Association for Information Systems
AIS Electronic Library (AISeL)

PACIS 2008 Proceedings

Pacific Asia Conference on Information Systems (PACIS)

July 2008

CONCEPTUAL AND OPERATIONAL LIMITATIONS OF EVALUATING IS FOR ENGINEERING ASSET MANAGEMENT

Abrar Haider
University of South Australia, abrarhaiders@gmail.com

CONCEPTUAL AND OPERATIONAL LIMITATIONS OF EVALUATING IS FOR ENGINEERING ASSET MANAGEMENT

Dr. Abrar Haider, School of Computer and Information Science, University of South Australia, abrar.haider@unisa.edu.au

Abstract

Asset managing organisations utilize a variety of information systems to support the lifecycle of their assets. Traditionally, engineering enterprises take a deterministic approach to technology adoption. Evaluation of these systems, therefore, is an important aspect of managing IT investments in these organisations. Information systems evaluation is not an inert or stagnant activity, in fact it is highly influenced by the organisational environment. There are certain conceptual and operational issues and challenges that impede the employment of an effective evaluation mechanism. This paper provides a discussion on the conceptual and operational dimensions of the evaluation of the information systems utilized in asset lifecycle management. It highlights that an effective approach to information systems evaluation calls for pluralism, which demands qualitative as well as quantitative measures, involving context based cultural, social, economic, political, technical, and organisational aspects.

Keywords: Information systems, Performance evaluation, Asset management.

1 INTRODUCTION

A critical aspect of Information Technology (IT) adoption in general and Information Systems (IS) in particular, is to find the strategic fit between the way an organisation executes its businesses and the technologies selected to aid in its execution. The variety of systems and the range of objectives associated with these systems demand that organisations need to take stock of their capabilities, resources, and aspirations to enable informed choices regarding IS investments. However, 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 implantation IT performance 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). Liyanage and Kumar (2003) argue that the changing competitive environment of engineering asset managing organisations along with stricter regulatory requirements, are forcing these organisations to have effective performance management mechanisms for their asset management processes. This trend is getting popular in capital intensive industries, such as petroleum (Dwight 1999; Tsang 1999; Liyanage and Kumar 2000). As these industries are increasingly becoming aware of the shortcomings of the classic techniques that typicaly have a financial focus, asset managing organisations like BP, Shell, and Phillips are broadening the scope of their evaluation exercises, so as to include soft as well as hard determinants of asset management (Liyanage and Kumar 2003). With increased automation of asset management processes and uptake of IS by asset managing organisations, measuring performance of IS is a major concern for engineering enterprises.

IS for asset management are required to provide an integrated view of lifecycle information such that informed choices about asset lifecycle could be made. An integrated view of asset management through IS, however, requires appropriate hardware and software applications; quality, standardised, and interoperable information; appropriate skill set of employees to process information; the strategic fit between the asset management processes and the IS; and a conducive organisational environment. Any attempt to evaluate IS investment, therefore, should be aimed at understanding the context within which the IS are deployed, as well as the processes that affect and are affected by their use. Evaluation of IT investments means assessments of hard quantifiable benefits that appear on an organisation's financial statements, as well as soft qualitative benefits that are reflected in organisational culture, behaviour, and intellectual capital (Irani *et al.* 1997).

The main purpose of this paper is to explore issues and challenges posed to evaluation of IS utilised in managing engineering assets lifecycle. This paper contributes to the literature by highlighting the operational and conceptual issues posed to IS evaluation. The barriers to objective evaluation of IS highlight the need for understanding the social nature, span of influence, and interpretation of IS adoption in the context of their implementation. This paper starts with a discussion of assets management and the role of IS in managing assets, next is the discussion on the nature of IS evaluation and the conceptual and operational issues of IS evaluation, followed by recommendations and conclusion.

