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Education in Engineering Asset Management – current trends and challenges

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Abstract

Engineering Asset Management (EAM) is an emerging inter-disciplinary field that combines technical issues of asset reliability, safety and performance with financial and managerial requirements. Asset owners are increasingly focused on improving competitive advantage and cost-effectiveness but are handicapped by lack of technical and managerial skills and processes specific to EAM at all levels of their organization. This paper provides an overview of the dynamic processes shaping EAM in the last two years and identifies current trends. Asset Owners are shaping the future of education programs in EAM by (1) determining the body of knowledge and associated competencies, (2) recognizing the need for continuous learning in this dynamic field for personnel at all levels and across different functional groups in organisations, and (3) requiring the use of systematic, data-driven, life-cycle and risk-based decision-making to improve competitive advantage and reduce costs.

1. Introduction to EAM

A definition of Engineering Asset Management is "systematic and coordinated activities and practices through which an organization optimally manages its assets, and their associated performance, risks and expenditures over their lifecycle for the purpose of achieving its organizational strategic plan" (PAS 55, 2004). The emphasis of EAM is clearly on sustainable business outcomes, risk management and value. EAM is concerned with assets throughout the lifecycle. This is the time interval that commences with the identification of the need for a physical asset[1], through defining the requirements, the acquisition and system implementation processes, in-service operation and maintenance management, and asset decommissioning and disposal. The entire process involves a wide range of disciplines and requires a range of technical and management tools and skills.

Companies who own and operate physical assets rely on what we commonly call the 'maintenance' team or department to maintain the asset(s) and ensure that it can deliver on the desired function. The process of 'doing' maintenance has changed remarkably over the last 30 years due to influences including but not limited to equipment design, computerization, electronics and communication, cost pressures and societal acceptance of risk and failures. As maintenance absorbs a significant percentage of operating costs (Tan, 1997; Tomlingson, 2005), it is now on the radar of senior management attention. The evolution of the term "engineering asset management"

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[1] Asset: Plant, machinery, property, building, vehicles and other items and related systems that have a distinct and quantifiable business function or service

is largely in response to the desire to better manage maintenance and associated efforts, and to align internal processes with strategic objectives.

This paper takes a snap-shot look at some of the major trends in the EAM field and evaluates their potential impacts from the perspective of an educational provider. In the context of this paper an educational provider may be a university or commercial course provider.

2. Background to the paper

The authors are engaged at academic research institutions in Australia and Chile with strong links to the public and private industry and defence sectors (collectively described as 'asset owners' in this paper). Both authors are involved in the development of postgraduate and undergraduate programs in the EAM and Maintenance fields respectively. This paper is the result of discussions between the authors and a range of practitioners, engineers, managers, consultants and academics involved in the maintenance, reliability and asset management communities in the US, Canada, Australia and Chile in 2005 and 2006. The paper also draws on the work conducted by a West Australian industry-university group, the West Australian Asset Management Initiative (WAAMI[2]) established in 2004 to examine education needs and research opportunities in EAM that would benefit WA businesses. The WAAMI industry advisory panel includes members from the oil and gas, power, water, mining, and defence industries, as well as service providers. WAAMI has been involved in advising on the development of a Masters of Engineering in EAM at the University of Western Australia.

3. Current Trends

3.1 Asset Owners driving the evolution of EAM

EAM is an emerging discipline, built on ideas originating with Terotechnology and supplemented by the practices embodied in Total Productive Maintenance, Systems Engineering, and related frameworks (Ministry of Technology, 1969; Nakajima, 1989; Blanchard, 2006). The vision for EAM is broader than any of its predecessors and applicable to all asset owners, not just production and manufacturing but also utility, defence and local and national infrastructure assets.

The strong interest by asset owners in developing EAM is illustrated by actions including:

- Establishing internal 'strategic asset management' and 'tactical asset management' groups
- Moving senior operations managers into 'asset management' roles
- Engaging in consortia to identify and develop asset management processes
- Collaborative efforts to collect and share equipment and failure-related data, and
- Sponsoring and attending asset management conferences and workshops.

