ISSUES IN IS BASED ENGINEERING ASSET MANAGEMENT
An Australian Perspective

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Abstract: Asset managing eengineering organisations traditionally take a deterministic view of information systems (IS) adoption. Iinvestments in IS, thus, carry the expectations of high returns in terms of process efficiency and quality of manufacturing/production/service provision output. In theory, IS serve two major benefits to asset managing organisations, i.e. by allowing for real time updated asset related information to stakeholders to assist smooth asset operation; and by providing a broad base of consistent and logically organised information relating to asset lifecycle for informed choices on effectuating asset management regimes. However, the case presented in this paper illustrates that when IS are deployed without accounting for the organisational, social and cultural dimensions of their context , there are little gains. This paper highlights that physically adopted technology needs to be socially composed, which develops organisation-wide consensus about what technology is supposed to accomplish and how it is to be utilised.

1 INTRODUCTION

Infrastructure assets maintain the lifeline of any economy. Continuously changing economic conditions, increased competition, and stricter regulatory and environment protection controls demand asset managing engineering organisations to ensure availability of these assets though effective management of their lifecycle. In doing so, they are embracing an enhanced level of informationalisation so as to enable informed choices at operational, tactical, and strategic levels of the asset lifecycle. This trend is particularly getting popular in capital intensive industries, such as petroleum (Yusof *et al.* 2006; Liyanage and Kumar 2003). Information systems (IS), thus, are becoming an integral part of asset lifecycle management and facilitate various tasks at each stage of the lifecycle through data acquisition, processing and manipulation operations. In actual effect scope of IS in engineering asset management extends well beyond the usual data processing and reaches out to business intelligence, value chain integration, and transformation of patterns of business relationships (Haider and Koronios 2005).

Asset managing organisations relate a diverse set of expectations from IS adoption, such as operational efficiency, reduction in operating expenses, and enhanced competitiveness (Rondeau *et al.* 2006; Markeset and Kumar 2005; Leibs 2002; Anderson *et al.* 2002). However, engineering organisations traditionally take a deterministic of IS adoption and emphasis is on actual installation of technology aimed at increase quality and quantity of output as well as substitution of human effort through process automation (Karlsson and Gennas 2005), rather than facilitating its institutionalisation in the organisations through effective transition and change management strategies. Haider *et al.* (2006) conclude that during asset lifecycle planning, technical aspects of the asset configuration and operation command most resources and factors like choice of IS to support asset lifecycle as well as skills, process maturity, infrastructure maturity, and organisational culture are seldom given due consideration. A recent study by Australian Government's Department of Communications Information Technology and the Arts concluded that less than a third of all respondents had any post or pre IS implantation evaluation mechanism for investments in IT. Well over half the respondents reported that they never had such an agenda on their strategic map (DCITA 2005).

The main purpose of this paper is to explore issues and challenges posed to asset managing

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organisations in wake of maximising value from IS adoption. This paper focuses on a case study of an Australian rail asset managing organisation, which was completed in 2007. This paper contributes to the literature by focusing on and describing in-depth the issues associated with IS adoption to support asset lifecycle management. The impediments to effective utilisation of IS for asset lifecycle management in this case highlight the need for understanding of the social nature of IS adoption and the ways in which engineering enterprises can address the complex activities of asset lifecycle. This paper first reviews asset management and role of IS in asset management, followed by discussion of a case study in a rail asset managing organisation.

2 ASSET MANAGEMENT

The term asset in engineering organisations is taken as the physical component of a manufacturing, production or service facility, which has value, enables services to be provided, and has an economic life greater than twelve months (IIMM 2006), such as manufacturing plants, roads, bridges, railway carriages, aircrafts, water pumps, and oil and gas rigs. Oxford Advanced Learner's Dictionary describes an asset as valuable or useful quality, skill or person; or something of value that could be used or sold to pay of debts (OALD 2007). These two definitions imply that an asset could be described as an entity that has value, creates and maintains that value through its use, and has the ability to add value through its future use. This means that the value it provides is both tangible and intangible in nature (Amadi-Echendu 2004). A physical asset should, thus, be defined as an economic entity that provides quantifiable economic benefits, and has a value profile (both tangible and intangible) depending upon the value statement that its stakeholders attach to it during each stage of its lifecycle. Management of assets, therefore, entails preserving the value function of the asset during its lifecycle along with economic benefits. Asset management processes are geared at gaining and sustaining value from design, procurement and installation through operation, maintenance and retirement of an asset (Blanchard and Fabrycky 1998).

