World Transactions on Engineering and Technology Education
Vol.12, No.4, 2014

Towards effective curricula for education, training and certification in *Engineering Asset Management*

Joe Amadi-Echendu

University of Pretoria
Pretoria, South Africa

ABSTRACT: Engineering assets pervade every aspect of human endeavour and improve almost every aspect of how people live; thus, one must advertently manage engineering assets, so that they sustain increased quality of life in a world of finite resources. The effects of globalisation, information and communication technologies, and consequential rapid socio-technical changes have pedagogical impacts on the education, training and certification of engineers, so much so that the world's cadre of engineers will seek ways to put knowledge into practice to meet the overarching grand challenge of sustainable joy of living. Artefacts that constitute an engineering asset base are derived from the combination of many conventional academic disciplines and practical knowhow. The author takes the view that managing engineering assets requires *cross-*, *inter-*, *multi-*, and *trans*-disciplinary integration of knowledge and, thus, provides a first-level delineation of a body of knowledge as a guide towards the development of effective curricula for education, training and certification of asset managers within the modern paradigms of globalisation, innovation and sustainability.

INTRODUCTION

Preamble

In general, assets range from natural endowments (e.g., intellect and talent capacities in human beings, land, mineral resources and natural surroundings) to capacities embedded in man-made infrastructure, plant, equipment, hardware and software tools and systems, and other physical artefacts that comprise the built environment. Land and non-financial assets, such as buildings, equipment, plant and various types of physical infrastructure are typically engineered towards achieving something valuable. In fact, a dictionary definition of an asset is …*a useful or valuable quality, skill or person, or a part of the usually valuable property of a person or organization which can be used for the payment of debts…*[1].

The definition construes three very important words - *ownership*, *utilisation* and *value*, and gives a suggestion on a way to measure value. Although value can be qualitatively subjective, it is often measured in quantifiable economic and financial terms, albeit that the advent of sustainability has created new imperatives. In a sense, this dictionary definition highlights the interconnectedness between assets and the skills required to manage them, with the objective to enhance, or at least sustain, the value of assets. In turn, the skills for managing assets depend on education, training and certification of asset managers, based on a body of knowledge that encompasses the disciplines involved in the creation of assets.

Throughout history, tangible technological innovations manifest as engineered assets that have provided and continue to provide impetus to advance human civilisation. Engineering assets feature across all industry sectors of human endeavour (e.g., from home appliances, office equipment to large industrial machines on the one hand, and from individual homes to large scale transportation infrastructure on the other hand). Engineered assets not only improve most aspects of how people live, but they also enhance the joy of living by complementing, supplementing and replacing humans in undertaking numerous laborious tasks. As people depend more and more on engineering assets to provide the means for enhancing their livelihoods, they must advertently manage engineering assets, so that they sustain increased quality of life in a world of finite resources. Quoting from Grand Challenges for Engineering:

> *In each of these broad realms of human concern - sustainability, health, vulnerability, and joy of living - specific grand challenges await engineering solutions. The world's cadre of engineers will seek ways to put knowledge into practice to meet these grand challenges. Applying the rules of reason, the findings of science, the aesthetics of art, and the spark of creative imagination, engineers will continue the tradition of forging a better future* [2].

Some Pedagogical Considerations

Cameron and Lewin discuss in reasonable detail the effects of globalisation, information and communication technologies, and consequential rapid socio-technical changes, and their influences on engineering education and practice [3]. They highlight recurring industry and professional views that include the vital needs to:

1. introduce interdisciplinary curricula for teaching and learning;
2. concurrently focus on theoretical understanding, creativity, innovation and practical application;
3. emphasise systems thinking with knowledge and skills in the use and application of mathematical modeling tools;
4. integrate ideas and technologies;
5. deal with topics of uncertainty, risk assessment, and valuation; and to
6. *…construct modern curricula and course designs that build student skills in a cohesive framework.*

Atkinson argued that *the failure to define and adopt a sound theoretical base was a major reason for ineffective curriculum development, and that a curriculum suggested should comprise four pedagogical components viz: a) objectives; b) content; c) programme of activities; and d) evaluation procedures* [4]. These components are echoed in the outcomes-based approach consistent with modern educational curricula, in as much as the contexts of scientific knowledge and application knowledge provide new paradigms for the development of effective curricula for professional practice and life-long learning [5]. Kocaoglu surmises that as engineers make the transition from technical specialty to management, they require rigorous educational programmes that blend mathematical approaches, behavioural and cognitive attributes, organisation learning, and *…decision-making methodologies in a delicate balance* [6]. Extrapolating from Davis, curricula that satisfy professional certification and industry practice should include discipline-specific standards, as well as guidelines emanating from legislative requirements [7].

