Data Quality in Enterprise Asset Management Systems

Shien Lin
School of Computer and Information Science
University of South Australia
Australia
Shien.Lin@unisa.edu.au

Jing Gao
School of Computer and Information Science
University of South Australia
Australia
Jing.Gao@unisa.edu.au

Andy Koronios
School of Computer and Information Science
University of South Australia
Australia
Andy.Koronios@unisa.edu.au

This research is conducted through the Centre for Integrated Engineering Assets Management (CIEAM)

Abstract

Data Quality (DQ) is a critical issue for effective asset management. DQ problems can result in severe negative consequences for an organisation. Several research studies have indicated that most organizations have DQ problems. This paper aims to explore DQ issues associated with the implementation of Enterprise Asset Management (EAM) systems. The study applies a DQ research framework for Asset Management (AM) in a preliminary case study of a large Australian utility organisation. The findings of the study suggest that the importance of DQ issues for the implementation of EAM systems is often overlooked; there is a need for more scrutinised studies in order to raise the general awareness.

***Keyword*:** Data Quality, Enterprise Asset Management

1. Introduction

Industry has recently put a strong emphasis in the area of asset management (AM). In order for organizations to generate revenue they need to utilize assets in an effective and efficient way. Often the success of an enterprise depends largely on its ability to utilize assets efficiently. Therefore, asset management has been regarded as an essential business process in many organizations. Furthermore, as companies today are running leaner than ever before, physical assets such as equipment, plants, and facilities are being pushed to their limits as engineering enterprises attempt to continuously drive more productivity out of their equipments in order to improve their bottom lines. Consequently, physical asset management is moving to the forefront of contributing to an organization's financial objectives. Effective physical asset management optimizes utilization, increases output, maximizes availability, and lengthens asset life spans, while simultaneously minimizing costs.

Further, the global nature of modern marketplace requires active players to internationalise their operations in order to maximise the benefits derived from a global supply chain. In order to meet this objective, large-scale information systems are developed for enterprise resource planning (ERP) and enterprise asset management (EAM). In reality, companies usually depend on a combination of production assets, facilities and fleets as well as their IT infrastructure for operational and financial success. Companies need to manage all their assets at any places — on the plant floor, in the machine shop, in the IT department, or in the vehicle repair bay. EAM is a holistic, inclusive and coordinated approach to facility asset management, which promotes both a philosophy and a set of best practices intended to overcome limiting conditions by coordinating asset-related business processes across multiple business units, integrating asset-related information systems, and adopting best-in-class practices for maintaining and using the information resource. According to a number of studies [24] [30], the practice of EAM allows companies to obtain an enterprise-wide view of asset related information (e.g. current status or conditions, performance, estimated life, etc). In addition, the EAM software packages even possess the tools needed to perform various asset management functions (e.g. maintenance work scheduling, parts inventory ordering, etc).

According to a number of related studies on EAM [7] [37] [35] [14], EAM systems often have a complex nature, which consists of a number of system modules (e.g. work event management, cost control, etc) for asset maintenance, monitoring, etc. Like all large-scale systems, there are cases of successful and unsuccessful implementations of EAM systems. However, among all failure reasons, the discussion of the data quality (DQ) issues is rarely found.

This research has been conducted collaboratively with an Australian-based state-wide infrastructure provider (state water supplier), which aims at exploring the data quality issues emerged from the various processes of asset management. During the initial contacts with the industry people, a number of complaints were identified in relation to the EAM system currently used within the organisation. This initial finding raises the importance of identifying the emerging DQ issues associated with the implementation of organisational-wide large-scale EAM systems, which has not been discussed in-depth from previous studies. This paper, therefore, examines the key dimensions of the adopted EAM system – Maximo, within the identified organisation and tries to explore the core DQ issues derived from this adoption. In particular, a multi-dimensional DQ issues model for EAM systems adoption is developed from this case study, which is thought of valuable to the researchers and industry practitioners who specialise in selecting, implementing, delivering and maintaining EAM systems.

2. Enterprise Asset Management - EAM Overview

Enterprise asset management maximizes the performance of fixed, physical or capital assets that have a direct and significant impact on achieving corporate objectives [25]. Companies and organisation rely on vital assets to provide goods and services to their customers. This process often involves the utilization of a number of inter-dependent assets. Knox [20] further asserts that these tightly inter-dependent assets should be managed as a set of unified enterprise resource at higher levels in the organization in order to achieve higher corporate performance (e.g. shareholder value, revenue growth, profitability or customer satisfaction). The concept of EAM suggests that companies should firstly focus on managing the interdependencies between all of the different types of assets that drive their operations, assets that have previously been viewed as functioning separately and independent from one another; and secondly recognize the need to manage assets from a strategic perspective across the entire organization, rather than purely from a maintenance perspective.

2.1. Asset management in general

Asset management essentially is the management of the plant and equipment during its whole life (i.e. from specification, manufacturing, commissioning, useful life, maintenance, and then managing the consequences from the decision to refurbish or replace the item before final decommissioning and recycling any components). At its core, the extended life cycle of a particular asset (also covering the period before the equipment asset has been in placed for operational purpose and the period after the asset has been deactivated) will be monitored and controlled. The consideration of this extended asset life cycle is critical to address the planning and historical requirements.

Steed [36] indicates that during its lifetime, the asset is subjected to a host of external factors: environmental conditions, system events, normal and abnormal loads, even changes brought about for whatever reason to the dielectric balance. At several critical stages, information is required on the condition of the assets. Knowing what to measure, how to measure it, and then what to do with the information becomes very important. Sandberg [29] argues that contemporary asset management demands an elevated ability and knowledge to incessantly support asset management process, in terms of data acquisition, real-time monitoring, and computer supported categorization and recording of divergences from standard operations.

The overall map of asset management processes is very complex and sophisticated because it is an engineering and planning process. There are a number of unique processes involved in asset management [46]. The process of asset management requires substantial information to be collected from many different parts of the organisation. This information must be maintained for many years in order to identify long-term trends. The asset management engineering and planning process uses this information to plan and schedule the asset maintenance, rehabilitation, and replacement activities [1]. There is a variety of required information for asset management and there is a need for establishing enterprise-wide asset management information systems. It is thought that these information systems will ease the processes of capturing, storing, processing and maintaining large volume of asset-related data for effective asset management.