Core asset management processes are derived from the asset management strategy and are arranged through operating plans and procedures. These processes represent the primary asset lifecycle through stages such as, asset design, acquisition, construction, and commissioning; operation; maintenance; refurbishment; decommissioning; and replacement. An asset lifecycle management process, thus, consists of three cycles, i.e. primary asset management cycle, learning and change cycle, and renewal cycle (figure 1).

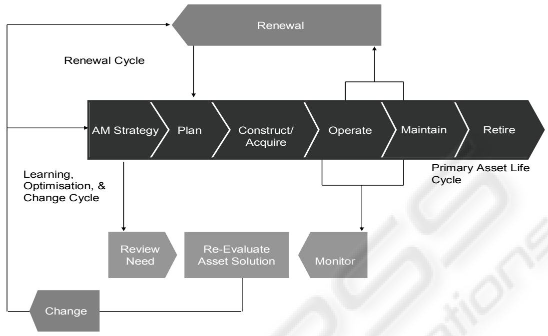

Figure 1: Core Asset Management Lifecycle.

The learning, optimisation, and change cycle is aimed at changing of an asset solution in the existing asset solution to meet stakeholders' needs. Therefore the essential aims of this exercise are, firstly, to identify enhancements in asset solution design, and secondly, if the first response to factors such as asset need redefinition, technology refresh, environmental and regulatory concerns, and maintenance and other economic trade offs. However, the crucial factor in this cycle is the ability of the organisation to have complete information on asset lifecycle so as to evaluate and compare its outputs with the business objectives. The gap analysis provides learnings on effectiveness of is not possible, to provide alternatives for asset renewal. Subsequently, the learning, optimisation, and change cycle has a much greater impact calls for redefinition of asset strategy, whereas the renewal cycle does not go as far and necessitates adjustment to asset management plan.

3 IS FOR ASSET MANAGEMENT

In theory IS in engineering asset lifecycle management have three major roles; firstly, IS are utilised in collection, storage, and analysis of information spanning asset lifecycle processes; secondly, IS provide decision support capabilities through the conclusions arrived at from analysis of information; and thirdly, IS provide an integrated view of asset lifecycle through integration of asset lifecycle functions. IS for asset lifecycle, thus, seek to enhance the outputs of asset management processes through a bottom up approach. This approach gathers and processes operational data for individual assets at the base level, and on a higher level provides a consolidated view of entire asset base.

At the operational and tactical level, IS are required to provide necessary support for planning and execution of core asset lifecycle processes. For example, at the design stage designers capture and process information such as, asset configuration; asset and/or site layout design and schematic diagrams/drawings; asset bill of materials; analysis of maintainability and reliability design requirements; and failure modes, effects and criticality identification for each asset. Planning choices at this stage drive future asset behaviour, therefore IS are also required to facilitate in analysis of information to make informed choices to ensure availability, reliability and quality of asset operation. As we move forward in the asset lifecycle, the complexity of information increases. For example, at maintenance stage it is important to have historic information on design, operations and condition monitoring, as well as previous maintenances carried out on the asset. This includes financial as well as non financial information. This information is required to perform a variety of actions such as locating and diagnosis of failure condition; allocating spares and maintenance work requests; and informing asset shut down schedules. After maintenance has been carried out, this information needs to be communicated throughout the asset lifecycle chain, such as to design function (to design out errors and faults in asset design, or enhancements required in asset design); to operation (in case asset was not being operated according to as designed specifications); to maintenance planners (to plan and schedule future routine maintenance); to decision makers (to identify the financial and non financial risks posed to asset operation, their impact, and ways to mitigate those risks); to environment protection agencies (to assess and define the level of contamination in case of environmental disaster as a consequence of asset failure). An important measure of effectiveness of IS, therefore, is the level of integration that they provide in bringing together different functions of asset lifecycle management, as well as stakeholders, such as business partners, customers, and regulatory agencies like environmental and government organisations. However, realisation of an integrated view of asset lifecycle through IS requires appropriate hardware and software applications; quality, standardised, and interoperable information; appropriate skill set of employees to process information; and the strategic fit between the asset lifecycle management processes and the IS.

