary stage of IQM capability. It is thought that by separating IQ goals in a number of levels, it may be easier to achieve partial IQ objectives in an incremental way. This research adapts the TDQM methodology for IQ improvement and aligns the TDQM cycle stages with maturity levels. Furthermore, it endeavors to provide additional

guidance by identifying specific process areas which are thought to be having an impact on IQ. Each level, except the first one, specifies a number of IM and IQM process areas which may provide a more detailed guidance for IQM.

This research is still at a nascent stage and the model will be further developed, enhanced and validated through an action research methodology in a number of asset management organizations.

BACKGROUND LITERATURE

In order to set the scene for the Information Quality Management Capability Maturity Model (IQM-CMM), a brief review of the relevant literature is presented in this section.

Information Quality

In recent times, there has been a rapid increase in the quantity of information available to and used by organizations, as well as reliance of organizations on that information [1]. Gartner Research reports that through 2008, organizations that ignore Information Management (IM), will struggle to maintain their status in business environments [18]. However, reports from META group have indicated that 75% of companies in US have yet to implement any IQ initiative [3]. Furthermore, a study, of a major manufacturer, has found that 70% of all orders had errors [26]. Additionally, a Gartner survey shows that many financial services providers (FSPs) are experiencing operational and decision support initiatives hampered by suboptimal quality information [10], and that at least 40 percent of companies undertaking a CRM strategy are unaware of IQ problems in their environment [15]. Moreover, many organizations recognize the existence of IQ problems but do little about it because of a lack of perceived value [10]. Examples abound where impact of poor quality information has caused significant financial losses and in some cases has lead to disastrous consequences.

IQ is pervasive and expensive with IQ problems costing hundreds of billion dollars each year. The impacts of poor IQ range from operational inconvenience and ill-informed decision-making to complete stoppage of business operations [1, 6, 11, 21]. Furthermore, inadequate information quality has serious implications for customer satisfaction (and thus retention) as well as operational costs and financial reporting [15]. Thus, there is a growing need in industry for tools and methods which can be used to assess and enhance the quality of information.

Quality has been defined by Juran [12] as “fitness for use”. It implies that quality is defined by the customer, so that quality and customer satisfaction are considered as being analogous. Thus, it can also be defined as meeting or exceeding customer expectations, given that a perfectly produced product has little value if it is not what the customer wants. Furthermore, Juran [12] also coined the term “cost of quality”, implying that dollar values can be associated with quality problems as well as quality management efforts. However, Crosby [8] argued that “quality is free” since all money spent on quality management is eventually saved by having less quality problems (defects). Even though, this doctrine was originally developed for the manufacturing industry, same principles have been applied to the field of Information Quality.

Common definition of IQ is also “fitness for use” [24]. “Fitness for use” however implies that the concept of IQ is subjective, which means that information with quality considered appropriate for one use may not possess sufficient quality for another use [23, 13]. Therefore, assessing IQ may be a challenging task. Additionally, even though conventional view of IQ has meant “Accuracy”, a range of IQ dimensions (or quality goals) have been identified by Wang and Strong [25] as shown in Table 1.

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

Table 1: Information Quality Dimensions (Source: Wang & Strong [25])

As a result, an IQ problem can be defined as any difficulty encountered along one or more quality dimensions that renders data completely or largely unfit for use [22]. Furthermore, the Total Data Quality Management (TDQM) framework adapts Total Quality Management (TQM) principles to IQM, by drawing a correlation between traditional product manufacturing and the manufacturing of information or Information Product (IP) [24] (Table 2). Therefore, the quality of resulting IP may be directly affected by the quality of processes employed in the Information System (IS).

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

Table 2: Product Manufacturing Analogy for IP Creation (Source: Wang [24])

The TDQM methodology has adapted the quality improvement cycle from the manufacturing industry to IQ enhancement (Figure 1). TDQM applies the "Plan, Do, Check, Act" cycle from Deming's (TQM) literature [9] to IP quality improvement emphasizing that IQ improvements depend on continuous feedback to the processes producing the IP.