Asset intensive companies in the process and manufacturing industries are dependent on complete information support. The system that provides this must be capable of collecting and managing all information throughout the entire life cycle of the facility. For example, as an integral part of the IFS Applications ERP system, IFS' solution for enterprise asset management is in direct contact with all the business processes in the company, which supports the entire business process from the project phase, through design, to purchasing, assembly and going live.

Competitive companies today utilize EAM systems not only to reduce costs but also to provide more opportunities for profit. They have realized that plant downtime costs money. In fact, in some asset intensive businesses, such as utilities, losses due to significant plant downtime can mean the difference between a positive or negative bottom line results for the company. The primary role of plant equipment maintenance has therefore become downtime prevention, which means that if the equipment does break down and stop, plant maintenance has failed in its main role. So, fortunately, the forward-looking and better performing companies have now discarded the old-fashioned view of maintenance as a necessary and often costly evil. Even the once common perception of the maintenance professional as a person in dirty overalls with an oilcan and a wrench is disappearing. Instead, the concept of EAM is considered a way to ensure that plant maintenance processes are used to contribute to bottom line performance. As such, plant maintenance is seen as an investment rather than a cost.

Due to tough market conditions, many industries today are being forced to operate at maximum efficiency and to work on a just-in-time basis. This means there is limited spare plant capacity, little tolerance on order delivery times, and few, if any, surplus resources. In addition, with many customers using the Internet to place orders and compare prices, companies must utilize their assets effectively to ensure that they retain their customer base. This is where EAM can add significant value to companies in ways that include:

- Minimizing downtime when the plant is needed for production, thus being able to respond to market and customer demand
- Ensuring that essential maintenance work is scheduled to maximize production or operational efficiency
- Preventing the delay of customer orders due to production equipment breakdowns
- Maximizing product or service quality by ensuring that the plant operates correctly.

2.2. Data quality issues in asset management

Numerous researchers have attempted to define data quality and to identify its dimensions [21] [18] [42] [12] [39] [43] [34] [19]. Traditionally, data quality has been described from the perspective of accuracy. However, this description has been challenged by a number of researchers (e.g. [38] [10] [28] [40] [3] [26]) with a view that data quality should be defined beyond the accuracy dimension. Although there is no universal agreement on the meaning of "quality data", a common understanding is found through the literature: "*quality data are data that are fit for use by the data consumer" by* Wang and Strong [43]. Orr [26] also suggest that the issue of data quality is intertwined with how users actually use the data in the system, since the users are the ultimate judges of the quality of the data produced for them. With the aim of improving data quality, Wang [41] suggests a Total Data Quality Management (TDQM) framework (define, measure, analyse and improve) for continuously managing data quality problems.

Previous studies in asset management [46] [47] [9] [17] suggest that a common, critical concern with EAM is the lack of quality data. Asset management is not considered as a core business activity by many businesses, which therefore depend on traditional organizational information sources to manage assets. These traditional sources reflect both the tacit and implicit knowledge of engineers, and operators, as well as information contained in information systems, which have been primarily designed to increase productivity rather than to improve the efficiency of the processes involved in production. At the same time, there are a variety of operational and administrative systems in asset management, which not only control and manage the operation of asset equipment but also provide maintenance and administrative support throughout the entire asset lifecycle. In practice, data is collected both electronically and manually, in a variety of formats, processed in isolation, stored in a variety of customized and off the shelf legacy systems, shared among an assortment of operational and administrative systems, and communicated through a range of sources to an array of business partners and sub contractors. Data captured and processed by these systems is not comprehensive and is process dependent, making it difficult to be reused for any other process or process innovation [13].

The effective process of asset management has to utilize a large number of data for maintenance requirements. There has always been a limited degree to which data has been obtainable, sometimes due to the lack of data acquisition standards, sometimes due to company culture, and often due to the inability of a business to discern operational from strategic data and information. Furthermore, due to the multiplicity of systems, stakeholders, and system requirements, and the level of unpredictability in asset operation within asset management, it is often difficult to tap user requirements. This consequently contributes to the 'dirtiness' of asset data. In managing physical assets through the entire asset life cycle, large amounts of data are needed for long term performance and reliability prediction, as well as informing the decision making process on when to retire an asset. Although very large amounts of data are being generated from condition-monitoring systems, little thought has been given to the quality of such generated data. Thus the quality of data from such systems may suffer from severe quality limitations [32].

2.3. DQ problems in EAM – a TOP-based view

This study takes Wang [41]'s TDQM framework into consideration; however, the framework has not explicitly suggested an approach for identifying specific data quality problems emerged from the business domain. Based on the previous discussion, it is found that the process of modern asset management consists of the adoption of enterprise-wide information systems, various business processes, participants (e.g. maintenance people, asset managers, etc) and organizational policies (and business goals, structures, etc). It is thought that Linstone's TOP approach can be used to establish a preliminary research model for this study (as a mean of identifying emerging DQ issues from EAM).

Mitroff and Linstone [23] argue that any phenomenon, subsystem or system needs to be analyzed from what they call a Multiple Perspective method – employing different ways of seeing, to seek perspectives on the problem. These different ways of seeing are demonstrated in Linstone [22], Mitroff and Linstone [23]'s TOP model. The TOP model allows analysts to look at the problem context from either Technical or Organizational or Personal points of view:

- The technical perspective (T) sees organizations as hierarchical structures or networks of interrelationships between individuals, groups, organizations and systems
- The organisational perspective (O) considers an organization's performance in terms of

effectiveness and efficiencies. For example, leadership is one of the concerns.

- The personal perspective (P) focuses on the individual concerns. For example, the issues of job description and job security are main concerns in this perspective.

Mitroff and Linstone [23] suggest that these three perspectives can be applied to any problems arising for or within that phenomenon or system, as “three ways of seeing”. Werhane [45] further notes that the dynamic exchanges of ideas which emerge from using the TOP perspectives are essential, because they take into account “the fact that each of us individually, or as groups, organizations, or systems, creates and frames the world through a series of mental models, each of which by itself, is incomplete”. In other words, a single perspective on the problem context is not sufficient to elicit an insightful appreciation.