The aim of this article is to provide a conceptual framework for an engineering asset management body of knowledge (EAMBoK), that is, a first-level delineation of what could be included in the body of knowledge (BoK) for engineering asset management (EAM). The objective is to identify tracks, topics and issues that may be considered towards the development of curricula that would be effective for education, training and certification of engineering asset managers within the modern paradigms of knowledge economy, globalisation and sustainability.

SCOPE OF ENGINEERING ASSET MANAGEMENT

A large scale engineering asset, such as an airport, a housing complex, a manufacturing plant, a mining/mineral processing complex, a shopping mall, rail/road network or an electricity/water utility comprises a wide range of immovable infrastructure, plant and systems, as well as movable artefacts, components and equipment. Take, for example, an engineering asset like an aircraft, the artefacts that constitute an aircraft encompass extensive knowledge derived from many conventional academic disciplines and practical knowhow. The knowledge is typically derived from the combination and integration of pure and applied mathematics, sciences, liberal arts, engineering, humanities and management, as well as knowhow from guidelines, standards and practice.

The earlier tenets of terotechnology (cited from [8]) emphasise that the combination of management, engineering and finance disciplines, as well as other practices, are to be applied to physical assets. As discussed in detail by Amadi-Echendu et al, *...definitions of asset management tend to be broad in scope, covering a wide variety of areas …constituting a multiplicity of spheres of activity…*, and conceived in terms of the engineering asset on the one hand, and the processes for managing the asset on the other hand [9]. Further, they argue that EAM is multidisciplinary, considering:

1. spatial generality - engineering assets are deployed in all sectors of human activity;
2. time generality - engineering assets extend over time;
3. measurement generality - engineering assets possess environmental (ecological), financial, and social dimensions and attributes;
4. statistical generality - of performance measurement, e.g., technical data regarding engineering asset condition, risk, vulnerabilities, and decisions; and
5. organisational/resource generalities - management of engineering assets demands cognitive synergy and interaction between strategic, tactical and implementation levels in an organisation irrespective of business persuasion [9].

Although there are numerous guidelines and standards in both private-sector and public-sector situations; however, the recent release of the ISO 5500x asset management standards in 2014 has stirred up much excitement towards the coalescence of the many and varied viewpoints typical for a subject matter that is *cross-*, *inter-*, *multi-*, and *trans-*disciplinary [10]. The ISO 55000 standard states that asset management is based on the fundamentals of value, alignment, leadership and assurance, and involves the *…balancing of costs, opportunities and risks against desired performance of assets, to achieve the organizational objectives*. Value, alignment, leadership and assurance are deeply rooted in psychological logic in conventional humanities disciplines, thus, it is not surprising that ISO 55001 is limited to specifying the requirements of an asset management system, even though there are many existing and well established guidelines (see, for example, [11][12]) that focus more on how to manage assets to satisfy organisational mandates. Taking the view that an asset provides the means to an end, then, a simple but, concise scope for asset management is that it must include all activities necessary for an asset to realise the profile of values demanded by its stakeholders. The implication of all activities (i.e., combination and integration of all necessary disciplines), is that the subject matter of asset management has ramifications across a wide range of knowledge areas, and this fact invariably presents the greatest challenge in developing and delivering effective curricula for education, training and certification in Engineering Asset Management.

As illustrated in Figure 1, it is worth acknowledging that various stakeholders have their respective views as to what the scope of an engineering asset curriculum should include or exclude. For example, business managers, financial controllers, plant operators and engineers have their views of what should be the scope of engineering asset management. Infrastructure managers have their views; equipment manufacturers and systems integrating vendors have their views; and academics and practitioners have their views. The views from society, regulatory bodies, learners and industry sectors can become perplexing, e.g., public sector versus private sector, consultant/equipment and spares supplier/service provider versus custodian/owner/steward/user, investor/shareholder versus stakeholder, professional associations versus academic institutions. In this regard, it is necessary to define a conceptual framework for the development of curricula that addresses the needs for education, training, research, skills development and professional competence certification in engineering asset management. The framework should at least configure a high level delineation of knowledge areas required for EAM, providing indication as to what could be taught and learned, and leading toward how teaching and learning could be done.