As with any new field, the content of the field and boundaries must be described. The authors note that in the case of EAM, this work is currently being done by institutional and asset-owner consortia bodies as well as individual companies. These groups are engaged in developing a structured hierarchy of content that defines their field of EAM. The resulting 'body of knowledge' includes management and technical areas, with major topics in each, and a list of skills and processes associated with each topic. Examples of programs developed by three independent bodies are discussed below.

- The Society of Maintenance and Reliability Professionals (SMRP[3], based in the USA) has a mission to support Maintenance Practitioners who are actively engaged in the maintenance process and maintenance management (for example, supervisor, planner,

[2] http://www.mech.uwa.edu.au/~mhodki/waami/index.html

[3] http://www.smrp.org/

technician, engineer). SMRP developed a body of knowledge in the 1990's and has an active certification process with over 2000 individual members across the globe.

- The Institute of Asset Management (IAM[4], based in the UK) is a relatively new body that aims to provide support for professionals engaged in the more strategic and tactical aspects of EAM. The IAM Competency Project recently published a framework defining the IAM body of knowledge and is in the process of conducting pilot studies with a view towards developing a certification and assessment program (Woodhouse 2006).
- The American Society for Quality has a number of certification processes including a Certified Reliability Engineer (CRE)[5]. This qualification and the body of knowledge on which it is based are aimed primarily at traditional reliability and quality engineers involved in the design and manufacture of equipment.

A comparison of the main topics in each 'body of knowledge' is provided in Table 1.

Organisation	**Institute of Asset Management (IAM)**	**Society of Maintenance and Reliability Professionals (SMRP)**	**American Society for Quality (ASQ)** **Certified Reliability Engineer**
Focus Area	Asset Managers	Maintenance Practitioners	Reliability Engineers
Status	Published 2005	Established with Certification Process	Established with Certification Process
Topics	Business Management	Business & Management	Reliability Management
	People management	People skills	Probability and Statistics for reliability
	Information management	Work Management	Reliability in design and development
	Risk Management	Equipment reliability	Reliability modeling and predictions
	Create/Acquire Assets	Manufacturing Process reliability	Reliability Testing
	Operate/Maintain Assets		Maintainability and Availability
	Dispose/Renew Assets		Data collection and use

Table 1: Comparison of topics in the Body of Knowledge defined by the IAM, SMRP and CRE.

These body of knowledge examples are not unique. We are aware of global companies who are engaged in their own internal projects to identify an EAM body of knowledge and competencies tailored to their specific business (Hodkiewicz, 2006). These global companies appreciate the potential impact on competitive advantage of improved EAM practices and are engaged in substantial projects to identify, assess and improve competencies.

The work by the Institute of Public Works Engineering Australia (IPWEA)[6] and the US Federal Facilities Council[7], has also been important in defining the EAM field specifically in the Infrastructure and Facilities areas (IPWEA, 2006; Cable, 2005).

[4] http://www.iam-uk.org/

[5] http://www.asq.org/

[6] http://www.ipwea.org.au

[7] http://www7.nationalacademies.org/ffc/

The IAM, CRE and others either have developed, or are in the process of developing, a set of outcomes which describe different levels of competence. The IAM has developed three levels of competence, Mastery, Professional, and Foundation. Other internal-company projects have a wider range of competencies with greater granularity in the Foundation level, which reflects their desire to have a single program that spans all job descriptions, not just those at the professional level.

Regardless of the number of competencies and their label, they span the learning levels described by the well known Bloom's taxonomy (Bloom et al, 1956). This describes a hierarchical and sequential set of educational levels: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. The 'knowledge' level is associated with facts, definitions, jargon and technical terms. Knowledge is necessary but not sufficient to solve problems (Wankat, 1993). The highest levels are associated with the synthesis and evaluation steps. Synthesis is associated with the solution of complex open-ended problems for which there is no single correct solution. Evaluation is the examination and judgement of a range of different solutions and the process of selecting the most appropriate way forward.