Moreover, having chosen a particular way of seeing, Linstone’s TOP perspectives are still useful in practice. Firstly, by employing TOP, the problem solvers can put stakeholders’ perspectives into categories. This process may help problem solvers understand the interconnections between different emerging perspectives in order to develop a ‘big picture’. For example, the “T” perspective is a synthesis of concerns from all technical people (e.g. system administrators, machine operators, etc); the “O” perspective gathers all managers’ and leaders’ thoughts; and the “P" perspective considers all other stakeholders’ concerns. In addition, TOP could also be used to explore an individual’s perspectives of the problem contexts. For example, “Do I have sufficient skills to complete the task?” is a Technical concern. “Will my task contribute to the organization’s success?” is an Organisational issue. “If I complete the task, will I get a promotion?” is certainly a Personal motivation.

Therefore, based on the processes of asset management (as illustrated above) and the TOP perspectives, the DQ research framework as shown in Figure 1 is developed in order to guide the process of exploring the data quality issues emerged from the modern approach (EAM Information Systems facilitated) of asset management.

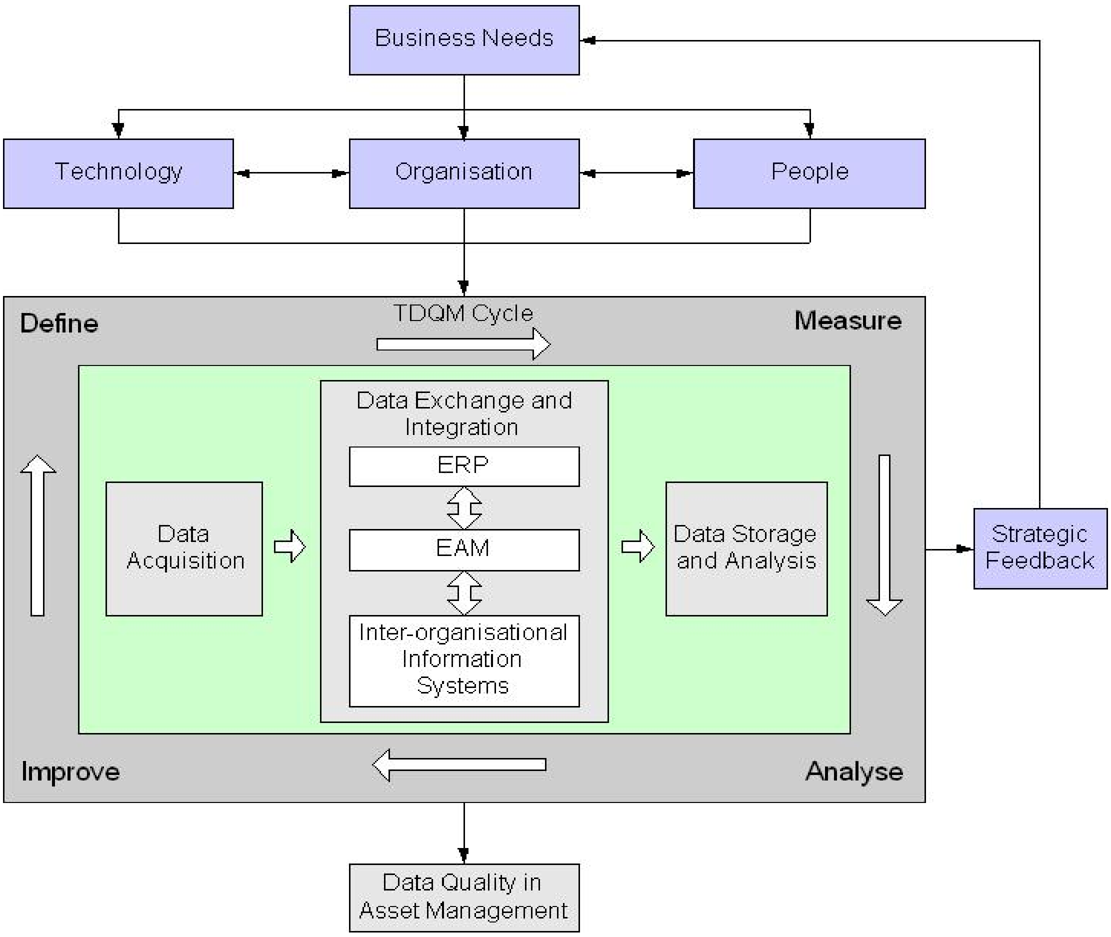


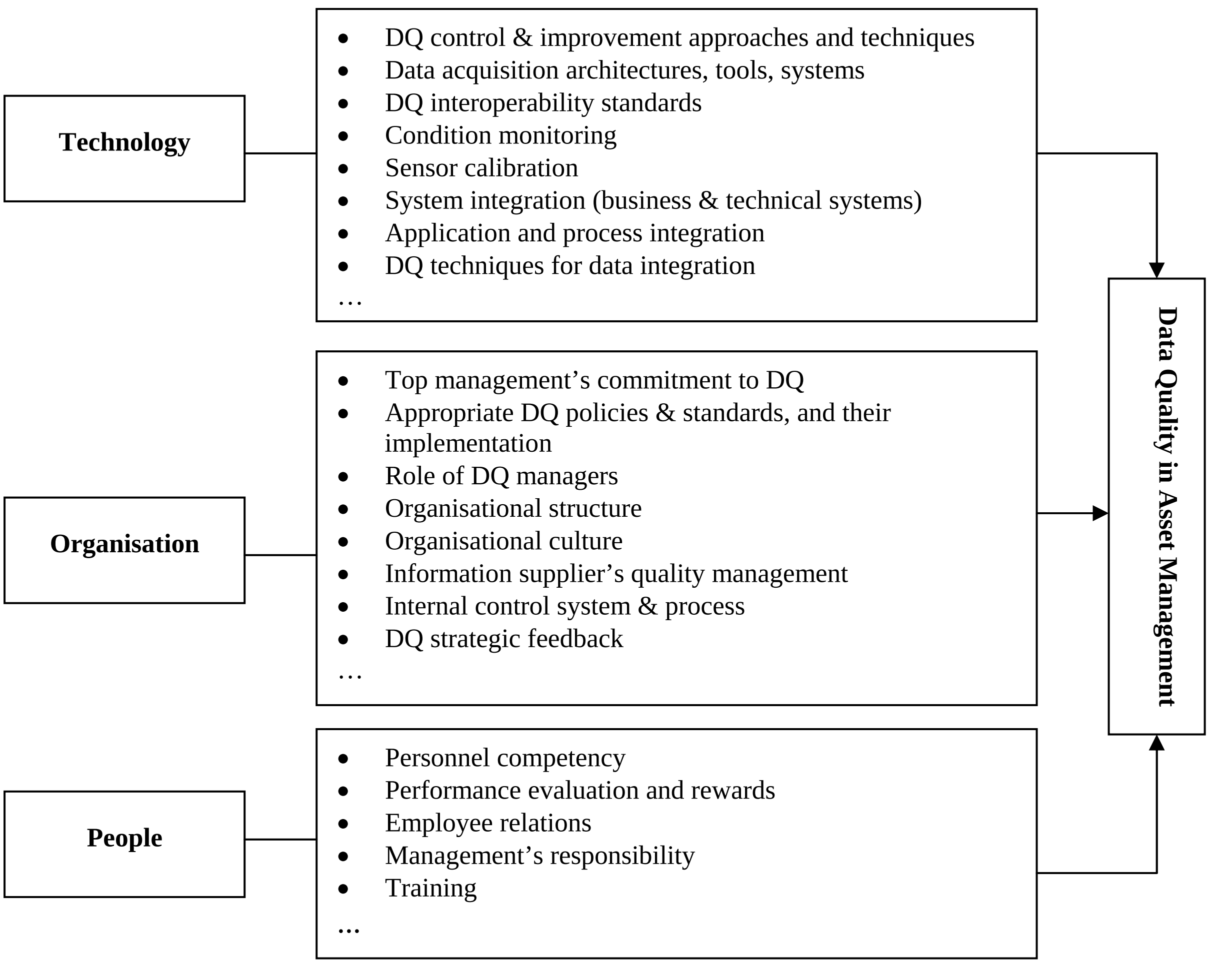
Figure 1 Data quality research framework

The above diagram has identified three possible view-angles (TOP) of exploring data quality issues in various stages of asset management. However, asset management is a broad concept, which is difficult to apply an overall analysis. Thus, in order to explore the DQ issues, the individual process of asset management should be considered because data will be captured, created and stored from these processes. Therefore, the collective understanding of various DQ problems emerged from individual AM processes allows researchers to obtain an insightful and overall understanding about what DQ problems are in AM and why they are emerged.

3. Data Quality Research Factors Table – Research Design

Although the key factors for high data quality in asset management have not been addressed, there have been many studies of key factors in quality management such as Total Quality Management (TQM) and Just-in-Time (JIT) [31] [27] [5] [2] [48]. Some of the data quality literature has addressed the key points and steps for DQ [11] [33] [15] [10]. Regarding asset management processes, the DQ factors as shown in Figure 2 is summarised from the literature review of DQ related research efforts in order to develop a semi-structured research protocol for interviews to understand the emerging DQ issues from individual process.

Figure 2 Summary of DQ factors identified from literature review



This factors table does not intend to be a complete list and these factors may not be relevant to all AM individual processes; however this table will be used to encourage conversations, obtain insights of the determined issues and prompt for un-covered issues on the fly.

Based on the previous discussion about the EAM problems, an interview-based case study is designed to explore the DQ issues emerged within the chosen organisation. Case study research is an accepted research strategy in IS. Cavaye [6] suggests that the term "case research" is not a monolithic one: case study methods can be applied and used in many different ways and, as such, case research is open to a lot of variation. The author further suggests that case research can be carried out taking a positivist or an interpretivist instance, can take a deductive or an inductive approach, can use qualitative and quantitative methods, and can investigate one or multiple cases. Weick [44] indicates that case study research has the following characteristics:

- does not explicitly control or manipulate variables;