2 TRENDS IN IT INVESTMENTS

Investments in IT have been increasing steadily in all industry sectors. According to Australian Bureau of Statistics (ABS 2007), during the year ended June 2006, engineering industry ranked highest among the IT enabled Australian businesses. 95% businesses of the electricity, gas and water supply industries were using IT to enable their business processes, which was way higher than the collective Australian industries' average 85%. However, construction industry lagged behind with a percentage of 78% for IT enablement. At the same time IT adoption between 2003—04 and 2004—05 increased in electricity, gas and water supply industries by 5% and web presence for manufacturing industries increased by 7 %. In a research survey conducted by Gomolski el al. (2001), it was concluded that generally IT investments in an organisation ranges between 1% and 3% of the total revenue. This figure, however, reaches 5% in service industries and thus outclasses expenditure on research and development activities. Bartels *et al.* (2006) reports that the global IT investment were tipped to reach $1.55 trillion (US) in 2007, which was a growth of 5% following 8% in both 2005 and 2006. A recent study conducted by OECD (2006) reports that the IT investment divide between US and the rest of the world is diminishing fast. IT investment in Europe and Japan were expected to grow at the rate of 2.2% and 2.8% respectively in 2006, whereas smaller OECD economies (Australia, Canada, Ireland, Korea, Mexico) and eastern European OECD countries (Czech Republic, Hungry, Poland, Slovak Republic) were all projected to have growth rates above the average OECD in 2006-07. This trend of augmented investments in IT shows that IT is increasingly being regarded as capital investment by businesses rather than operating expenditure (see for example Bajaj and Bradley 2005; Serafeimidis and Smithson 2003).

3 ASSET MANAGEMENT

The term asset in engineering organisations is defined 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 2005). 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. A physical asset should be taken 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 (Amadi-Echendu 2004). Management of assets, therefore, entails preserving the value function of the asset during its lifecycle along with economic benefits. Consequently, asset management processes are geared at gaining and sustaining value from design, procurement and installation through operation, maintenance and retirement of an asset, i.e. through its lifecycle.

Management of assets has been approached in various ways in industry and academic research. Economic benefits have traditionally been an implicit or explicit value expected from an asset, the concept of terotechnology was therefore introduced in Britain around 1970 (Husband 1976). Having its origin in resources management, it terms asset management as combination of management, financial, engineering, and other practices applied to physical assets in pursuit of economic life-cycle costs. Its practice is concerned with specification and design for reliability and maintainability of plant machinery, equipment, buildings, and is structured by their installation, commissioning, maintenance, modification, replacement, and feedback of information on design, performance, and costs (British Standard 1993).Concept of terotechnology stresses minimising cost of owning an asset over its lifecycle. To achieve this aim, this concept states that it is necessary to lower the traditional boundaries between the design, operation, maintenance, production, finance, and other functions. Terotechnology embraces both the aim of lifecycle cost optimisation and the multifunctional approach to achieving it. Modern asset management owes its genesis to terotechnology, which although extensive, still is predominantly maintenance oriented and cost focused.

Asset management is a strategic and integrated set of processes to gain greatest lifetime effectiveness, utilisation and return from physical assets (Mitchell and Carison 2001). According to Hastings (2000), asset management is derived from business objectives and represents set of activities associated with asset need identification, acquisition, support and maintenance, and disposal or renewal, in order to meet the desired objectives effectively and efficiently. Fundamental aim of asset management is the continuous availability of value that it enables to its stakeholders through its service, production, or manufacturing provision. Consequently, asset management processes interact with a variety of other business processes within the business as well as with business partners, in order to allow for activities such as demand management, procurement, logistics, maintenance and repairs, and customer relationship management. Therefore, asset management is a set of disciplines, methods, procedures and tools derived from business objectives aimed at optimising the whole life business impact of costs, performance and risk exposures associated with the availability, efficiency, quality, longevity and regulatory/safety/environmental compliance of an organisation's assets (Woodhouse 2001). 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).

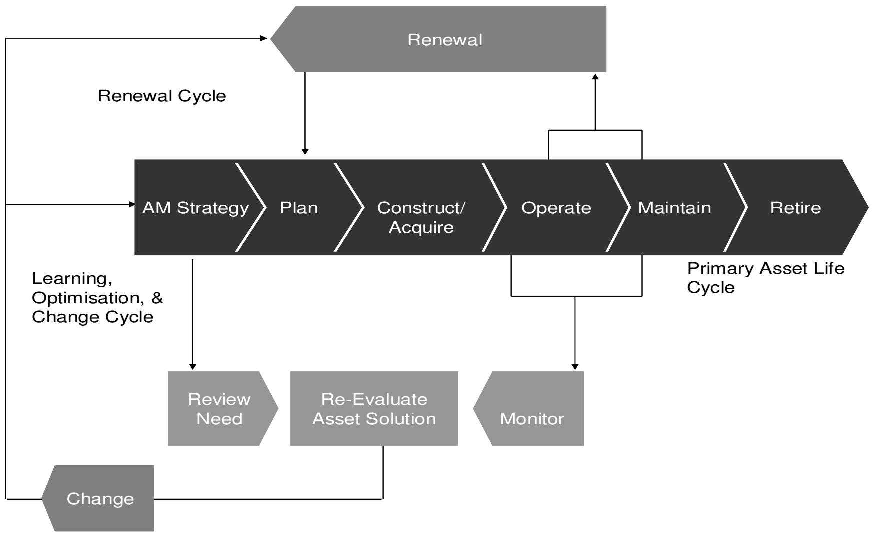

Figure 1. Core Asset Management Lifecycle, Source (Haider 2007)