One of aims of the Competency Programs is to develop individual assessment and hence training plans for people in different job classifications. For example, what skills and competency levels are required for the position of Maintenance Planner? The perceived benefits of this approach include (a) the asset owner deciding the competencies required to effectively manage the assets, (b) clarity of assessment of the competence of the incumbent person, (c) defining the gap between current and required competencies, (d) developing plans to bridge gaps for individual incumbents, and (e) defining essential competencies for new hires.

In our opinion, the developments described above represent a seismic shift in the way education in this field will be organised in the future. Previously, courses were developed and offered by academic and private groups who defined the course content based on their view of the body of knowledge and the competencies required. What we are seeing now is asset owners defining the educational field (through specification of areas and topics) and required competencies. From this we will see some of the following effects:

- Asset owners seeking to improve the level of competence of their personnel[8] will examine a range of educational options.
- Development of new courses geared towards the outcomes defined by the body of knowledge and associated competencies.
- The educational providers will be encouraged to demonstrate how their courses will assist students (personnel) in moving from one competency level to another in a specific range of topics.
- Greater scrutiny by asset owners of educational programs for cost effectiveness and efficiency of achieving desired asset-owner defined outcomes.
- Increase in number of students engaged in educational programs as developing new competencies will be an integral part of the progression policies of asset owners.
- Greater appreciation for the depth and range of skills required by those involved in sustaining (operating and maintaining) assets.
- Acceptance by asset owners and their staff of the need for continuous learning through the life cycle of an individual's career.

[8] We avoid the use of the term 'employee' as an increasing proportion of the workforce are contractors, either free-lance or working for another company.

3.2 Continuous educational development

It is apparent that there is a desire to change how maintenance and associated decisions are made. Decision-making is moving from the routinely subjective to using systematic, holistic, data-driven, life-cycle and risk-based decision processes that are clearly aligned with the organization's strategic plan. Moving away from subjective decision making requires skills, techniques and processes that may not be part of the historical toolbox of those currently responsible for operating and maintaining engineering assets. In our experience, maintenance personnel at all levels are often baffled by decisions made by senior management that can have quite significant long term negative effects on asset life cycle cost. Often the problem is two-way; maintenance has failed to provide accurate data and a convincing business argument to management, and management does not fully understand the complex maintenance environment and potential consequences of their decision.

These issues have been recognized by asset owners and there are ongoing active discussions at senior levels about the need to continuously update the skills of their personnel. Targeted staff include not just maintenance teams, but also operations/production, logistics (purchasing, inventory, contracts, suppliers), and also senior management.

This is not a new idea. The development of the Total Productive Maintenance (TPM) process in the 1970s stressed the need to involve representatives from all functional groups in the development and implementation of maintenance programs (Wireman, 2003).

One of the main challenges is to make personnel at all levels of the organisation aware of the impact of their own decisions on the performance of the entire system. This is especially true in maintenance in which decisions are routinely made by technicians working on equipment that can have major effects on the availability of the process, product quality and hence sales and costs. Companies accustomed to training senior management in decision making processes are now facing the prospect of needing to implement consistent decision processes that extend to the most functional levels of the organisation.

Currently, training at the technician level is largely skill-oriented, this will have to change to include an understanding of the systems in which the technicians operate and their links with key business processes. An example of this is the need by planners, maintenance and reliability engineers, logistics and OEMs for information concerning equipment failures: the what, when and why. Often the details of the 'what failed?' and 'why?' is reliant on observations made by maintenance technicians. It is vital that this information is captured accurately and appropriately so that it can be used by others in the organisation for planning and decision making. Maintainers recording this information should be aware of its wider uses and relative importance (Hodkiewicz et al, 2006). There are both cultural and cost challenges associated with providing education at practitioner/technician levels in an organisation due in part to the large numbers involved and the difficulties in designing effective programs and realistic assessment mechanisms.

3.3 Development of Information Systems

The emergence of Enterprise Resource Planning systems (ERPs) in the last 10 years has had a major impact on the development of EAM. Maintenance groups can no longer act independently. In addition to their core function of maintaining assets, they have to use and feed the company's information system, and be fully integrated with other functional units, and increasingly into the supply chain (such as equipment and supply vendors and customers).