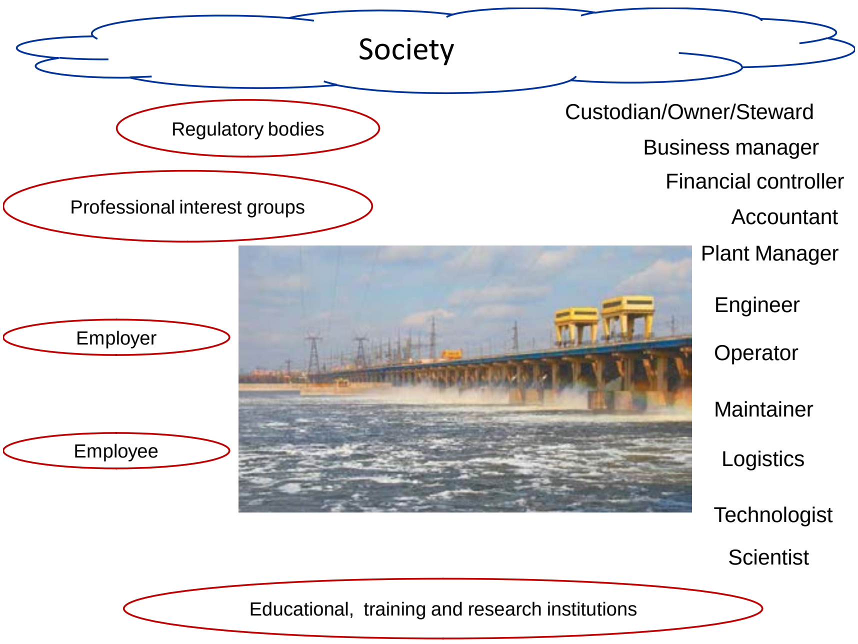

Figure 1: Stakeholders to an engineering asset.

A CONCEPTUAL FRAMEWORK FOR EAM CURRICULA

Framework

From a curriculum perspective, the picture shown in Figure 2 may be regarded as a conceptual framework that embodies the knowledge areas required for EAM.

The framework considers the management of an engineering asset in three so-called lifecycle stages - *acquire*, *utilise*, and *terminate*, with *plan*ning fundamental to each stage. The forward loop shows the precedence of the stages even though the management processes do not necessarily represent a linear progression; hence, the feedback loops emphasise the recurrence of activities and issues, especially for an asset that comprises components, equipment, infrastructure and systems with varying lifecycles. The picture illustrates that sustainability, especially in terms of value-add and minimisation of ecological footprint, are imperatives that must be integrated into a curriculum. Similarly, risk, communication and people skills, technology and systems are aspects that must also be integrated into a curriculum.

The picture depicts the specialised and technical areas of focus, and highlights some of the associated primary activities, issues and corresponding targets for management in each lifecycle stage. For example, financing arrangements are not only critical to how assets are acquired and who owns and controls the use of an engineering asset base, but also, the source of funds and taxation regulations determine decisions as to whether to replace, renew or even upgrade part of, or the main asset, depending on the level at which assets are managed. Rapid and disruptive changes in information and communication technologies will mean shorter shelf-life of courses and modules that are focused on the technology and systems aspects of a curriculum.