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. The core objective of asset management processes is to preserve the operating condition of an asset to near original condition. IS are an integral part of an asset lifecycle management and perform various tasks at each stage of the lifecycle through data acquisition, processing and manipulation operations. However, the scope of IS in asset management extends well beyond the usual data processing and reaches out to business value chain integration, enhancing competitiveness, and transformation of patterns of business relationships (Haider and Koronios 2006).

4 IS FOR ASSET MANAGEMENT

Asset managing organisation have twofold interest in IS, first that they should provide a broad base of consistent logically organised information concerning asset management processes; and, second the availability of real time updated asset related information available to asset lifecycle stakeholders (Rondeau *et al.* 2006). However, engineering organisations traditionally conform to technological determinism, where technology is viewed as the prime enabler of change and, therefore, is the fundamental condition that is essential to shape the structure and pattern of an asset management regime (Haider and Koronios 2007). In turn, asset managers are looking for pragmatic solutions that exhibit solid proof of their value to the organisation. IS departments, therefore, are becoming an integral part of strategic evaluation and planning exercises.

Having its origin in mass production aimed at capturing market share, quality management calls for standardization of business processes managed by data and facts that focus on certain targets set by informed choices. However, quality of these informed choices cannot be guaranteed in business areas where such positivist assumptions are not valid. Engineering asset management is one such area, where business processes are carried out in unpredictable environments, with conflicting objectives, and function on basically non-market transactions. Therefore creation; acquisition; dissemination; reuse; and management of information have serious operational and financial implications for an engineering organisation. The fundamental issue in asset management is not just the quality of converting input to output, but also the control of information and knowledge guiding it and the eventual use and reuse of such information for decision support and enterprise wide planning and execution. In simple words, the fundamental issue here is not only doing things right, but also to have information that guides about what are the right things to do. However, current information systems in operation within engineering enterprises have paid for themselves, as the methodologies employed to design these systems define, acquire and build systems of the past not for the future (Haider and Koronios 2004a). For example, the maintenance IS development, which has attracted considerable attention in research and practice are far from being optimal. While maintenance activities have been carried out ever since advent of manufacturing; modelling of an all inclusive and efficient maintenance system has yet to come to fruition (Duffuaa *et al.* 2001; Yamashina 2000). This is mainly due to the continuously changing and increasing complexity of asset equipment, and the stochastic nature or the unpredictability of the environment in which assets operate, along with the difficulty to quantify the output of the maintenance process itself (Duffuaa *et al.* 1999). Current IS employed for condition monitoring identify a failure condition when the asset is near breakdown, and therefore serve as tools of failure reporting better than instruments for pre-warning the failure condition in its development (Haider and Koronios 2004b).

In response to the increased competitive pressures, asset managing strategies that once were run-to-failure are now fast changing to being condition based, thereby necessitating integration of asset management decision systems and computerized maintenance management systems in order to provide support for maintenance scheduling, maintenance workflow management, inventory management, and purchasing (Bever 2000). However, in practice, data is captured both electronically and manually, in a variety of formats, shared among an assortment of off the shelf and customized operational and administrative systems, communicated through a range of sources and to an array of business partners and sub contractors; and consequently inconsistencies in completeness, timeliness, and inaccuracy of information leads to the inability of quality decision support for asset lifecycle management (Haider and Koronios 2005). In these circumstances, existing asset management IS could best be described as pools of isolated data that are not being put to effective use to create value for the organisation.

