RAILWAY ASSET MAINTENANCE AND MANAGEMENT EDUCATION INITIATIVES AT THE UNIVERSITY OF PRETORIA

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1. INTRODUCTION

There has recently been a paradigm shift in the focus of civil engineering activities over the life cycle of civil engineering infrastructure. There is now a better appreciation of the whole life cycle of typical civil engineering infrastructure projects in the civil engineering industry (Milford, 1999). In Figure 1 the concept of this shift in the civil engineering activities over the life cycle of a typical infrastructure facility, as described by Abbot (1996), is shown. Planning, design and construction activities have traditionally been the main focus in practice and consequently also formed the focus of under-graduate training and education of civil engineers (Horak, 2002). The "upstream and downstream" engineering activities normally tended to be seen as outside the realm of civil engineering as it was deemed less technical and analytical in nature than these hard-core historic "mid-stream" focus areas.

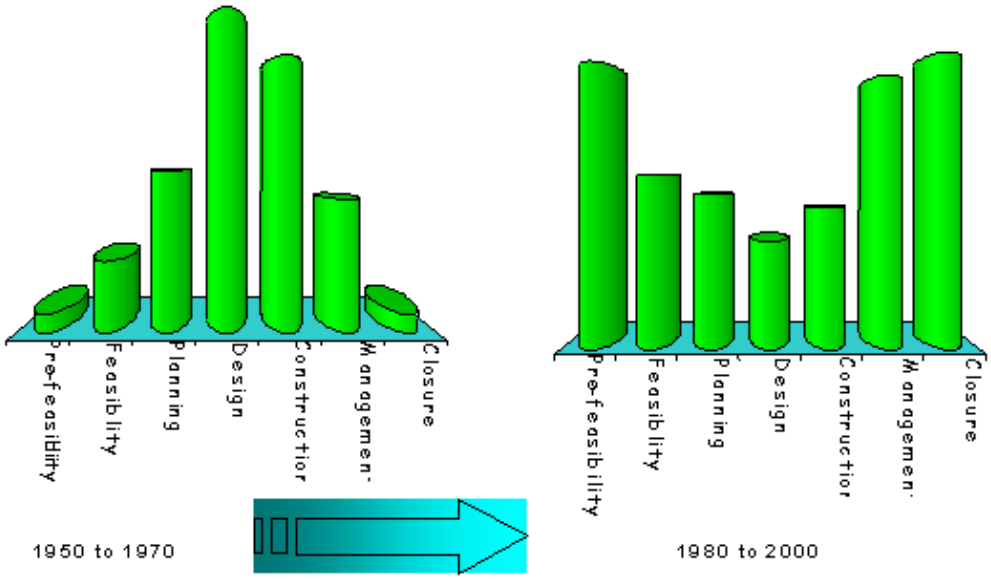

Figure 1: Shift in Civil Engineering activities over the life cycle of typical infrastructure facilities (Abbot,1996)

The recent shift of emphasis towards increased involvement in "upstream activities", such as pre-feasibility and feasibility, and "downstream activities", such as management and closure, is clearly illustrated in Figure 1. If these activities were to

be shown on a time scale over the whole life of a fixed asset, the "downstream activity" of maintenance and management in particular would take up to 95% of the whole life of the fixed asset. The largest portion of the life of fixed asset infrastructure therefore deals with the maintenance and rehabilitation of the facility and represents a present worth of cost which will usually be larger than the initial construction cost. Maintenance and rehabilitation of fixed assets have traditionally not been the focus of under-graduate training and education. Even at post-graduate level this aspect has been a Cinderella type subject until recently.

Names and concepts like Fixed Asset Management, Infrastructure Asset Management, Asset Life Cycle Costing and Management and Integrated Infrastructure Management and Maintenance are increasingly being used as buzz words in this field. These are all different names for a common growing awareness of the importance of the life cycle maintenance, rehabilitation, closure and management needs of civil engineering type fixed asset infrastructure.

In this paper the terminology of fixed asset maintenance and management follows from Hudson et al (1997), which states that *The term "asset management" has arisen primarily from use in the private sector. Private corporations in the profit-making business try to manage their "assets," which include physical infrastructure as well as capital, personnel, technology and technology ideas"* In this paper the broader concept of facilities management is not included as Hudson et al (1997) define *"Facility management" is most often used with a physical entity broadened to include operations and furnishings. In fact, the term facility management is generally meant to describe operation and use of a facility, such as a hotel, including both the infrastructure or building itself, as well as furniture, ballrooms, banquet facilities, dishes, linen, and so forth. The activity therefore often includes scheduling setting up furniture in a ballroom for a banquet, and similar operations.*

The term "fixed asset" and "infrastructure asset" are therefore used synonymously in this paper. Hudson et al (1997) define…. *The term "infrastructure management" has been coined to generalize the concepts of pavement management, bridge management, and building management and has most often been applied to public civil engineering infrastructure, such as water, waste water, bridges, airports, parks, pavements and the like.*

Infrastructure or fixed assets are therefore broadly classified by Hudson et al (1997) as shown in Table 1:

Table 1. Infrastructure classification

Number	Classification	Examples
1	Transportation	Roads, bridges, airports, railways
2	Water and waste water	Dams, pipe networks, water treatment plants, sewerage works
3	Waste management	Waste disposal sites, retention and pollution control facilities
4	Energy production and distribution	Power generation plants (electrical, nuclear, gas, etc.) power lines or pipe network systems
5	Buildings	Public buildings, commercial developments, housing stock, etc.