- studies a phenomenon in its natural context
- studies the phenomenon at one of a few sites
- makes use of qualitative tools and techniques for data collection and analysis.

It is believed that the choice of these interviews meets the following requirements of asset management processes:

- from different organisational levels,
- from different AM responsibility areas, and
- from different geographical locations.

In data quality studies, four types of stakeholders [38] [41] have been identified:

1. data producers
2. data custodians
3. data consumers
4. data managers

To apply this stakeholder's concept into an asset management environment:

1. Data producers are those who create or collect data for asset management system
2. Data custodians are those who design, develop and operate the asset management system
3. Data consumers are those who use the asset information in their work activities
4. Data managers are those who are responsible for managing data quality for asset management systems

Data was collected using semi-structured interviews with key stakeholders of asset management systems. In total, 15 interviews were conducted with contractors, employees and managers at all levels from the participatory organisation within the field of asset management. Each interview included questions about the background of the organization, as well as its asset management practice, the participants' roles, and their views about data quality issues in managing assets. Additional information was obtained from secondary data including reports and internal and external documents. The purpose of the case study was to investigate what was actually happening in the real-world organisation in relation to data quality issues associated with the implementation of EAM systems within engineering enterprises.

Through a number of interviews, new issues were raised. These issues were recorded and were rephrased as questions during the follow-up interviews. It is believed that after a number of interviews, the majority important issues all have been covered. Moreover, in order to ensure the validity, the issues have been raised to different people for cross-checking.

4. Case Study - Company Background

4.1. Company overview

The company is a water utility organisation responsible for the provision of water and wastewater services to approximately 1.1 million people in Australia. These services include the continuous supply of high quality water and the efficient operation of water and wastewater systems whilst still providing financial returns to government.

This company is an internationally recognised water utility wholly owned by the state government of Australia. It delivers water and wastewater services to almost 1.4 million people across the state. With an annual turnover of about $550 million per annum, assets of more than $6 billion and more than 1100 staff, the company is a big part of the Australian landscape. As one of Australia's leading water utilities, the company:

- Has an annual turnover of $550 million
- Employs more than 1100 people
- Delivers about 277,000 megalitres of water across the state each year
- Reuses about 19% of wastewater, mainly for irrigations purposes

In addition to the existing five major pipelines, the company owns a number of water treatment stations, pump stations and supporting facilitates located across the state. In order to ensure continuous and reliable service performance and respond to emergency (e.g. leaking, etc) in a timely fashion, the company has a number of maintenance teams and contractors who are responsible to monitor, perform maintenance or reparation jobs on these facilitates. Due to the massive maintenance requirements for the utility's infrastructure assets and the large number of these types of jobs required, a computerized EAM solution, Maximo, has been adopted to assist the job planning and recording.