4 RESEARCH METHODOLOGY

This exploratory research employs an interpretive epistemology with a qualitative perspective. It is obvious that the issues relating to IS investments in asset lifecycle management are multifaceted and require a broad and flexible perspective for comprehensive examination. It include investigation of technical as well as an assortment of others dimensions such as organisational, social, and cultural. The aim of this research is to explore the issues and impediments to maximising IS value for asset management from technical, social, and cultural perspective. The research question framed for this research is: How do IS facilitate an integrated view of asset lifecycle and what factors impede maximising value of IS adoption? In order to address this question, 17 middle managers representing various roles associated with asset lifecycle management were interviewed in a large rail asset managing organisation during January 2007 – August 2007. These interviews were conducted over a one - one and half hours period and included the following job descriptions, asset designers, maintenance engineers, network access manager, business development manager, Operations and Maintenance manager, manager projects, manager assets management, project officer assets, finance manager, and IT manager. Interviewees were chosen based on their responsibilities as they are between senior mangers (who make decisions) and operational employees (who act on the decisions made by senior mangers). They are the actual implementers of IS and, therefore, are well placed to provide insights into policy setting and decision making of the senior management and the issues and challenges posed to these policies and decisions at the operational level. The interview questions were open-ended and interviewees had freedom to describe their experiences and problems beyond the scope of the questions. In addition, researchers were provided access to all documentation concerning asset lifecycle management, as well as access to sites of asset operation. The interviews were transcribed and data from all sources were analysed using typical case study techniques of themes, descriptions and assertions as detailed in Creswell (1998). The interviews were followed up by email and telephone for further clarifications, where it was deemed necessary. The conclusions drawn in the following case, thus, represent interpretations of the evidence as understood by the authors.

5 RAIL ASSET MANAGEMENT - CASE STUDY

Rail infrastructure is a vital component of Australia's national transport infrastructure. Australian railway industry has an annual turnover in excess of 8 billion Australian dollars and employs approximately 75000 staff (Austrade 2006). However, till 1990's railways in Australia was publicly owned and had a vertically integrated operation. Concerns for improving efficiency necessitated reforms, and thus the industry underwent major changes through which some state railways transformed into private/public structures, separating ownership, operation and regulation (Australian Infrastructure Report Card 2005). Ozrail (Pseudonym) owns, operates, and manages rail assets in one of the largest states of Australia. It's nearly 4 billion Australian dollars worth of rail network stretches throughout the important industrial and agriculture stretch of Australia. The company has been in operation for nearly 150 years and is one of Australia's largest passenger, coal, and freight transport provider. In the financial year 2005-06, more than 2600 staff of Ozrail operated approximately 260000 passenger services, and carried over 54 million passengers. In all Ozrail employs more than 13000 staff and provides a broad range of freight services to a wide customer base in many industries in Australia, through its 9500 km rail network. Ozrail's state based fleet includes over 12300 units of rolling stock, which includes more than 10200 wagons, 508 diesel and electric locomotives, 143 three-car electric trains, and 177 passenger carriages. All of which are used to transport people, coal, bulk or containerised freight. Ozrail employs in excess of 1400 staff (including 176 apprentices and trainees) at four geographically dispersed locations all over the state to manage these units.