Most engineering enterprises mature technologically along the continuum of standalone technologies to integrated systems, and in so doing aim to achieve the maturity of processes enabled by these technologies, and the skills associated with their operation (Haider and Koronios 2006). Konradt *et al.* (1998) further assert that engineering enterprises adopt a traditional technology-centred approach to asset management, where technical aspects command most resources and are considered first in the planning and design stage. Skills, process maturity, and other organisational factors are only considered relatively late in the process, and sometimes only after the systems are operational. However, human, organisational, and social factors have a direct relationship with IS (Orlikowski and Barley 2001; Walsham 2001, 1995; Orlikowski and Robey 1991; Checkland 1981), which underscore the conceptual and operational constraints posed to effective IS implementation. It is, therefore, important to assess the performance of IS investments for compliance to their intended purpose and the contributions that they make in managing the asset lifecycle. This performance evaluation may be aimed at different dimensions of asset lifecycle management, such as, effectiveness, reliability, and cost effectiveness of design, operation, and maintenance. The Institute of Public Works Engineering Australia (IIMM 2006) specifies minimum criteria to measure performance of IS for asset lifecycle management for contributions and compliance in terms of,

a. justifications of planned levels of service;
b. monitoring, and reporting and requirements;
c. planned techniques and methodologies to enable cost effective asset lifecycle treatment options, such as risk management, predictive modelling, and optimised decision support;
d. identification of task priorities and resources requirements;
e. justification of the roles and responsibilities for various organisation units in relation to asset management activities;
f. information requirements of asset lifecycle; and
g. continuous improvement of asset management plan.

5 ISSUES WITH EVALUATION OF IS FOR ASSET MANAGEMENT

5.1 Nature of IS Evaluation

IS evaluation is often difficult and a wicked problem (Farbey *et al.* 1999; Smithson and Hirscheim 1998), due mainly to its varying roles in different organisations. Evaluation by nature is a subjective term and is defined in the Oxford Advanced Learner's Dictionary as, the process of judging or forming an idea of the amount, value, or worth of an entity (OALD 2005). Neely *et al.* (1995) suggest that performance is the measure of efficiency and effectiveness of action; and performance evaluation is the process of measuring accomplishments, where measurement deals with quantification of action and accomplishment illustrates performance. Tangen (2004) takes the argument further and contends that performance evaluation represents the set of metrics used to quantify the efficiency and effectiveness of organisational actions taken towards achieving its objectives. The efficiency and effectiveness constitute the value profile that the organisational stakeholders attach to action in an organisation. In light of this discussion IS evaluation could be defined as "an assessment of value profile of IS to asset lifecycle using appropriate measures, at a specific stage of IS lifecycle within each stage of an asset lifecycle, towards continuous improvement aimed at achieving the overall organisational objectives*"*.

5.2 Conceptual limitations of IS for asset management evaluation

Evaluation, conceptually, is a subjective activity that is biased and cannot be detached from the human understanding, social context, and cultural environment, within which it takes place. Evaluation, therefore, is influenced by the actors who carry out this exercise; and the principles and assumptions that they employ to execute evaluation. Scope of asset management spans engineering as well as general business or administrative activities. In addition, most of these activities are cross functional and even cross enterprise. For example, maintenance processes influence areas such as, quality of operations; safe workplace and environment; manufacturing management, and accounting. The outputs from maintenance are further used to predict asset remnant lifecycle considerations, asset redesign/rehabilitation, and planning for the support resources management. A single information snapshot is open to interpretation from different perspectives for various dimensions of quality and efficiency. Considering the fact that human interpretation shapes and reshapes over a period of time, the nature of evaluation also changes from time to time. Evaluation, thus, represents the existing meanings and interests that individuals or communities associate with the use of technology within the socio technical environment of an organisation. The focal point of socio technical perspective is the interactive association between people, IS and the social context of the organisation (Bijker and Law 1992). However, action is an important element of this interaction. This notion of action is contained in the structuration theory (Giddens 1984), which describes that it is facilitated and influenced by the social structure. People's interaction is, therefore, fashioned by the social structure and their actions persistently shape or transform social structure (Hayes and Walsham 2000). There is a dynamic relationship between technology, and the context within which it is employed and the organisational actors who interact with technology. This duality of technology is characterised by Orlikowski (1992), who argues that technology is socially and physically constructed by human action. When technology is physically adopted and socially composed, there is generally a consensus or accepted reality about what the technology is supposed to accomplish and how it is to be utilized. This temporary interpretation of technology is institutionalised and becomes associated with the actors that constructed technology and gave it its current significance (Orlikowski 1992), until it is questioned again for reinterpretation. This requirement of reinterpretation may grow owing to changes in the context, or the learning that may render the current interpretation obsolete. Technology, therefore, is not an objective entity, such that it could either be evaluated without considering its interaction with social and human factors (Manion and Evan 2002), or it could be evaluated in basic and one-dimensional economic terms (Bjorn-Anderssen 1988; Orlikowski 1992; Sauer and Yetton 1997; Truex *et al.* 1999; Atkins and Dawson 2001).