4.2 Maximo within the organisation

Traditionally, organizations have turned to solutions designed to meet the specific needs of different asset groups; now, a single solution Maximo suite, claimed to be able to manage all of the asset groups - production, facilities, fleet and IT - within most organizations, as suggested below:

According to MRO [25], Maximo allows customers to manage the complete lifecycle of strategic assets including: planning, procurement, deployment, tracking, maintenance and retirement (Figure 3).

Figure 3 Strategic asset lifecycle in Maximo

Acquire – The decision to acquire assets can have a tremendous impact on a company's financial position. To make informed decisions during this phase, organisations need comprehensive and accurate historical data related to capital assets, the kind of data Maximo provides. Armed with cost, performance and maintenance histories on all assets, organisations can make better repair or replace decisions.

Track – Tracking an asset means knowing exactly the type of asset it is, where it is located, and how it is performing. Organisations can't maintain an asset if they can't find it. Maximo makes these information easily accessible, enabling organisations to share or redeploy assets, manage warranties, analyse and compare service histories and facilitate audit compliance.

Operate/Maintain – Operate/Maintain is the most complex phase of the asset lifecycle. Capital assets generate value during this phase and demand care to maintain their performance. This phase includes asset maintenance planning, asset status and condition monitoring, workforce management and resource management. Maximo provides capabilities in asset management, work management, materials management and purchasing capabilities enabling organisations to implement consistent maintenance practices, allowing them to extract the maximum value from their assets and achieve significant savings.

Retire – The final phase of the asset lifecycle involves equipment decommissioning and disposal. Even at this point, good asset management matters. Retired assets may require management for safety and environmental compliance. Also, the detailed and comprehensive asset history developed in Maximo can help promote the sale of the asset, support a higher sale price or suggest redeployment rather than outright disposal.

Due to the complicated maintenance requirements, Maximo has been adopted as a work event solution in the company for logging, planning asset maintenance jobs for both metropolitan and regional areas. Each work event has a location index, which links to the central Geographic Information System (GIS) server in order to retrieve actual asset location (e.g. where is the pipe located under the ground?). When an on-site job is completed, a job completion form is filled. The details of each job description is then entered and stored in the system, which can be used for future reference (e.g. the pipe materials, the ground condition, etc).

5. Preliminary Findings and Discussion

Linstone [22]'s TOP approach is used to categorise the findings from this research.

5.1 Technology (T)

5.1.1 Integration of AM-related systems

Most companies today purchase specialized systems from many suppliers. In addition to Maximo, the participating organization uses some of these AM-related systems including reliability assessment systems, turbo-machinery safety systems, rotating machine vibration condition monitoring systems, electrical motor testing systems, operational data historians, enterprise asset maintenance systems, root cause analysis systems, asset capacity forecasting systems, and physical asset data warehouse systems. Normally these systems are bought from multiple vendors and each is specialized to accomplish its task. Such disparate systems have often led to an extremely difficult integration job for the end-user.

5.1.2 Data exchange

The participating organisation indicated that there is a need for data exchange between the various asset management applications for seamless access to information across heterogeneous systems and different departments within an engineering enterprise. The life cycle performance data of the various assets are kept in individual uncoordinated databases, which make inter-process, inter-functional analysis very difficult.

Moreover, the various computer software programs written for condition monitoring and diagnostics of machines that are currently in use within the organisation cannot easily exchange data or operate in plug-and-play fashion without an extensive integration effort. For example, the maintenance work event forms which contain the hours that a contractor has worked cannot be directly input to the payroll system as an alternative to the traditional timesheets. This makes it difficult to integrate systems and provide a unified view of the condition of assets to users.

5.1.3 Data access

One of the main technical problems that the organization has encountered in the implementation of EAM system has been with the accuracy of data. The EAM system requires the retrieval of old data from the legacy systems that has to be normalised, screened and stored in a sensible data format within the new systems data repository. The duplication and transformation of data was a major concern that the organisation had to address. It was found that in an attempt to improve the timeliness and accuracy of management data, many system vendors are making end-users responsible for updating their own information rather than relying on IT resources.

Designers and asset manufacturers represent the external source of asset data. As part of the asset creation/acquisition phase all asset information required to own and operate the asset should be handed over to the organisation at the commissioning of the asset in a form that can be assimilated readily into the organisation's asset information systems. Because so many sources exist for parts, machines, equipment and facilities, the company faces the challenges to deal with a bewildering diversity of data sources, and to harness two main different kinds of data: structured and unstructured. The organization indicated that in some cases the modified, updated asset information from asset makers were not accessible. It was found that a data gap exists between the maker and user of equipment, consideration also must be given to the role of the information stakeholder. EAM system implementation need to solve these data access problems, from the time the information is imported into the EAM environment and through all its operational updates.

5.1.4 Sensor calibration and integrity check for condition monitoring

Through interviews with field workers (asset maintenance team), it was found that data captured by intelligent sensors may not be always accurate. The data collection devices typically used in condition monitoring are electronic sensors or transducers, which convert numerous types of mechanical behaviour into proportional electronic signals, usually voltage-sensitive signals, that can be processed with various electronic instruments. As signals are generally very weak, a charge amplifier is connected to the sensor or transducer to minimize noise interference and prevent signal loss. The amplified signal, which is in analog form, can then be sent via coax cable to a filter for noise removal and routed to a signal conditioner and/or computer for further analysis. To ensure the data received by SCADA system conforms to the original signal data captured by sensors, integrity check for signal transmission process and sensor calibration need to be performed and maintained. However, the sensor calibration and integrity check are often neglected in the asset maintenance in most industry, the extent to which data acquired is correct and reliable is of concern.