5.1 Asset Management at Ozrail

Ozrail manages a number of assets, including rolling stock, track assets, carriages, godowns, railway bridges, signals, and engines. However, for this case study the subject under study is the below train assets, i.e. track, bridges, and other civil infrastructure. Ozrail has generally followed a whole lifecycle approach to managing its assets. In order to optimise the assets, the company has developed an asset management framework that has a ten years time span. However, it is subjected to minor modifications so as to make it relevant to current legislations as well as changes in the market. Nevertheless, the asset management framework is based on five key elements, which are Ozrail's network development plan; Ozrail's network maintenance plan; an alliance-style maintenance and project agreements with specified goals; a detailed performance monitoring framework; and independent asset condition and service provision auditing. Ozrail's asset management framework also includes a financial asset corridor model to provide historical and projected indications of the financial performance of each asset in company's rail network. This model accounts for the revenues, capital investments, maintenance activities, capital charges and internal costs and service charges. Ozrail has a number of systems aimed at enhancing and maintaining asset management capability, which encompass range of asset lifecycle management dimensions. These systems include, procurement and materials logistics; track and structures performance management; detailed long and short-term planning advice; rail infrastructure condition monitoring; asset inspection and safety auditing; regulatory and operational compliance assurance; and property and contract management.

5.2 Information Systems at Ozrail

Ozrail is also participating in two federal government funded cooperative research centres to enhance its IS platforms. The scope of these technologies ranges from standalone process facilitating tools to integrated decision and planning systems. The company has recently set up a scheduling optimisation tool to increase the speed and effectiveness of train, crew and maintenance scheduling on track, and its business intelligence technical infrastructure. However, major technologies employed by Ozrail are SAP R/3; CAD; CMMS; and a variety of industry specific asset lifecycle management softwares such as RailFrame, TRIM, PST, V0, RIMS, and RDMS. Ozrail does not conform to a common information model for asset management. It is for the same reason that traditionally IS adoption is driven by need of individuals or departments, rather than the process or organisational need. Consequently, there are numerous isolated islands of useful data in the organisation. Ozrail's IT manager summarises the technology adoption approach and states, "w*e are not early adopters, and we are not explorers and we are not easily influenced or driven by whatever the latest thing on the market is. Its need driven and business case driven. Basically in past our motivating factors have been tactical needs of individual areas, so it hasn't been strategic at all but its moving towards being more strategic mainly for information integration. We now have stronger governance and cost focus, since we are now viewing ourselves as a market player as we are expanding nationally and are moving into more commercial roles"* - IT Manager (Ozrail)

5.3 IS at Operational Level

Ozrail is a representative case of semi government public sector organisations. It has a hierarchical structure, bureaucratic culture, and centralised decision making. There is no culture of process or technology audit, which could highlight the needs of business processes, such as information needs, skills level, and maturity of existing technology to accommodate new technology. For example, investment in SAP was made due to pressure from regulatory agencies, rather than as a response to needs of asset management regime. Consequently, asset lifecycle management stakeholders saw it as a necessary evil and its adoption was not taken seriously. Being an engineering organisation, functional level employees are more interested in executing the workflow than recording data and information on what they do. As a result Ozrail has struggled to develop a culture that values information, and staff struggle with primary and secondary job quandaries. General feeling among the staff is that "their performance will be judged on the execution of their primary roles such as asset maintainer, designers, and monitors and not on how much and how good they enter data into a system" – Maintenance Manager Ozrail. It was only around the year 2004 that the change of guards at the senior management saw more technology savvy management and efforts have since been made to think laterally on how these technologies could benefit asset lifecycle management. However, there is a long way to go before IS could be institutionlised in the organisation, as one of the design engineer notes that "*from the outset when the decision was made for SAP as the core asset management tool its adoption should have initiated. This project started in Sept 05 and we are still (May 2007) umming and ooing about SAP as the core technology for asset lifecycle management. We should sit down and work through all the cobwebs, recruitment issues, training, and a smooth transition to use this technology. My SAP training was left up to me to book in and when you hear so many negative things about it its not something you rush to do".* A corollary to this issue is the varying quality of information that exists within the IS in Ozrail. For example, in asset design the quality of information is restricted to the drawings, since the same have been subjected to a number of reviews. However, quality of the financial and administrative information cannot be guaranteed since it is not audited. In the words of the civil works reviewer, *"we probably can ensure that the checks and balances that we can put in the systems are operating properly. But in terms of the type of information that gets entered, well, you can't check everything. You can check certain things that give a certain level of assurance that things are doing OK".* Although the intent of business change has been communicated and well publicised within the organisation, change initiatives to achieve the same have been far and few between. Instead of building around the core IS technologies of the organisation, such as SAP and CMMS, different asset lifecycle functions prefer to use simple spreadsheet and database applications. The use of these technologies is justified as *'they are easy to use'*, and that '*they can be customised to meet changing needs'*. This lack of control and disregard of quality culture had led to islands of data throughout the organisation, without being put to effective use.