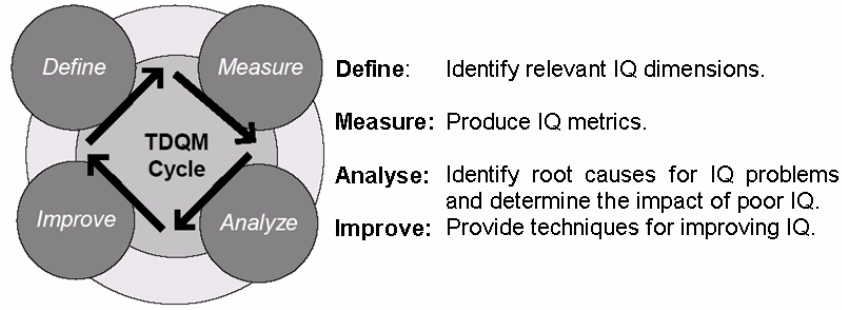

Figure 1: TDQM Cycle (Source: Huang at el. [11])

Maturity Models

Capability Maturity Models originate from the Software Engineering discipline. The original CMM was developed by the Software Engineering Institute (SEI) at the Carnegie Mellon University (CMU) and the United States Department of Defense (US DOD), beginning in 1986. 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 organization's software development process. It establishes a framework for continuous process improvement and defines 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. Even though CMM doesn't itself address any IM/IQM issues, we have adapted the CMM doctrine to IQM.

A number of IQM related maturity models have been proposed. Caballero at el. [4] employ a concept of an Information Management Process (IMP) and consider an IS as a set of IMPs. Subsequently, the maturity model is applied to each IMP. Kyung-Seok [16] describes a number of maturity stages relating to IM, showing that higher IM maturity may result in improved information quality. We have conducted a comprehensive literature review in the fields of IM and IQM and we have identified an array of process areas which are thought to be having an impact on the quality of information. In the next section, we endeavor to present those process areas and organize them into staged levels.

RATIONALE AND PURPOSE

Many organizations admit to having IQ problems however they often find it difficult to assess their current IQM capability. Furthermore, many organizations are also interested in knowing how they compare to others in terms of IQM. By adapting and combining the TDQM and CMM doctrines, this paper presents a theoretical framework that addresses these issues. Additionally, we have identified from literature, a wide range of IM and IQM process areas, which are thought to be of value to practitioners undertaking IQM initiatives, by providing additional specific guidance to the existing and well accepted TDQM methodology.

RESEARCH METHODOLOGY

This research is mainly concerned with theory building and thus it can be classified as being 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 [14]. 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 [19]. Thus, the model development can further be described as qualitative research since it is subjective, holistic, interpretative and inductive in nature. The IQM capability maturity model presented in this paper has been developed by reviewing existing relevant literature in the domains of data and information quality, quality assurance, and maturity models. The theoretical framework presented in this paper consists of concepts and their relationships, as identified from literature, which have been then further grouped and categorized. Thus, this research can be described as being interpretive, qualitative and grounded in literature.

TOWARDS AN INFORMATION QUALITY MANAGEMENT CAPABILITY MATURITY MODEL

This section discusses the process of IM and its potential impact on IQ. It identifies a range of IM and IQM process areas and presents an IQM capability maturity model based on the TDQM framework.

The Impact of Information Management on Information Quality

According to the TDQM framework, the quality of IP may be affected by the processes involved in producing the IP. Thus, IM processes can affect the quality of the resulting IP. Figure 2 shows a traditional information lifecycle; from information capture to potential disposal. However, Figure 3 probably shows a more realistic scenario, since the information flow is not necessarily circular. “Access”

is considered as being analogous to "Viewing" and thus acts as a sink in this model. A comprehensive literature review in the field of IM has been conducted, and consequently a wide range of IM process areas which may have an impact on the quality of IP have been identified. Table 3 shows those process areas and identifies information lifecycle stages that each process area covers. The mapping has been done intuitively, based on the literature reviewed as well as practical experience and still needs to be formally validated. A more detailed description of each process area can be found in the appendix.