5.1.5 Condition monitoring

It is found that condition monitoring equipment and systems are proliferating. However, an apparent lack of dialogue among vendors (as found in the organisation) has led to incompatibilities among hardware, software and instrumentation. Data collected by current outdated equipment could become obsolete and inaccessible to new upgraded systems. To fully realize integrated systems over the levels of asset maintenance and management, new standards and protocols are needed. Focuses should be on standardization of condition monitoring data modeling and exchange tools and methodologies e.g. Standard for the Exchange of Product model data (STEP). Moreover, asset managers in the company indicate that there is a need to be able to accurately assess asset condition with the capacity to comprehensively record key asset condition data, as a fundamental objective of the inspection and maintenance policy. Whilst comprehensive asset databases generally exist, not all of them have been designed to accurately record asset condition data. For example, one plant records system holds data on all items of operational plant in terms of age, location, and date last inspected/maintained, but it does not provide the means to hold data on the condition of the plant. Where a comprehensive asset database exists containing both asset details and recorded defects, the database however does not permit the recording of successive inspection data (any new record overwriting the current record) and so the important function of developing generic aging curves is not supported.

5.1.6 Integration of business systems and technical systems

The participating organisation has frequently adopted systems for the management of the financial, human resource, inventory and maintenance aspects of the business which are incompatible with technical systems such as SCADA and Condition Monitoring systems. Most users are unable to translate the vast amount of available data into meaningful management information to optimize their operation and control the total asset base. One interviewee said that “we got data, data and data, but they are useless to me”. It is found that the technical systems are often capable for obtaining data for from its application, but failed to store them in a meaningful format which can be exchanged with business systems (e.g. decision-support systems).

The company discovered that bringing real-time information from the plant into business systems is more difficult than anticipated. There are disconnects between the transaction-driven, product-centric business data environment and the continuous data, process-centric open control system and manufacturing data environments. It is found that there is a need to provide for process-to-product data transformation capabilities to link business systems and plant floor EAM applications.

5.1.7 GIS and Maximo database synchronization

The capability of Maximo within the organization can be enhanced with the link between Maximo and GIS by providing the ability to access, use, display, and manage spatial data. The ability to effectively use spatial asset data is important for utilities with geographically dispersed utility networks. However, it was found that one of the most critical activities when integrating Maximo and GIS is to establish synchronization between the two database environments. One asset manager indicated that there has been an issue existed for overcoming the synchronization of asset register in Maximo with GIS in the company. Both automated and manual processes need to be defined and implemented to maintain synchronization between the GIS and Maximo databases. Database triggers and stored procedures need to be defined to automate the attribute update process maintaining synchronization between the GIS database and Maximo database. Work flows or business rules must be developed for GIS and Maximo data editing, to ensure synchronization from both applications.

5.2 Organisation (O)

5.2.1 Organisational readiness

Many companies that attempt to implement EAM systems run into difficulty because they are not ready for integration and the various departments within it have their own agendas and objectives that conflict with each other. Organizational readiness can be described as having the right people, focused on the right things, at the right time, with the right tools, performing the right work, with the right attitude, creating the right results. It is a reflection of the organization’s culture. EAM implementations involve broad organisational transformation processes, with significant implications to the organisation’s asset management model, organisation structure, management style and culture, and particularly, to people.

EAM implementation project within the utility organisation expected a high acceptance of the system in areas that provide just as good or better functionality than the old system. However some functions and processes did not get the full appreciation the legacy systems once had. Through interviews with technicians and data collectors, it was found that field workers are frustrated with the need to use Maximo and are losing confidence on it. One staff said that “…with Maximo there so much problems, people are not interested”. The other interviewee said that “Maximo hasn’t solved the speed problem which you would thought it would have…..At day 1, workers were starting to acknowledge the good points of old systems compared to Maximo”.

5.2.2 Business process reengineering

Organisational fit and adaptation are important to implementation of modern large-scale enterprise systems. Like enterprise resource planning systems, EAM systems are also built with pre-determined business process methodology that requires a fairly rigid business structure for it in order to work successfully. They are only as effective as the processes in which they operate. Companies that place faith in EAM systems often do so without reengineering their processes to fit the system requirements. Consequently, this often results in negative impacts on the effectiveness of both the EAM system and the asset management practices. It is found that the business process for asset management in the organisation was not modified to fit the EAM system.

5.3 People (P)

5.3.1 Training

From a data quality perspective, training has not been addressed enough. Thus, there was a lack of a general awareness of data quality. For example, staff often made mistakes in entries because they don’t feel that it is important to enure high level of data quality. In particular, they were not aware of the severe consequence caused by these mistakes. In the organisation, when the new state-wide asset management system was first introduced, several ordinary staff members were chosen to take a merely 3-day training workshop and then were assigned to be trainers for the rest of the organisation. Due to the insufficient knowledge and skills of trainers, the system implementation experienced tremendous problems. One manager mentioned that “training has been provided, but a lot of attendants are old and hence can’t be bothered”. However, through the interviews with field workers, one said that “training is same for everyone” and “most of us have very little training, mostly self-taught”. It was found that the gap between current practices and capabilities, and those required to harness everybody’s best efforts, is wide in the organisation. On the education front alone, simple things like ‘awareness of the cost of downtime’ and ‘how the data being collected is going to be used’ can transform the motivation, performance and creativity of the asset operators/technicians.

Managing assets requires all aspects of training as well as appropriate documentation of the system. It was found that organisations tended to focus more on the 'hardware' part of the systems' development process, putting less effort on the 'soft' part, that is, the training of how to operate, manage the system. The people's skills, people's abilities to use the system efficiently are very critical to ensure data quality in asset management system. If people do not have the skills and knowledge to control the system, then even the perfect system would not be able to produce high quality information. Lack of training can cause serious damage and have an adverse impact on information quality. It is easy for organisations to find reasons/excuses for avoiding adequate training for the staff and management.

5.3.2 Data recording

In asset management, all of the analytical methods, prediction techniques, models, and so on, have little meaning without the proper input data. The ability to evaluate alternatives and predict in the future depends on the availability of good historical data, and the source of such stems from the type of data information feedback system. The feedback system must not only incorporate the forms for recording the right type of data, but must consider the personnel factors (skill levels, motivation, etc.) involved in the data recording process. The person who must complete the appropriate form(s) must understand the system and the purposes for which the data are being collected. If this person is not properly motivated to do a good thorough job in recording events, the resulting data will of course be highly suspect.