Companies like Oracle and SAP were founded in the 1970s. Their ERP products (and those of their competitors) only really became established in the last 10-15 years. The integration of Computerised Maintenance Management Systems (CMMS) and ERP has raised the lid on the maintenance process allowing greater scrutiny by senior management. There is a rapidly evolving consulting business advising management on the development of metrics to measure the performance of maintenance groups.

The recent developments in Extended ERP (EERP) systems will further increase pressure on the supply chain integration effort (Kumar, 2001). Examples of this include the development of performance-based contracts and increasing after-sales support by vendors through on-line monitoring of their product. This relatively new availability of system level information and the ability to share it with partners (vendors and contractors) is changing decision processes and opening the way to the use of an increasingly sophisticated set of integrated tools and models. Few incumbent personnel currently have the required skills to use these new tools.

In addition, we have more data than ever before due to the rapid developments and reduction in cost of sensors, communications and data storage. There are currently significant challenges in the management of this data and in transforming it into 'knowledge' (Hodkiewicz, Coetzee at al, 2006). The availability of maintenance and operations data in real time to management and other not directly involved in the hour-to-hour management of the assets, has resulted in increased scrutiny of operating and maintenance decisions.

3.4 External and internal influences

The cause and effect chart shown in Figure 1 is an attempt to illustrate some of the influences on the development of EAM. Many of the key processes on which EAM is founded were developed in the 1970s and 80s but were not widely implemented until the 1990s. Changes in the type and granularity of data that we can collect, store and use for decision making is one of the key drivers for implementation. This process has also been assisted by the rapid development in functionality and use of ERP and CMMS mentioned above.

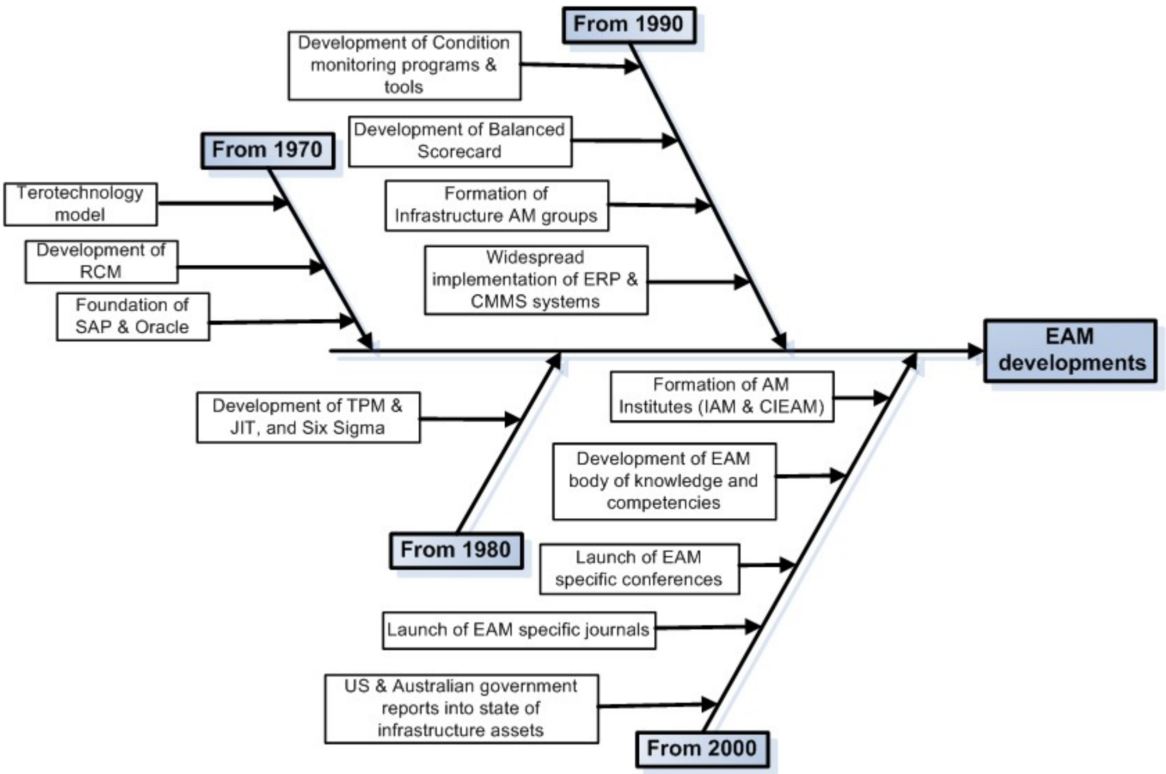

Figure 1: Cause and effect diagram illustrating influences on the development of EAM