When IS evaluation is employed it is expected that it will expose a number of different dimensions of IS implantation, such as, financial, technical, behavioural, social, and management aspects of IS. Furthermore, these endeavours may be aimed at stakeholder satisfaction, role of IS, and IS lifecycle. These expectations change during the lifecycle of an IS. An ex ante or pre implementation is aimed at ascertaining cause and effect of technology; whereas, ex post or post implementation evaluation may be aimed at evaluation of strategic translation as well strategic advisory role of IS. Each of these dimensions, their related objectives and aims have their own theories, postulates, and evaluation criteria, which makes IS evaluation complicated and difficult.

5.3 Operational limitations of IS for asset management evaluation

Contemporary asset management paradigm demands an elevated ability and knowledge to incessantly support asset management processes, with support in terms of quality data acquisition, real-time data exchange, and computer supported categorization and analysis of asset operation divergences from standard procedures (Sandberg 1994). Bamber *et al.* (1999) argue these factors are essential for effective planning, scheduling, monitoring, quality assurance, and acquisition of necessary resources required for supporting asset lifecycle, and consequently enhancing the competitive profile of the asset managing organisation. Role of IT investments is no more considered as inwardly looking systems aimed at operational efficiency through process automation; in fact, it extends beyond the organisational boundaries and also addresses areas such as business relationships with external stakeholders, to deliver business outcomes. This complicates the process of decision making for IT investments, since this decision needs to take care of the impact of the investment on business processes and resources, as well as integration of these technologies with other systems. However, IS evaluation, generally has a narrow focus and involves people who cannot evaluate IT on anything other than technological dimensions (Wilicocks and Lester 1997). Consequently, simplistic measures are adopted to measure the effectiveness of IS, while these efficacy criteria are aimed at process efficiency rather than its prospectus of organisational transformation. The measurement attributes involved in such IT investments, require both aspects of IT benefit to be taken care of i.e. soft benefits, such as stakeholder satisfaction, and customer relationship management; and hard benefits, such as cost, IS throughput. However, evaluation methods wanting in completeness render the accuracy and credibility of evaluation mechanisms questionable, in terms of their role as instruments of decision support. In IS evaluation the generally applied generic performance measures are financial measures, such as costs of implementation; technical measures, such as response time; system usefulness attributes, such as user satisfaction; and quality of the information (DeLone and McLean 1992). IS, however, are social systems embedded within the organisational context and choosing criteria that encompasses evaluation of all the IS benefits is a difficult task. Teubner (2005) points out these difficulties are due to a range of factors, such as,

5.3.1 Technical Embedding.

Individual IS components are often embedded in the overall technological infrastructure, which makes it difficult to assess the performance of these individual components. For example, while evaluating the effectiveness of a condition monitoring system, it is difficult to quantify the contribution of individual sensors.

5.3.2 Organisational Embedding.

IS infrastructure is an integral part of an organisation, and influences and is influenced by a number of organisational factors, such as culture and structure of the organisation. Consequently it has progressively become difficult to take the impact of IS apart from these organisational aspects. IS utilised in engineering asset management not only have to provide for the decentralized control of asset management tasks but also have to act as instruments for decision support. For example, a critical aspect of effective asset lifecycle management is the learning or knowledge gained at each stage, which provides for the feedback to other processes. Asset operation profiling has significance for asset redesign as well as asset maintenance, asset operation cost benefit analysis, and lifecycle decision support (Haider and Koronios 2003). Furthermore, the utility of an IS is not just restricted to the business process or process that it enables, but is also reflected in the ambiance of the organisation, such as through job satisfaction, culture, and social environment.

5.3.3 Social Construction.

The social impact of IS is well documented, which makes it much more than just a technical solution. Impact of changes that IS implementation brings affect work practices as well as the intellect and working habits of employees. However, impact of IS on staff, social life of the organisation, and collective sense making, is intangible and is difficult to measure.