Researches in data collection have found that data quality and validation effectiveness improve, the sooner the collected data is entered and the nearer the data entry is to the asset and its work. If data entry point is remote from the asset, then the capability for accurately confirming the data is considerably reduced and the temptation to enter something - anything that the system will accept - is great. One manager said in the interview that "I feel that most of the (data) errors overtime have been because of the lag between the field data and being continued in the computer somewhere….they (field people) might wait a week before they complete their work order (entry)". It was found that the longer the time lag between using the entered data and the time it was initially created, the less chance of cleaning up the data to make it useful.

5.3.3 Communication and management feedback

Competitive asset intensive companies have reported that most of their asset improvements come from their workforce. Despite the fact that "people are our greatest asset", evidence of the opposite is often found. People problems, people relationships, people aspirations and people personal agendas are seldom given the consideration appropriate to their importance in the successful implementation of an EAM system. In fact, the problem needs to be stated more emphatically. Most system implementations neglect the people factor and, as a result, most systems ultimately fail to achieve the objectives upon which their original funding was justified.

It appears to be that the company continues to see the operators & technicians as skilled hands, rather than also having brains and very sophisticated sensors. It was also found that field people within the organisation have generate the view that "year after year they filled out field data without feedback and a lot of them worked out that if they did nothing, nothing happens so why bother?".

6. Implications and Conclusions

It is believed that the above model derived from this study may assist the implementation process of complex organisational-wide information system in organisations. There are some implications for real-world practitioners, which emerged from this preliminary case study. The following conclusions and recommendations were drawn from the case study findings.

6.1 Understand data quality issues for EAM systems

Data quality issues are critical to the success of asset management. The framework proposed in this paper provides a useful tool for planning the establishment of an awareness of data quality issues in managing assets. The discussion of this paper highlighted some data quality problems, which existed in the current condition monitoring systems and engineering asset management systems, such as intrinsic, accessibility and contextual data quality problems, and the key factors that impact on data quality while managing assets. Data quality issues need to be widely understood and managed in order to ensure effective asset management. When analysis is required for making decision to establish a data quality project regarding the management of engineering assets, issues discussed in this paper can help practitioners to perform a cost/benefit analysis in relation to data quality issues. The identification of data quality issues within the area of asset management will serve to provide additional research opportunities for the development of tangible solutions to data quality problems in asset management.

6.2 Understand the key factors that impact on data quality while managing assets

There are certain factors that influence data quality when managing assets. Organisations should focus on those key factors as defined by the framework in this paper, which include system integration, training, management support, employee relations, and organisational culture. Understanding the key factors should lead to high-level data quality management practices, which is a key to the successful implementation of effective asset management. The knowledge of specifications of the key factors of data quality management in engineering asset management permits organisations to obtain a better understanding of data quality management practices, and perform better data quality controls in managing engineering assets. Particularly important factor for data quality project is adequate training. Implementing a data quality project requires an effective project team that works together. Both engineering and IT personnel perform very important roles in the implementation process to ensure that the project is on the right track. Quality communication among engineering, business, field and IT people will significantly reduce data quality problems.

6.3 Adequate training is essential

Adequate training on data quality for all personnel involved in managing engineering assets is important for ensuring and improving data quality. People's ability to use the system is equally important to ensure a relatively high level of data quality in asset management. Sufficient training should be provided to all employees to obtain a broad understanding of the system as a whole, as well as providing particular personnel with adequate documentation and specific training to deliver the critical mode of knowledge (know-what, know-how, know-why) for their specific data roles (data collector, data custodian, data customer) in their relevant functional areas in relation to the system.

EAM system vendor's standard training procedures normally covers the 'what' and 'how' to do things, but rarely covers the 'why' aspect. And it is the 'why' aspect that concerns most individual users, affects their daily work and affects their concerns about the future. The 'why' aspect will in part depend upon the group culture and in this respect may be addressed by extending the training activity to include sessions on the objectives of the organisation and where asset management, maintenance and the individuals concerned fit into this plan. However, the 'why' aspect has also to be looked at from the individual's viewpoint in order for the system to be able to achieve any measure of success.

6.4 Future research

These case studies provided a better understanding of data quality issues for asset management as well as providing useful practitioner findings from real-world practice. Key data quality issues discussed and the use of the identified framework should help organisations obtain a better understanding of data quality issues throughout the process leading to activities which will help ensure data quality. This research was conducted in a utility company, but similar issues could be found across different industries. Although the organisations may not have controls on those factors, organisations can actively manage those changes. Organisations could use external pressures to accelerate the internal information quality management. Finally, the paper provided some recommendations with implications for practitioners. It is particular useful when designing organisational policies regarding the data usage and storage. Also, the prevention and correction techniques can be applies according to the issues found in order to ensure a high level of data quality. In addition it provided guidance to further explore these issues during the next phase of this research and in the development and validation of a framework for Data Quality for Asset Management. Due to the unique requirements of AM in different types of organisations, it will be useful to conduct a cross-industry study in near future.

7. Acknowledgements

This research is conducted through the Centre for Integrated Engineering Assets Management (CIEAM). The support of CIEAM partners is gratefully acknowledged.

References

[1] Autin, E., 1998, Ready. Set, Go To Successful CMMS Implementation: Carefully consider the implications of people, process, technology, and economics, *Maintenance Technology*, 1998. 15 March 2005 <**http://www.mt-online.com/current/04-99mis.html**.>.

[2] Badri, M. A., Davis, D. & Davis, D., 1995, A Study of Measuring the Critical Factors of Quality Management, *International Journal of Quality and Reliability Management*, (12,2), pp.36-53.

[3] Ballou D., Wang R., Pazer, H., Tayi, G.K., 1998, Modeling Information Manufacturing Systems to Determine Information Product Quality, *Management Science*, (44,4), pp 462-484.

[4] Bever, K., 2000, Understanding Plant Asset Management Systems, *Maintenance Technology*, July/August, pp. 20-25.

[5] Black, S. A. & Porter, L. J., 1996, Identification of the Critical Factors of TQM, *Decision Sciences*, (27), pp. 1-21.

[6] Cavaye, A. L. M., 1996, Case study research: a multi-faceted research approach for IS, *Information System Journal* (6), pp. 227-242.

[7] Chen, J. C., 2002, Enterprise computing asset management: a case study, *Industrial Management & Data Systems*, (102,2), pp. 80-88.