Information Management Process Area	Lifecycle Stage				
	Capture	Storage/Update	Analysis	Access	Disposal
Roles and Responsibilities in Relation to Information Products	X	X	X	X	X
Information Dictionary and Information Syntax Rules	X	X	X	X	
Input Authorization Procedures	X				
Constraint Enforcement on Transactional Information	X				
Training and Mentoring	X	X	X	X	X
Information Stewardship and Ownership	X	X	X	X	X
Enterprise Information Architecture Model (Data Flow & Work Flow)	X	X	X	X	X
Information Classification Scheme		X	X	X	X
Information Input Error Handling	X				
Meta-Information Management	X	X	X	X	X
Information Redundancy Management	X	X	X	X	X
Information Processing Error Handling		X	X		
Storage Retention Management		X			
(Offsite) Backup Storage and Restoration		X		X	
Security Requirements for Information Management	X	X	X	X	X
Information Integration Management		X		X	X
Information Disposal Management					X
Output Review and Error Handling				X	

Table 3: Information Management Process Areas (adapted from [7])

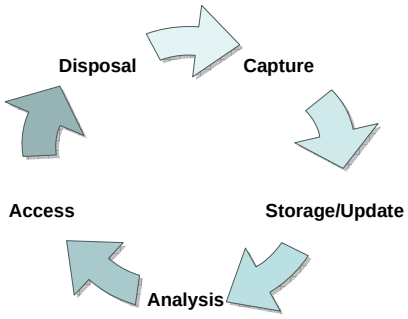

Figure 2: Traditional Information Lifecycle (developed by the authors)

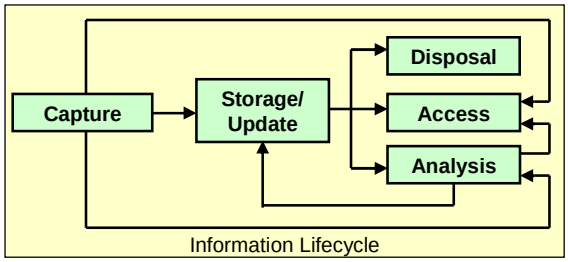

Figure 3: A More Realistic Information Lifecycle (developed by the authors)

Information Quality Management Capability Maturity Model Based on the TDQM Framework

We construct the IQM capability maturity model based on the TDQM improvement cycle by adapting the TDQM cycle into five staged maturity levels (Figure 4). Levels two to five represent TDQM cycle stages; whereas level one indicates that no attempts are made to manage the IQ. We then organize the IM and IQM process areas (as identified from literature) into those maturity levels, aiming to provide further and more specific guidance. We include the IM process areas shown in Table 3 as well as additional IQM process areas identified from literature. The resulting model can be seen in Table 4, which also maps each process area to IQ categories which are thought to be addressed by it. Similarly to Table 3, mapping in Table 4 has been done intuitively, based on the literature and previous practical experience, and thus is yet to be formally validated. For instance, the first process area presented in Table 4 "Roles and Responsibilities in Relation to Information Products" defines roles and responsibilities for all personnel in the organization in relation to IP creation, access, manipulation and so on. It defines both authority and responsibility; including definitions of skills and experience needed in the relevant position. It is believed that by implementing this process area, organizations may enhance intrinsic, representational, contextual and accessibility IQ. Other process areas follow the same principle.