Ozrail caters for metropolitan as well as countryside track assets, and therefore is not only concerned with the traffic on the tracks but also the weight borne by these tracks. Traffic is managed by state of the art software that manages as well as allocates traffic on the tracks; whereas, the condition of the track is monitored through sensors and manual inspections. Ozrail has an extensive network of track inspectors, which includes a substantial number of indigenous Australians who are well known for their knowledge and familiarity with outback terrain and geography. Ozrail relies heavily on their tacit knowledge, and these track inspectors have also proven to be extremely reliable sources of track information. However, there has been no effort made to record information collected through these manual inspections, while there are certain aspects of asset operation that seem to be over automated, as described by the Operations Manager of Ozrail. He states, *"for a case of a broken rail, essentially it's about train coming off. One system records broken* *rail, which goes to the network controller who can stop trains from going on the track. Another system records the same incident the same information in a track incidence system to raise signal alarms. Yet another one of the systems records the same incident in the rail defect management system, such that a request could be generated to fix it. Now you have the same information available in three different systems. There is not only duplication, in fact triplication of information. Information in each system is biased towards a particular function, so which version is more credible?".*

This symbolises the typical behaviour of an organisation where each function trusts its own information and does not believe in sharing the same. As a result there is significant wastage of effort and finances, and quality of information is undermined due to lack of integration. According to a design engineer at Ozrail, *"a piece of track looks the same today, looked the same five years ago, and will look the same in five years from now. However, it's the formation that keeps on changing…………Although we have got fair bit of say over what software applications we use, we miss the old system where we had somebody that was sort of monitoring what was happening in the market with regards to design software from across Ozrail. At the moment where I see some degree of connectivity with civil engineering design, there is little connectivity when we go across other areas like electrical design".*

5.4 IS at Tactical Level

Ozrail has an old set of asset infrastructure as majority of these assets were laid in 1920s and 30s, with some even earlier. Design information for most of these assets is not available in digital format. There are, therefore, significant issues in managing these assets and most of decisions have to rely on the tacit knowledge of middle to senior mangers. While designing assets, design engineers are required to take into consideration asset workload and work out the asset need profile. However, it is all done manually or with support from simple Excel based spreadsheets. Traditionally, design engineers surveyed the area and identified particular routs, they would then design the asset accordingly. In so doing, there has been heavy reliance on the knowledge of filed staff in designing or refurbishing sections of asset, since they are closest to assets. However, times have changed and for the up-gradation of assets Ozrail utilises a range of technologies to aid design and designing workflow. Now Ozrail utilises design technologies such as AutoCAD, Microstations, and 12D civil design software. However, design information is held locally in the regional offices and is not exchanged between regional offices or with other functions of asset lifecycle management. In addition, recommendations on asset lifecycle supportability design form a part of the design feasibility study, however the actual information remains with the designers and is not exchanged or transferred to a system where it could be reused. Although Ozrail is aware of these issues, there has been no effort made to improve the situation. Business development manager of Ozrail summarises the quandary and argues that, *"Ozaril needs to capture, manage, and maintain knowledge for future generation of Ozrail, so we don't have to reinvent the wheel every time. We are long away from that. In terms of information we have proliferation of tactically disparate databases and spreadsheets. We have got the information but it stays with designers. It is not exchanged and even if it were exchanged it could not be merged with other information".*