Since 2000 there has been an exponential increase in the number of articles, conferences and reports on EAM. Starting in 2004 there have been a number of consortia and institutional bodies seeking to represent their national EAM communities: for example, the Institute of Asset Management in the UK, the Asset Management Council and Centre for Integrated Engineering Asset Management in Australia. These bodies, their associated programs and the opportunities for information exchange at conferences et al, will assist EAM in gaining a measure of respectability in the eyes of the engineering, business and government communities.

4. Challenges and opportunities

4.1 Adapting existing programs or developing new programs

The development of an externally-determined body of knowledge endorsed by asset owners presents both a dilemma and opportunity for the educational providers. The dilemma is whether to amend or adapt existing programs to meet these new developments. The opportunity is that, if they can show their programs do achieve desired objectives, then companies may fund personnel to attend the courses. This would significantly increase numbers engaged in ongoing educational programs.

4.2 Assessing programs and competing in the new world

Academics engaged in the development and delivery of EAM related courses must expect to be judged by the same measures that they are teaching their students to use. This means that students and their company sponsors will expect the course to be well-managed, professional, with clearly defined deliverables and timelines. Educational Providers should give thought to the development of their own 'balanced scorecards' for the courses.

4.3 Designing efficient and effective learning strategies

It is already possible with current technology to deliver educational programs almost anywhere in the world. Educational providers are finding themselves competing not just with local competitors but with offshore providers. Careful thought will have to be given by the local providers to differentiate their course from competitors, especially those which may offer substantial cost savings due to their offshore base. In all of this talk of competition, it is important not to lose sight of the education process and the challenges inherent in balancing the achievement of higher learning levels with the efficiency of course delivery.

Learning strategies are evolving and we have seen increased emphasis on strategies that stress active learning approaches aimed at clearly defined and assessable outcomes. Active learning includes a blend of support techniques, for example, problem-solving sessions, oral presentations, peer-peer exchange, case studies, research work and projects aimed at contextualising concepts learned in class (Pascual, 2006). Many of these approaches, for example, problem based learning, involve considerable emphasis on the development of soft skills such as team working and communication. The use of these learning strategies is crucial in the development of courses in the EAM field, due mainly to its inherently transdisciplinary nature and the emphasis on both technical and managerial development.

One of the main practical challenges to the improvement of EAM practices in companies is the disconnect between tactical and implementation groups. Tactical groups, often comprising reliability engineers and managers, evaluate and recommend new programs and then engage with a small group of maintenance and operations staff for implementation. These programs are difficult to sustain when the wider body of maintenance and operations staff are not engaged in the process and have little knowledge of the aims of the program and potential benefits that changes in the way they do or think about a process will have on the business (Hodkiewicz, 2005). However useful a tool or process may be, it does not 'exist' in the eyes of practitioners until it is being used regularly by those actively engaged in the maintenance and operations process.

For the educational providers, the inclusion of participants in the EAM process from outside the range of traditional 'maintenance' practitioners presents challenges. The class may include people from a wide range of backgrounds, experience and educational levels. There will need to be individual tailoring at the start of courses to bring the group to a common level of 'knowledge' before moving up to the tasks involving application, analysis and higher skills.

4.4 Desire for external certification

There has long been tension between asset owners who develop or offer internal programs to improve specific competences of personnel and the desire by personnel to participate in programs that offer an externally recognised and hence portable qualification. The anticipated development of certification processes, as evidenced by the work of IAM and the existing CRE and SMRP programs, are a recognition of this.

Educational providers include those in universities who offer university-accredited degrees or certificates, web-based course providers and private course providers. In the field of accreditation, universities have the advantage of offering degrees. However, institutional bodies also permit private educational providers to deliver professional development units. One of the key components of accreditation is assessment. Non-assessed courses are not as highly regarded as assessed courses and hence do not carry as much weight in the 'external' world.