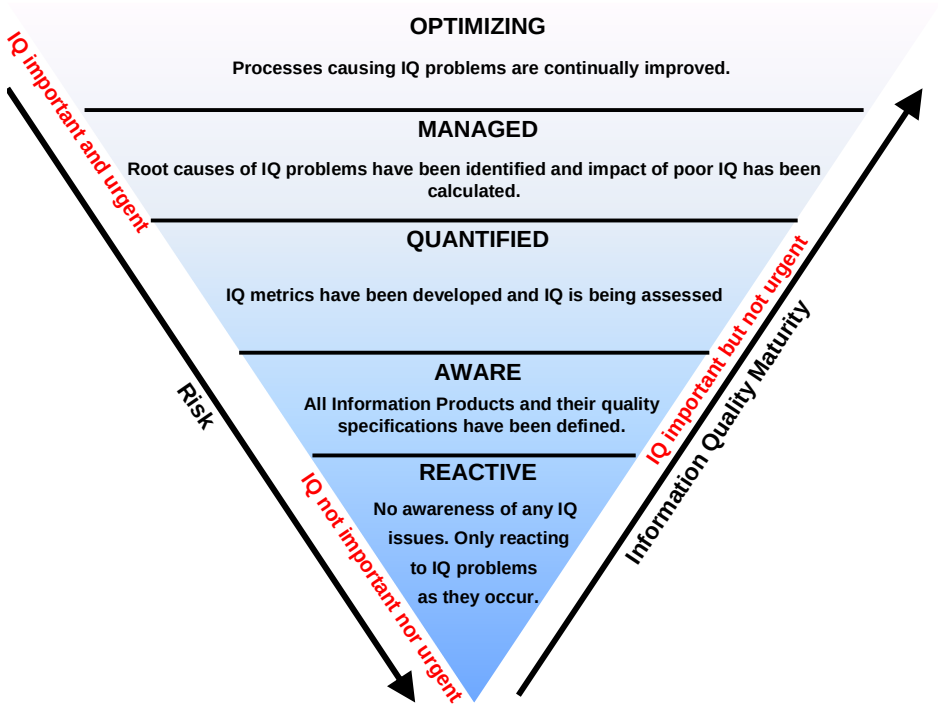

Figure 4: Information Quality Management Maturity Levels (adapted from [24])

			Intrinsic IQ	Representational IQ	Contextual IQ	Accessibility IQ
Level 1 REACTIVE		**IM/IQM processes are not standardised or documented (they are ad-hoc). There is no awareness of any IQ issues. No attempts are made to assess or enhance IQ. Organisation is only reacting to IQ problems as they occur.**				
		This maturity level, by definition, does not contain any process areas.				
Level 2 AWARE		**All Information Products (IPs) together with their quality requirements have been defined and documented. Thus, relevant IQ dimensions and required degrees of adherence have been identified.**				
	IM	Roles and Responsibilities in Relation to Information Products	X	X	X	X
	IM	Information Dictionary and Information Syntax Rules		X		X
	IM	Constraint Enforcement on Transactional Information	X			
	IM	Input/Access Authorization Procedures	X			X
	IQM	Information Quality Customer Focus (Internal/External)	X	X	X	X
	IQM	Roles and Responsibilities for Information Quality Management	X	X	X	X
	IQM	Information Quality Management Project Planning	X	X	X	X
Level 3 QUANTIFIED		**IQ metrics have been developed and IQ is being measured / assessed.**				
	IM	Training and Mentoring	X	X	X	X
	IM	Information Stewardship and Ownership		X	X	X
	IM	Enterprise Information Architecture Model (Data Flow & Work Flow)	X	X	X	X
	IM	Information Classification Scheme		X		X
	IM	Information Input Error Handling	X			
	IQM	Information Quality Policies Management	X	X	X	X
	IQM	Information Quality Standards and Quality Practices	X	X	X	X
	IQM	Information Quality Assessment	X	X	X	X
	IQM	Information Consistency Assurance (Data Cleansing)		X		
Level 4 MANAGED		**Root causes of IQ problems have been identified and impact of poor IQ has been calculated.**				
	IM	Meta-Information Management	X	X	X	X
	IM	Information Redundancy Management	X	X	X	X
	IM	Information Processing Error Handling	X	X	X	
	IM	Storage Retention Management		X		X
	IM	(Offsite) Backup Storage and Restoration		X		X
	IM	Information Security Requirements				X
	IQM	Root Cause Analysis (RCA)				
	IQM	Information Quality Risk Management & Impact Assessment				
Level 5 OPTIMIZING		**Processes causing IQ problems are continually being improved.**				
	IM	Output Review and Error Handling	X	X	X	X
	IM	Information Integration Management	X	X	X	X
	IM	Information Disposal Management			X	X
	IQM	Continuous Process Improvement	X	X	X	X
	IQM	IQM Support for IT & Business Strategies			X	X
	IQM	Information Quality Accountability	X	X	X	X

Table 4: Information Quality Management Maturity Model (adapted from [7, 24])

CONCLUSION

In this paper, we have presented an Information Quality Management Capability Maturity Model, basing the maturity levels on the TDQM improvement cycle. Additionally, we have identified from literature a wide range of IM and IQM process areas, which we further organized within the maturity model. The model presented may be used by organizations to assess and enhance their IQM capability. Thus, this paper contributes to the field of IQM by providing additional specific guidance to the already well accepted TDQM improvement methodology.