All maintenance in Ozrail is carried out in house, and no part is sublet to a third party. It follows a periodic preventive maintenance schedule and since the company maintains a number of different assets this schedule varies for each type of assets. Though track assets are fairly stable and do not develop failure conditions too frequently, the inspection of track assets is held frequently. Information on condition of an asset as well as the treatments carried out are kept with the regional offices and only a summarised version of this information (chiefly financial) is communicated to the corporate head offices, unless the track requires a major overhaul or relaying. Major software tools used in maintenance function are the Rail Infrastructure Maintenance System, and Royal Defects Management System. These systems help in condition monitoring, defect detection, and maintenance scheduling and execution; however these systems are not integrated. Therefore, more or less each activity has a separate IS, but the information thus captured cannot be used for any strategic advantage. Ozrail's Maintenance Manager describes this trends and states that *"for asset life cycle decision support we generally rely on historic data. There is not a huge amount of data available though. It (decision making process) is a lot based on engineering knowledge, lot of our people have been involved in operational management of the* *assets. So they know how the asset performs and behaves. They know the discreet life cycle of the asset components, and by putting those things together we can come up with the forward projection of asset. There is no rocket science there, its based on personal knowledge of particular engineers involved".* Heavy reliance on tacit knowledge and the inability of the organisation to preserve this knowledge is resulting in significant intellectual capital drain from the organisation. With nearly 35% of employees due to retire in the next 10 years, Ozrail will lose significant business knowledge. However, to sieve out learnings from the execution of routine business, integration and interoperability of information is as important and facilitative as developing the culture of information sharing and exchange to achieve higher levels of coordination and cooperation. However, with more information technology savvy staff moving into senior management, these issues are being understood and acknowledged. Infrastructure Group Manager, thus, notes that *"when we talk about the big picture, you may have one piece of information and someone else can have the other piece. He doesn't necessarily see the other piece of information which together can actually point you to a totally new area. For continuous improvement we have to change technology and also have to change the way we do daily business".*

5.5 IS at Strategic Level

Being a public sector organisation, Ozrail has traditionally been insulated from competition. However, with deregulation business environment is changing and the company is expanding its operations to other geographic location in Australia. At the same time, with programs like Auslink (Federal government's initiative to improve roads) Ozrail is facing increased competition from alternative service providers. Nevertheless, it has been only recently that the top management has started considering itself as a market player rather than a monopoly. This change is forcing Ozrail to view information and IS in a different way, as is evident from the business manager's response, who argues, *"we are going beyond total (asset) life (profiling), we are going to total community benefit and trying to financially quantify some of those things such as enhanced access stations and the sort of benefits of integrated bus-train interchange to the community".* However, a transition to this vision requires quality support from IS in terms decision support for effective asset lifecycle management; whereas lifecycle management functions in the organisation are struggling with the basic questions whether the technology has the depth or detail and elegance required to manage assets. In the words of Group manger infrastructure services, *"SAP doesn't provide engineering state of lifecycle, since our data is not integrated. For example, we may know how much we are spending on track maintenance overall, but we cannot straight away find out how much was spent where. Furthermore, this information is not integrated with maintenance or design or operation. We are in the process of building some systems now and our group is also reviewing several different life cycle scenarios, costing and planning tools for our track. But at this point, we haven't got an integrated life cycle asset management".*

6 DISCUSSION AND CONCLUSIONS

Ozrail has reactive rather than proactive approach to asset management, which is the major hurdle in effective long term planning for an effective asset management enabling IS infrastructure. Most of IS adoptions have been in response to foreign influences and not due to the need pull of the asset lifecycle processes. The lack of vision and the unavailability of an enterprise wide information or IS architecture has led to a plethora of ad hoc solutions throughout the organisation. These solutions symbolise a number of organisations within the organisation, as the information collected and processed by each asset lifecycle function is geared at fulfilling its own demands rather than contributing to the overall objectives of an integrated asset lifecycle view. IS in Ozrail could best be described as disparate sets of data dumps reflect history of business execution with varying degree of credibility and in no way are near enabling or informing strategic asset management objectives. Ozrail needs to ascertain both hard as well as soft benefits that IS adoption brings to the organisation and their connection to organizational development. This can only be attained if process and organisational maturity is evaluated and compared with the technical maturity such that the evaluation provides a roadmap in terms of alternatives and choices for IS investments. This then becomes a strategic advisory mechanism that supports planning, decision making, and management processes. Such evaluations provide feedback that facilitates organizational learning and indicate the fundamental reasons, factors, and causes for investment in technology.