5.3.4 Social Adoption.

IS adoption is a social process, since their use evolves over time and depends heavily upon skills of employees and culture of the organisation. It also means that IS may not start delivering desired results straight after their implementation. Evaluation criteria, therefore, needs to account for the time frame of IS lifecycle within which evaluation is to be carried out. IS evaluation has different objectives and aims ex ante and ex post. In ex ante or pre implementation technology, decisions are generally based on cost benefits, and the perceived value that the investment may bring to the organisation. These investigations are usually carried out by functional teams, who evaluate different choices of technologies and then arrive at a decision. The measurement criteria are often not clear and basically governed by the assumptions of the future use of technology, as conceived by the evaluators. On the contrary, during a post implementation evaluation a report card on the investment in IS is developed. This type of evaluation is generally not conducted by the people who conduct the ex ante evaluation, and therefore susceptibilities of technology in terms of purpose, and effectiveness of use are not considered. These two factors change with time, due mainly to technological innovation and changes in business environment. Post implementation evaluation is often expected to produce learnings and feedback that could be used for strategic reorientation. However, this form of evaluation requires long term involvement, and experience, such that the purpose, use, and fit of technology within the organisation are understood. This makes the success or failure of IS open to interpretations according to the judgements and experiences of the evaluators.

6 CONCLUSION

IS evaluation is a subjective activity that is highly influenced by the context within which the IS are employed. It involves a variety of organisational stakeholders, and a range of activities, processes, and conditions, which underscores the complexity of IS evaluation. Evaluation of IS investments by nature is unique and different from other evaluations, due mainly to the tangible and intangible impacts of IS. IS are social systems and their interpretation is influenced by the use and meaning that organisational communities associate with them within the socio technical environment of the organisation. Evaluation, therefore, is subjected to the principles, assumptions, and concepts that the evaluators employ in carrying out the evaluation exercise. In a social setting, human interpretation is continuously evolving and thus the interpretation of IS also reshapes due to the changes in business environment and information requirements. Evaluation, thus, represents the current meanings and interests that individuals or communities associate with the use of IS within the organisation. When asset managing engineering enterprises attempt to evaluate IT, managerial emphasis is mostly on improving cost benefit of IT adoption, using cost benefit analysis, payback and return on investment. These evaluations only give a slice of the total impact of IT investments and disregard the human and organisational aspects of IT adoption, and, therefore, not only keep the softer benefits hidden but the costs of managing these benefits also remain uncovered. Furthermore, these unobserved benefits prevent the systems from delivering at its full potential. Consequently, such evaluations fail to measure the total impact of IT and contribute to failure of IT investments to achieve desired objectives.

The operational and conceptual issues involved in IS evaluation make the realisation of an all encompassing IS evaluation difficult to achieve. Enacting appropriate methodologies, techniques, and tools for evaluation provide the rational underpinnings between the evaluation measures and the effectiveness of evaluation. Due consideration to this relationship is important, for the fact that IS implementation has a direct relationship with organisational context, human behaviour, and other structures developed around IS. Choice of evaluation method and tools needs to be comprehensive enough to encompass all these issues. Evaluation of IS for asset lifecycle management calls for ascertaining both hard as well as soft benefits to the organisation by using quantitative as well as qualitative means and their connection to organizational development (Grembergen and Bruggen 2003). This can only be attained if IS evaluation provides a roadmap in terms of alternatives and choices (Fasheng and Teck 2000), and hence becomes a strategic advisory mechanism that supports planning, decision making, and management processes (Karlsson and Gennas 2005). Such evaluations provide feedback (Serafeimidis and Smithson 2003) that facilitates organizational learning (Argyris and Schon, 1996; Farbey *et al.* 1999). This feedback indicates the fundamental reasons, factors, and causes for variations in performance of IT investments (Davern and Kauffman 2000).

References

ABS (2007). Business Use of Information Technology, Australian Bureau of Statistics, Catalogue No. 8019.0, Commonwealth of Australia, Canberra, ACT.

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

Argyris, C., & Schon, D.A. (1996). Organizational Learning II: Theory, Method and Practice, Addison-Wesley, Reading, MA.

Atkins, M., & Dawson, P. (2001). The Virtual Organization: Emerging Forms of ICT-Based Work Arrangements, Journal of General Management, 26(3), Spring, pp. 41-52.

Bajaj, A., & Bradley, W. (2005). An Exploration of the Role of Systems Analysis for Ex Ante Business Value Evaluations of Information Systems, in Proceedings of the Eleventh Americas Conference on Information Systems, Omaha, NE, USA August 11th-l4th.