FUTURE RESEARCH

This preliminary model was developed from literature and further research is still required to test, verify and enhance it. Where a specific new methodology or an improvement to a methodology is being studied, action research may be the only relevant research method presently available [2]. Therefore, it is intended to conduct two action research cycles in two large Australian Asset Management organizations, which will enable the researchers to test and further refine the model. Figure 5 shows how each cycle may lead to improvement of the original model (M1), resulting in a sequence of successively refined and improved models M2, M3 and so on [19]. Thus, the model may further be specialized to the domain of Engineering Asset Management.

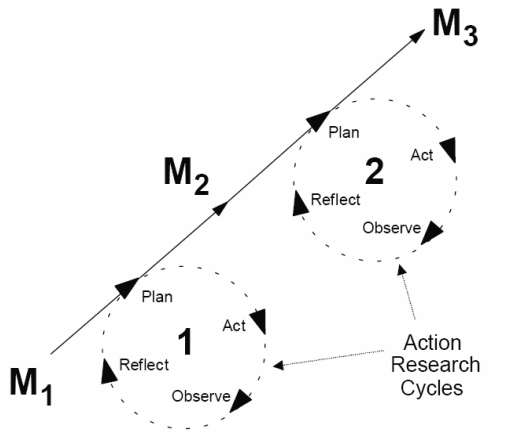

Figure 5: The action research spiral (Source: Moody & Shanks [19])

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APPENDIX: DESCRIPTION OF PROCESS AREAS

Various process areas have been adapted from CobIT 4.0 [7].

Roles and Responsibilities in Relation to Information Products

Organization should clearly define and communicate roles and responsibilities for all personnel in relation to IPs. Role descriptions should outline both authority and responsibility; including definitions of skills and experience needed in the relevant position.

Information Dictionary and Information Syntax Rules

Information dictionary enables the sharing of information elements amongst applications and systems by providing a common understanding of information, and preventing incompatible IPs from being created.

Constraints Enforcement of Transactional Information

Transactional information entered for processing (people-generated or system-generated) should be subject to a variety of controls to check for information quality (these can typically be built into a DBMS). Procedures also assure that input information is validated and edited as close to the point of creation as possible. Integrity constraints may help ensure information consistency.

Input/Access Authorization Procedures

Only authorized staff members may perform information input/access/edits. This could be ensured through the use of various authentication mechanisms.

Information Quality Customer Focus (Internal/External)

All IPs need to be identified and defined by customers (information users). It is also important to appropriately manage IQ requirements, since IQ is defined by the user ("fitness for use"). Thus degree of conformance that is required needs to be appropriately managed and recorded. In other words, ensure that quality management focuses on customers by determining their requirements.

Roles and Responsibilities for Information Quality Management

Assign responsibilities for IQM and provide the quality assurance group with appropriate authority. The organizational placement, responsibilities and size of the quality assurance group should satisfy the requirements of the organization.

Information Quality Management Project Planning

A project plan that provides a structured framework for IQM should be developed. The project scope, timelines, milestones, deliverables, budget and so on should be defined.

Training & Mentoring

Staff dealing with information at any stage of IM lifecycle should be appropriately trained and mentored. Standardized policies and procedures for training and mentoring should be in place and they should be followed.

Information Stewardship and Ownership

This process manages information stewardship responsibilities and implements a formal stewardship program. It clearly defines responsibilities for ownership of IPs and information systems. Owners may for instance, make decisions about classifying information and systems and protecting them in line with this classification.

Enterprise Information Architecture Model (Data Flow and Work Flow)

Establish and maintain an enterprise information model to enable applications development and decision-supporting activities. The model may facilitate the creation, use and sharing of information in a way that maintains integrity and is flexible, functional, cost-effective, timely, secure and so on.

Information Classification Scheme

Establishes a classification scheme that applies throughout the enterprise based on the criticality and sensitivity (e.g., public, confidential, top secret, etc.). This scheme includes details about information ownership, definition of appropriate security levels and protection controls, a

description of information retention and destruction requirements, criticality, sensitivity and so on.

Information Input Error Handling

Procedures for the correction and resubmission of information that was erroneously input are in place, documented and followed.

Information Quality Policies Management

Develop and maintain a set of policies to support IQM strategy. These policies should include policy intent, roles and responsibilities, exception process, compliance approach and references to procedures, standards and guidelines.