Universities in Australia offer a range of primarily distance-based programs in Maintenance Management and Maintenance & Reliability Engineering. However, the number of people enrolled in these programs is small compared to the population engaged in the asset management process. We estimate that less than 300 students per year in Australia complete a Graduate Certificate, Diploma or Masters degree in a Maintenance or Reliability field. Engineers Australia, the professional body, has over 80,000 members, many of whom are involved directly or indirectly in the management of assets. Historically these low numbers may, in part, be due to cost, which has often been the responsibility of the student who undertakes the course for personal development and may or may not be supported by their employer. With the active participation of the asset owners in establishing and improving the competencies of their personnel, it is conceivable that, if acceptable programs are available, there will be an increase in employer-sponsored student places in university programs.

4.5 Resistance to change at universities

Historically academics in the EAM (and Maintenance/Reliability) fields have sat uneasily in traditional university departments, often inside Mechanical Engineering Schools, sometimes in the Business School. There are comparatively few academics working in this field compared to traditional engineering disciplines. One of the challenges for academics is that the EAM field is both trans-disciplinary and interdisciplinary: trans-disciplinary because EAM problems almost always involve aspects of engineering, operations research, organizational issues, and human factors; and interdisciplinary because assets are not just mechanical, but civil, electrical, electronic and of course software related. In 'Revolutionary Wealth', Alvin Toefler states that "against enormous resistance, more and more work on campus is becoming transdisciplinary" (Toefler 2006). This transition cannot come quickly enough for academics involved in EAM.

While we anticipate that these changes will initially impact the post-graduate arena, they will in time filter down to undergraduate level. In Australia, we have seen a rapid increase in the number of our brightest undergraduate students opting for combined degrees in engineering and commerce, rather than in engineering alone (Hodkiewicz, 2005). These degrees include existing units from both faculties but at present there are few units that are co-developed. The multi-disciplinary nature of an Engineering Asset Management course, requiring multiple faculties to work together on the course and share revenues, is likely to be barrier to establishment of these courses within some universities.

Global companies seeking cohesion in EAM practices between their regional business units are interested in educational opportunities that are globally coherent but with local, culturally-sensitive, educator-support. This can be achieved through a consortia of universities delivering a common program using blended learning techniques (local classroom support combined with distance learning protocols). However, a suitable business model that accommodates the universities' individual regulations regarding enrolments, accreditation and funding, has yet to be developed.

The need to adapt traditional assessment mechanisms to more effectively assess higher learning levels is an active topic in academic circles. “The ‘knowledge’ of an individual cannot be directly observed, its existence can only be inferred from actions” (Boisot, 1999). Transparent and consistent methods that are efficient and cost-effective for student and academics alike are required to assess the knowledge of participants engaged in learning new management and technical topics in EAM.

The dynamic nature of the EAM field and the speed of change pose a challenge to universities who, like many comparable institutions, are not synchronized with the speed of change of business. Establishing, developing, reviewing and accrediting new units and courses take time, and there needs to be recognition by both sides of the need for timely due process.

5. Summary

The emerging field of EAM is being driven by asset owners who are proactively engaged in defining bodies of knowledge and competency levels to enhance decision-making processes and hence ensure their competitive advantage. The asset owners are not waiting for traditional educational providers to react, but are actively working to define and move the EAM field forward. Challenges exist for education providers to synchronise the development of new programs and collaborative processes, and be actively involved, in this dynamic process.

Significant improvement in decision-making, team and communication skills are required at all levels, and throughout, organizations; not just within maintenance and operations groups. Rapid developments in EAM processes and expectations require personnel and companies to engage in a continuous learning process. Learning objectives are determined by both the competence the person in the role and the needs of the asset owner who has decided what competencies are required. The move away from making learning the responsibility solely of the incumbent/student is resulting in greater engagement between the educational provider and asset owners. As a consequence educational providers can expect increased scrutiny of outcomes.

These are among the most significant challenges facing educational providers in the engineering asset management arena.

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