Bamber, C.J., Sharp, J.M., & Hides, M.T. (1999). Factors Affecting Successful Implementation Of Total Productive Maintenance: A UK Manufacturing Case Study Perspective, Journal of Quality in Maintenance Engineering, 5(3), pp. 162-81.

Bever, K. (2000). Understanding Plant Asset Management Systems, Maintenance Technology, July/August, pp. 20-25

Bijker, W.E., & Law, J. (eds.) (1992). Shaping Technology/Building Society: Studies in Sociotechnical Change, MIT Press, Cambridge, MA.

British Standard (1993). Glossary of Terms Used in Terotechnology BS 3811:1993, British Standards Institution Publishing Limited, London ISBN: 058022484 8.

Checkland, P. (1981). Systems Thinking, Systems Practice. John Wiley & Sons, Chichester.

Davern, M., & Kauffman, R. (2000). Discovering Potential and Realizing Value from Information Technology Investments, Journal of Management Information Systems, 16(4), pp. 121-143.

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

DeLone, W.H., & McLean, E.R. (1992). Information systems success: The quest for the dependent variable, Information Systems Research, 3(1), pp. 60-95.

Duffuaa, S.O., Ben-Daya, M., Al-Sultan, K., & Andijani, A. (2001). A Generic Conceptual Simulation Model For Maintenance Systems, Journal of Quality in Maintenance Engineering, 7(3), pp. 207-219.

Duffuaa, S.O., Cambel, J.D., & Raouf, A., (1999). Planning and Control of Maintenance Systems: Modelling and Analysis, John Wiley & Sons, New York.

Dwight, R. (1999). Frameworks for measuring the performance of the maintenance system in a capital intensive organisation, PhD thesis, Department of Mechanical Engineering, University of Wollongong, Wollongong.
Farbey, B., Land, F. & Targett, D. (1999). Moving IS evaluation forward: learning themes and research issues, Journal of Strategic Information Systems, 8, pp.189-207.
Fasheng, Q., & Teck, Y.K. (2000). IS/IT Project Investment Decision Making, in Proceedings of the IEEE International Conference on Management of Innovation and Technology, ICMIT, 2, pp. 502-507.
Giddens, A. (1984). The Constitution of Society: Outline of the Theory of Structure, University of California Press, Berkeley, CA.
Grembergen, W.V., & Bruggen, R.V. (2003). Measuring and improving corporate information technology through the balanced scorecard, Electronic Journal of Information Systems Evaluation, EJISC, 1(1).
Haider, A., & Koronios, A. (2003). Managing Engineering Assets: A Knowledge Based Approach through Information Quality, in Proceedings of 2003 International Business Information Management Conference, Cairo, Egypt, pp.443-452.
Haider, A., & Koronios, A. (2004a). Converging monitoring information for integrated predictive maintenance, in Proceedings of 3rd International Conference on Vibration Engineering & Technology of Machinery (VETOMAC-3) & 4th Asia -Pacific Conference on System Integrity and Maintenance (ACSIM 2004), New Delhi, India, December 6-9, paper No. 40.
Haider, A., & Koronios, A. (2004b). RFID for Integrated Condition Monitoring, in Proceedings of 5th International We-B Conference 2004, Perth, WA.
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, eds J. Mathew, L Ma, A Tan & D Anderson, 11-14 July 2006, Gold Coast, Australia
Haider, A. (2007). Information systems based engineering asset management evaluation: operational interpretations, Phd Thesis, University of South Australia, Adelaide, Australia.
Hastings, N.A.J. (2000). Asset management and maintenance, Queensland University of Technology, Brisbane, Queensland.
Hayes, N., & Walsham, G. (2000). Competing interpretations of computer-supported cooperative work in organizational contexts, Organization, 7(1), pp. 49-67.
Husband, T.M. (1976). Maintenance Management and Terotechnology, Saxson House, Hampshire, England.
IIMM (2006). International Infrastructure Management Manual, Association of Local Government Engineering NZ Inc, National Asset Management Steering Group, New Zealand, Thames, ISBN 0-473-10685-X.
Irani, Z., & Sharp, J.M., (1997). Integrating continuous improvement and innovation into a corporate culture: A case study, The International Journal of Technological Innovation, Entrepreneurship and Technology Management (Technovation), 17(4). pp. 199-206.
Ittner, D., Larcker, D.F., & Randall, T. (2003). Performance implications of strategic performance measurement in financial services firms, Accounting Organisation and Society, 28(7/8), pp.715-741.
Karlsson, T., & Gennas, J.B. (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.
Konradt, U., Zimolong, B., & Majonica, B. (1998). User-Centred Software Development: Methodology and Usability Issues, in The Occupational Ergonomics Handbook, eds W Karwowski, & WS Marras, USA, CRC Press.