Information Quality Standards and Quality Practices

Identify and maintain standards, procedures and practices for IQM to guide the organization in meeting the intent of the Quality Management System (QMS). Use industry best practices for reference when improving and tailoring the organization's quality practices.

Information Quality Assessment

Develop IQ metrics and perform IQ assessments.

Information Consistency Assurance (Data Cleansing):

Data cleansing is a well recognized approach to IQ improvements. Many software tools are available that provide a wide range of functionalities including profiling, matching, enhancement and so on. These tools however mostly ensure information consistency, and do not necessarily enhance information accuracy.

Data Profiling

Data profiling is mainly concerned with discovering the quality and characteristics of various data sources. It uncovers information anomalies by inspecting the content, structures and relationships of data sources (it verifies relationships across columns and tables by looking at primary key - foreign key relationships). It also analyses data values to find areas that are incomplete or inaccurate.

Data Matching

Data matching is usually performed after data profiling and it standardizes, validates and corrects data. It collects data from various different sources, parses it into atomic components, and then compares it, identifying duplicate records, assessing integrity, and identifying inaccuracies.

Data Enhancement

Data enhancement (sometimes called augmentation) appends additional data to the existing one. This data may come from internal (the same database) or external (external database, CD, etc.) sources. For instance, it can be used to add manufacturer, given the serial number.

Data Monitoring

Data monitoring refers to the task of monitoring data continuously (in real-time). It may be performed at the point of entry, thereby identifying dirty data early and addressing the problem before the IQ on the whole is compromised.

Data Consolidation

Data consolidation is used to create a single view of the information by merging or linking duplicate or related records. Thus, it may aid in better understanding of data.

Meta-Information Management

Meta-information can be used to enhance information quality by providing additional information about various information products. Not all information products need to be meta-tagged; only the critical ones may need to have this option. Meta-information may describe various properties such as, ownership, security, edit-history and so on.

Information Redundancy Management

It may be necessary to capture and store some information in a redundant manner. Thus, this task needs to be appropriately managed and documented.

Information Processing Error Handling

Information processing error-handling procedures ensure that erroneous transactions are identified without being processed and without undue disruption of the processing of other valid transactions.

Storage and Retention Management

Define and implement procedures for information storage and archival. The procedures should consider retrieval requirements, cost-effectiveness and security requirements.

(Offsite) Backup Storage and Restoration

Store offsite all critical backup media &, documentation. Offsite arrangements should be periodically assessed for content, environmental protection, security and so on.

Information Security Requirements

Establish arrangements to identify and apply security requirements applicable to the receipt, processing, physical storage and output of information and sensitive messages. This includes physical records, information transmissions and any information stored offsite. Ensure sensitive transaction information are exchanged only over a trusted path or medium with controls to provide authenticity of content, proof of submission, proof of receipt and non-repudiation of origin.

Root Cause Analysis (RCA)

Investigate and categorize the root causes of IQ problems. Only when we are able to determine why IQ problems occurred we will be able to specify workable corrective measures that prevent future problems.

Information Quality Risk Management & Impact Assessment

Identify IPs and IQ dimensions at risk (critical IPs). Predict consequences and probabilities of IQ problems as well as evaluate acceptable levels of risk.

Output Review and Error Handling

Procedures assure that the provider and relevant users review the accuracy of output IPs. Procedures are also in place for identification and handling of errors contained in the output.

Information Integration Management

Various IQ related problems may occur during the process of information integration. Thus, standardized policies and processes should be in place to ensure that any information integration does not create further IQ problems.

Information Disposal Management

Defines and implements procedures to prevent access to sensitive information from equipment or media when they are disposed of or transferred to another use. Such procedures should ensure that information marked as deleted or to be disposed cannot be retrieved.

Continuous Improvement

An overall quality plan is in place, which promotes continuous improvement, and is maintained and communicated regularly.

IQM Initiative Support for IT & Organizational Strategies

IQM initiative is aligned with IT and Organizational strategies. Thus, ensuring IQM is adding value to the organization on the strategic level.

Information Quality Accountability

This process ensures that every person is accountable for the quality of his or her work and does not send poor quality information to the next person in the process.