[8] CIEAM, 2003, Business Plan V1.0

[9] Eerens, E., 2003, *Business Driven Asset Management for Industrial & Infrastructure Assets*, Le Clochard, Australia.

[10] English, L.P., 1999, *Improving Data Warehouse and Business Information Quality: Methods for reducing costs and increasing Profits*, Willey & Sons.

[11] Firth, C., 1996, Data Quality in Practice: Experience from the Frontline, *Proceedings of Conference of Information Quality.*

[12] Fox, C., Levitin, A.V., and Redman, T.C., 1994, The notion of data and its quality dimensions, *Information Processing & Management* (30:1), pp. 9-19.

[13] Haider, A., Koronios, A., 2003, Managing Engineering Assets: A Knowledge Based Asset Management Methodology Through Information Quality, *E-Business and Organisations in the 21th Century,* pp. 443-452.

[14] Hipkin, I., 2001, Konwledge and IS implementation: case studies in physical asset management, *International Journal of Operations & Production Management,* (21,10), pp. 1358-1380

[15] Huang, K., Lee, Y. W., and Wang, R. Y., 1999, *Quality Information and Knowledge*, Prentice Hall, Upper Saddle River, N.J.

[16] IFS Applications, 2004, Enterprise Asset Management, *IFS*

[17] IPWEA, 2002, *International Infrastructure Management Manual,* Australia/New Zealand Edition.

[18] Ives, B., Olson, M., and Baroudi, J.J., 1983, The measurement of user information satisfaction, *Communications of the ACM,* (26:10), pp.785-793.

[19] Kahn, B.K., Strong, D.M., and Wang, R.Y., 2002, Information Quality Benchmarks: Product and Services Performance, *Communications of the ACM* (45,4), pp. 184-192.

[20] Knox, M., 2004, Asset Managers Move to Centralized Data and Data Management, Research Note, *Gartner Research*

[21] Kriebel, C.H., 1979, Evaluating the quality of information systems, in *Design, and Implementation of Computer Based Information Systems,* Szysperski, N., and Grochla, E., eds. Germantown: Sijthroff and Noordhoff.

[22] Linstone, H. A., 1999, *Decision Making for Technology Executives: Using Multiple Perspectives to Improve Performance,* Artech House Publisher.

[23] Mitroff, I. I. and H. A. Linstone, 1993, *The Unbounded Mind: Breaking the Chains of Traditional Business Thinking,* New York, OxFord University Press.

[24] MRO, 2003, Strategic Asset Management, Executive White Paper.

[25] MRO, 2004, Strategic Asset Management Methodology, Executive White Paper.

[26] Orr, K., 1998, "Data Quality and System Theory", *Communications of the ACM,* (41,2), pp. 66-71.

[27] Porter, L. J. & Parker, A. J., 1993, Total Quality Management - the Critical Success Factors, *Total Quality Management*, (4), pp.13-22.

[28] Salaun, Y., and Flores, K., 2001, Information Quality: Meeting the Needs of the Consumer, *International Journal of Information Management*, (21,1), pp. 21-37.

[29] Sandberg, U., 1994, The Coupling Between Process and Product Quality – The interplay Between Maintenance and Quality in Manufacturing, *Euromaintenance*, Amsterdam.

[30] SAP, 2004, Enterprise Asset Management, SAP Service and Asset Management Brief.

[31] Saraph, 1989, An Instrument for Measuring the Critical Factors of Quality Management, *Decision Sciences,* (20,4), pp.810-829.

[32] Saunders, D., 2004, Innovation in Asset Management - Achieving a Nexus of Cost and Capability, *UDT Pacific 2004,* Hawaii, USA.

[33] Segev, A., 1996, On Information Quality and the WWW Impact a Position Paper, *Proceedings of Conference of Information Quality.*

[34] Shanks, G., and Darke, P., 1998, Understanding data quality in a data warehouse, *Australian Computer Journal* (30,4), pp. 122-128.

[35] Spires, C., 1996, Asset and maintenance management – becoming a boardroom issue, *Managing Service Quality,* (6,3), pp. 13-15.

[36] Steed, J. C., 1988, Aspects of how asset management can be influenced by modern condition monitoring and information management systems, IEE.

[37] Steenstrup, K., 2005, Enterprise Asset Management Thrives on Data Consistency, Research Article, *Gartner Research.*

[38] Strong, D.M., 1997, "IT Prosess designs for Improving Information Quality and reducing Exception Handling: A Simulation Experiment", *Information and Management,* (31), pp. 251-263.

[39] Wand, Y., and Wang, R.Y., 1996, Anchoring Data Quality Dimensions in Ontological Foundations, *Communications of the ACM* (39,11), pp. 86-95.

[40] Wang, R. Y., Strong, D., and Guauascio, L. M., 1994, Beyond Accuracy: What data Quality Means to Data Consumers, *Technical Report TDQM-94-10*, Total Data Quality Management Research Program, MIT Sloan School of Management, Cambridge, MA.

[41] Wang, R., 1998, A product perspective on data quality management, *Communications of the ACM*, (41, 2), pp. 58-65.

[42] Wang, R.Y., and Kon, H.B., 1993, Toward Total Data Quality Management (TDQM), in *Information Technology in Action: Trends and Perspectives*, Wang, R.Y. (Eds), Prentice Hall, Englewood Cliffs, NJ.

[43] Wang, R.Y., and Strong, D.M., 1996, Beyond Accuracy: What Data Quality Means to Data Consumers, *Journal of Management Information Systems* (12,4), pp. 5-33.

[44] Weick, K. E., 1984, Reclaiming qualitative methods for organisational research: A preface, *Administrative Science Quarterly*, (24), pp. 539-550.

[45] Werhane, P. H., 2002, Moral Imagination and Systems Thinking, *Journal of Business Ethics*, (38), pp. 33-42.

[46] Woodhouse, J., 2001, Asset Management, The Woodhouse Partnership Ltd, online accessed on April 10, 2004 at http://www.plant-maintenance.com/articles/AMbasicintro.pdf

[47] Woodhouse, J., 2003, Asset Management: concepts & practices, The Woodhouse Partnership Ltd.

[48] Yusof, S. M. & Aspinwall, E., 1999, Critical Success Factors for Total Quality Management Implementation in Small and Medium Enterprises, *Total Quality Management*, pp. 803.