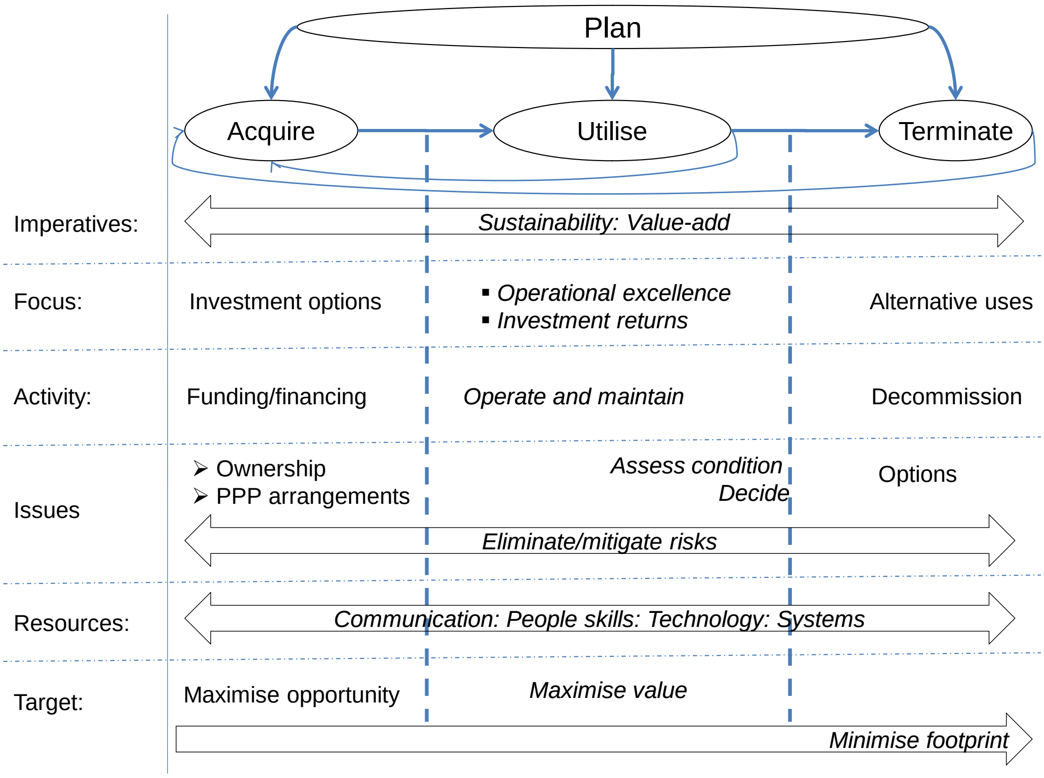

Figure 2: A conceptual curriculum framework for EAM.

Tracks, Topics and Issues

Using this framework, a body of knowledge for Engineering Asset Management may be resolved into curriculum tracks, topics and issues as illustrated in Table 1.

Table 1: Towards an EAMBoK - an illustration of curriculum tracks, topics and issues.

Tracks	Topics	Issues
EAM strategies	• Investment	• custodianship, ownership and stewardship • asset acquisition planning • asset funding and financing options • valuation • private-public partnerships • private-private partnerships • product/service transformation (servitisation) • outsourcing
	• Operations and maintenance strategies	• utilisation, demand loading and forecasting • operational philosophy, planning and scheduling • maintenance planning, scheduling and work execution
	• Divestment and sustainability	• divestment options (i.e. alternative uses) • environmental impact - ecological footprint
Condition, risk and vulnerability	• Operability - maintainability - reliability - availability • Condition, risk and vulnerability assessments • Diagnostics and failure mechanisms • Prognostics • Life-cycle decisions	• condition • useful life • remaining life • replacement - refurbishment - renewal - upgrade, etc
EAM data and information	• Asset register and data • Information and knowledge management • Asset performance indicators • Performance measurement	• acquisition data • asset identification • accounting • utilisation - value profile

Technologies and systems	• Information and communication networks • Enterprise resource planning systems • Knowledge and project information systems • Operational and safeguarding systems	• data and information integration • interchangeability - interoperability • supply chain - logistics support
Standards and guidelines	• Management systems • ICT systems • Engineering design and technical • Accounting and financial • Legal and legislative • National/local guidelines	• international standards • operating standards • national and local guidelines
Case studies	• Industry sectors, e.g. - Agriculture - Manufacturing - Energy - Mining - General services - Utilities - Telecommunications - Transportation	• research areas

CONCLUDING REMARKS

The development of curricula must still address the standard pedagogical issues, such as:

1. entry requirements;
2. curriculum design to suit local requirements;
3. curriculum delivery modes and methods;
4. quality of teaching and supervision;
5. accreditation, qualifications, certification; and
6. packaging of a curriculum towards specific industry and employment opportunities.

A generalised outcome for a curriculum in Engineering Asset Management should at least lead towards the acquisition of the *knowhow* depicted in Figure 3, including the attributes of:

1. problem identification, formulation and solution;
2. communication and networking;
3. life-long learning with global outlook;
4. professional and ethical responsibilities; as well as
5. cultural, social, ecological responsibilities.