Liyanage, J.P., & Kumar, U . (2000). Utility of maintenance performance indicators in consolidating technical and operational health beyond the regulatory compliance, in Proceedings of Safety Engineering and Risk Analysis: The International Mechanical Engineering Congress and Exposition-2000, pp.153-160.

Liyanage, J.P., & Kumar, U. (2003). Towards a value-based view on operations and maintenance performance management, Journal of Quality in Maintenance Engineering, 9(4), pp. 333-350

Manion, M., & Evan W.M. (2002). Technological catastrophes: their causes and prevention. Technology in Society, 24, pp. 207-224.

Mitchell, J.S., & Carlson, J. (2001). Equipment asset management – what are the real requirements?, Reliability Magazine, October, pp. 4-14.

Neely, A., Kennerley, M., & Martinez, V. (2004). Does the balanced scorecard work: an empirical investigation, in Proceedings of Performance Measurement Association Conference, Edinburgh, July.

OALD (2005). The Oxford Advanced Learner's Dictionary, 7th revised edition, Oxford University Press, ISBN: 0194316491.

OECD (2006). OECD Information Technology Outlook 2006, OECD, ISBN Number: 92-64-02643-6, Paris.

Orlikowski, W.J., & Robey, D. (1991). Information Technology and the Structuring of Organizations, Information Systems Research, 2(2), pp. 143-169.

Orlikowski, W.J. (1992). The Duality of Technology: Rethinking the Concept of Technology in Organizations, Organization Science. 3(3), pp. 398-427.

Orlikowski, W.J., & Barley, S.R. (2001). Technology and institutions: what can research on information technology and research on organizations learn from each other?, MIS Quarterly, 25(2), pp. 245-265.

Rondeau, E.P., Brown, R.K., & Lapides, P.D. (2006). Facility Management, John Wiley & Sons, Hoboken, New Jersey.

Sandberg, U. (1994). The Coupling Between Process and Product Quality – The interplay Between Maintenance and Quality in Manufacturing, in Proceedings of 12th Euromaintenance Conference, European Foundation of National Maintenance Societies, Amsterdam.

Serafeimidis, V., & Smithson, S. (2003). Information systems evaluation as an organizational institution - experience from a case study, Information Systems Journal, 13(3), pp.251-274.

Smithson, S. & Hirschheim, R. (1998). Analysing information system evaluation: another look at an old problem, European Journal of Information Systems, 7(3), pp. 158-174.

Teubner, R.A. (2005). The IT21 Checkup for IT Fitness: Experiences and Empirical Evidence from 4 Years of Evaluation Practice, in working papers, European Research Center for Information Systems No. 2., eds. J Becker, K Backhaus, HL Grob, T Hoeren, S Klein, H Kuchen, U. Muller-Funk, UW Thonemann, G Vossen, Munster, ISSN 1614-7448.

Truex, D.P., Baskerville, R., & Klein, H. (1999). Growing Systems in Emergent Organizations, Communications of the ACM, 42(8), August, pp.117-123.

Tsang, A.H.C. (1999). Maintenance performance management in capital intensive organisations, PhD thesis, Department of Manufacturing Engineering, The Hong Kong Polytechnic University, Hong, Kong.

Walsham, G. (1995). Interpretive Case Studies in IS Research: Nature and Method, European Journal of Information Systems. 4(2), pp. 74-83.

Walsham, G. (2001). Making a World of Difference IT in a Global Context, John Wiley, Chichester.

Willcocks, L.P., & Lester, S. (1997), In search of information technology productivity: Assessment issues, Journal of the Operations Research Society, 48 , pp. 1082-1094.

Woodhouse, J. (2001). Asset Management, The Woodhouse Partnership Ltd, online accessed on September 10, 2007 at http://www.plantmaintenance.comlarticles/AMbasicintro.pdf

Yamashina, H. (2000). Challenge to world class manufacturing, International Journal of Quality & Reliability Management, 17(2), pp. 132-143.