At the moment technology adoption in Ozrail has fundamental issues. There is disconnect between the nature of IS and the form of the organisation. As a hierarchical organisation, Ozrail needs to stability whereas IS adoption induces change. This change is geared at various levels and in various forms and calls for adjustments such as job redesign, cross functional communication, and informed and proactive management. Conceptually, staff in Ozrail is fearful of change and finding it hard to match the capabilities of technology with organisational success as well as to adapt to it. Operationally, technology requires changing the way Ozrail has traditionally been doing business, such as the need for information exchange and cross functional communication. Technology therefore has different meanings for different departments and stakeholders within Ozrail under different socio technical environments. There is need to reinterpret use of technology according to changes in the broader context of asset management through change management strategies that that would render the current interpretation of technology use obsolete. In this way when IS are physically adopted and socially composed, there is the possibility of a general consensus on accepted reality about what the technology is supposed to accomplish and how it is to be utilized.

REFERENCES

Amadi-Echendu, JE 2004, 'The paradigm shift from maintenance to physical asset management', in Proceedings of 2004 IEEE International Engineering Management Conference, IEEE, Austin TX, Volume 3, pp. 1156-1160.

Anderson, M, Banker, RD, & Hu, N 2002, '*Estimating the business value of investments in information technology*, in Proceedings of the Eighth Americas Conference on Information Systems, AMCIS 2002, Dallas, TX. pp. 1195-1197.

Austrade 2006, 'Railways overview', The Australian Trade Commission, accessed online on November 12, 2007 at http://www.austrade.gov.au/Railways-Overview/default.aspx.

Australian Infrastructure Report Card 2005, 'Australian Infrastructure Report Card', Engineers Australia, Barton, ACT.

Blanchard, BS, & Fabrycky, WJ 1998, *System Engineering and Analysis*, 3rd edition, Prentice Hall, Upper Saddle River, New Jersey.

Creswell JW 1998, *Qualitative inquiry and research design: choosing among five traditions*, Sage Publications, UK

DCITA 2005, 'Achieving Value from ICT: Key Management strategies' ICT research study', Department of Communications Information Technology and the Arts, Commonwealth of Australia Australian Government, April 2005, Opticon and Australian National University; Australian ICT Research Study, Canberra

Haider, A, & Koronios, A 2005, 'ICT Based Asset Management Framework', in Proceedings of 8th International Conference on Enterprise Information Systems, *ICEIS*, Paphos, Cyprus, vol. 3, pp. 312-322.

Haider, A, Koronios, A, & Quirchmayr, G 2006, 'You Cannot Manage What You Cannot Measure: An Information Systems Based Asset Management Perspective', in Proceedings of Proceedings of Inaugural World Congress on Engineering Asset Management, 11-14 July 2006, Gold Coast, Australia.

IIMM 2006, 'International Infrastructure Management Manual', Association of Local Government Engineering NZ Inc, National Asset Management Steering Group, New Zealand, Thames.

Karlsson, T, & Gennas, JB 2005, 'Content Management Systems – Business effects of an implementation', Master Thesis in Informatics, Department of Informatics, Goteborg University and Chalmers University of Technology, Goteborg, Sweden.

Leibs, S 2002, 'A step ahead: Economist Erik Brynjolfsson leads the charge toward a greater appreciation of IT', *CFO Magazine*, NY, pp.38-41.

Liyanage, JP, & Kumar, U 2003, 'Towards a value-based view on operations and maintenance performance management', *Journal of Quality in Maintenance Engineering*, vol. 9, no. 4, pp. 333-350

Markeset, T, & Kumar, U 2005, 'Product support strategy: conventional versus functional products', *Journal of Quality in Maintenance Engineering*, Vol. 11, No. 1, pp. 53-67.

OALD 2007, 'The Oxford Advanced Learner's Dictionary', 7th revised edition, OXf. Uni. Press.

Rondeau, EP, Brown, RK, & Lapides, PD 2006, *Facility Management*, John Wiley & Sons, Hoboken, NJ.

Yusof, MM, Paul, RJ, & Stergioulas, LK 2006, 'Towards a Framework for Health Information Systems Evaluation', in Proceedings of the 39th Annual Hawaii International Conference on System Sciences, *HICSS '06*, vol. 5, Hawaii..