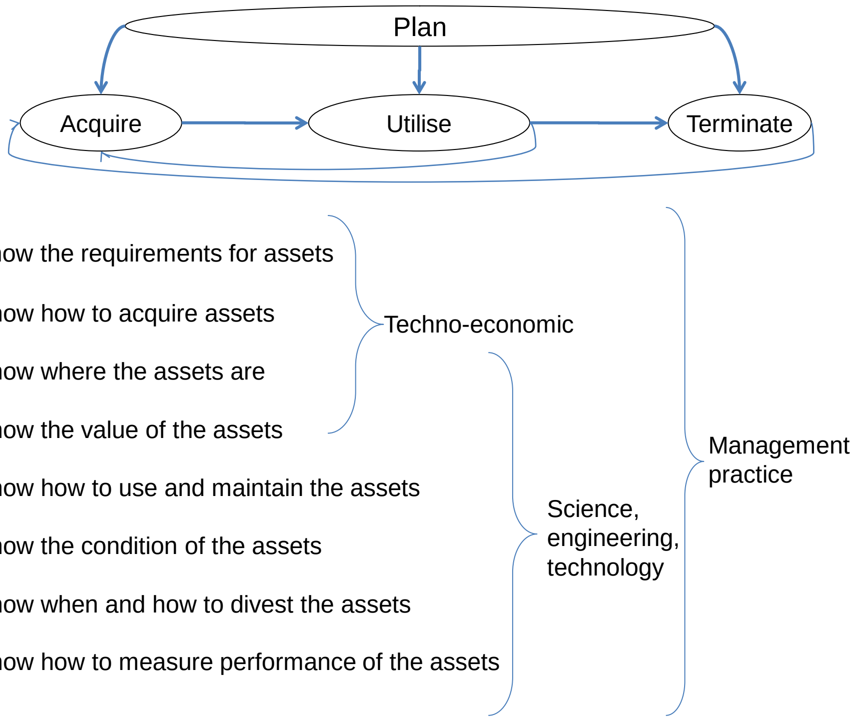

Figure 3. A set of generalised learning outcomes for curricula in Engineering Asset Management.

For brevity, the delivery of curricula must ensure that an engineering asset manager will be able to:

1. integrate knowledge, logistics and systems required;
2. configure and maintain assets register;
3. conduct evaluation to validate the investment value of assets;
4. develop and implement utilisation, operations and maintenance plans and budgets for assets;
5. assess the condition and determine useful life of assets;
6. determine the levels of service required, as well as demand for the assets;
7. examine business and enterprise risk exposure for financing and funding needs of assets.

REFERENCES

1. Cambridge International Dictionary of English. Cambridge University Press (1995).
2. NAE Grand Challenges for Engineering. National Academy of Sciences on behalf of the National Academy of Engineering (2012), 7 January 2015, http://www.engineeringchallenges.org/?ID=11574
3. Cameron, I.T. and Lewin, D.R., Curricular and pedagogical challenges for enhanced graduate attributes in CAPE. *Computers and Chemical Engng.*, 33, 1781-1792 (2009).
4. Atkinson, W.D., Curriculum development in tertiary agriculture and horticulture. *Agricultural Systems* 26, 165-177 (1988).
5. Aldridge, M.D., Technology management: fundamental issues for engineering education. *J. of Engng. and Technol. Manage.*, 6, 303-312 (1990).
6. Kocaoglu, D.F., Engineering management programs as aids in moving from technical specialty to technical management. *Engng. Manage. Inter.*, 2, 33-47 (1984).
7. Davis, G., Formulating an effective higher education curriculum for the Australian waste management sector. *Waste Manage.*, 28, 1868-1875 (2008).
8. Harvey, G., A Study into the Concept and Practice of Terotechnology and Life-cycle Costing as Applied to Manufacturing Industry. Doctoral Thesis, Loughborough University, UK (1978).
9. Amadi-Echendu, J.E., Willet, R., Brown, K., Hope, T., Lee, J., Mathew, J., Vyas, N. and Yang, B-S., *What is Engineering Asset Management. Part 1*, *Engineering Asset Management Review*. 1, Springer (2010).
10. ISO 55000, ISO55001, and ISO55002 standards. (1st Edn), ©ISO (2014)
11. Final Asset Management Guide. National Treasury, South Africa (2008).
12. Total Asset Management Manual. New South Wales, Australia (2003), 7 January 2015, http://www.treasury.nsw.gov.au/__data/assets/pdf_file/0015/5109/tam_manual.pdf