6	Recreational facilities	Stadiums, opera houses, sport facilities, etc.
7	Communication	Communication towers, repeater stations, satellite dishes, etc

In some disciplines of civil engineering there have been development of asset management systems to deal with the life cycle management of specific fixed assets. A few examples are as follows:

- Pavement or Road Management Systems (PMSs or RMSs)
- Gravel Roads Management Systems (GRMSs)
- Road Signs and Furniture Management Systems (RSFMSs)
- Footway and Verge Management Systems (FVMSs)
- Road Maintenance Management Systems (RMMSs)
- Building Maintenance Management Systems (BMMS)
- Bridge Management Systems (BMSs)
- Storm Water Management Systems (SWMSs)
- Water Supply Management Systems (WSMSs)
- Railway Asset Management Systems (RAMSs)

These specific management systems are all tools of asset management restricted to specific types of fixed assets or infrastructure. They invariably suffer from a "silo-effect" of invariably being viewed in isolation and do not deal with the broader aspects of life cycle engineering and integrated asset management. As example, in an urban local authority these various fixed assets often compete head on for funding without proper consideration of broader strategic issues and the value to the portfolio of total integrated assets. Hudson et al (1997) describe how the need for an integrated asset or infrastructure management system has led to the definition…*infrastructure management system (IMS) consists of the operational package (methods, procedures, data, software, policies, decisions, etc.) that links and enables the carrying out of all the activities involved in the infrastructure management.*

In the urban engineering environment there is lately an increased recognition for the need to integrate these asset management systems to facilitate budget prioritisation and allocation. Integrated Infrastructure Management Models (IIMMs) are now prescribed by law in countries like Australia and New Zealand and are in the process of also finding support in South Africa (Viljoen, 2002). The new Systems Bill and the Integrated Development Planning (IDP) legislation will give further support to this integration of asset management systems.

Commercialisation of infrastructure asset management is a clear indicator of the paradigm shift which occurred lately in this field in South Africa and abroad. The all in one model of owner, manager and maintainer of fixed assets is largely seen as ineffective and inefficient. The newfound openness to commercialisation possibilities and even privatisation have led to the development of various innovations, such as Build, Operate, Maintain and Transfer concessionaire models. Such concessions have found application in SA in areas like toll roads, water network and supply, prisons building and management and other government buildings and facilities. Such concessions cover anything from 20 to 40 years (in some cases even longer) which form the better part of the total life of such civil engineering facilities. Public-Private Partnerships (PPPs) and concepts like Municipal Service Providers (MSPs) are all

innovative approaches to improve the efficiency and effectiveness of maintaining and managing fixed asset infrastructure.

2. NEED DESCRIPTION AND PROGRAMME REQUIREMENTS

Major asset manager client bodies and role-players have expressed a need for asset maintenance and management education and training courses to be developed as a matter of urgency. The needs of role-players such as SASOL, KUMBA Resources, ISCOR, SPOORNET, Departments of Public Works (local, provincial and central government levels) and the DBSA are all common in asset maintenance and management. In some cases their asset maintenance and management needs are strongly linked to specific engineering disciplines such as chemical, electrical or mechanical engineering activities. In some cases the need is expressed as a focus on movable assets such as specific plant, movable plant and large machinery while the fixed assets are often taken for granted.

It is acknowledged that asset maintenance and management in the Railway environment should include both plant or movable assets and fixed assets. For the purpose of definition a distinction is made between movable and fixed assets due to the educational interests of other infrastructure owners. Fixed assets are distinguished from the other types of assets primarily based on the fact that they are invariably part of the fixed asset infrastructure in or on which the movable assets and machinery are installed. Fixed assets are not only immovable, but have much longer life spans compared to equipment, machinery and other movable assets. Fixed asset life spans range from 25 to 100 years depending on the operating environment and design criteria used. Movable assets generally have shorter life spans in the range of 5 to 15 years. In most cases the construction costs of fixed assets are more than the costs of the movable assets. Most of the abovementioned role-players are therefore primarily fixed asset owners or have an interest in maintenance and management of portfolios of fixed assets.

A scan of courses offered by overseas universities and educational institutions indicates that a number of them do offer such asset maintenance and management courses, but are invariably too expensive if expressed in Rand terms, particularly if it includes all the associated costs of going overseas. These courses often lack the specifics of the South African environment. There is not any complete programme or dedicated courses available on asset maintenance and management at present in South Africa. Infrastructure related courses mostly focus on the development and design aspects of new infrastructure and life-cycle aspects are not dealt with as the main focus. The need for such locally available asset maintenance and management courses was expressed as an urgent matter by the abovementioned role-players. This implies that local solutions need to be found in the short term.

The under-graduate programmes in civil engineering at universities are very full and do not leave space for this specialisation field of asset maintenance and management. The undergraduate curricula in civil engineering are currently in transition to accommodate inclusion of environmental engineering and information technology (Horak, 2002). There is a clear drive to move away from a structural engineering design and construct focus in the under-graduate curricula to better accommodate other fields of specialisation. Not only should urban-, geotechnical-, transportation-

and water engineering have a larger share of the curriculum, but also the ECSA identified areas of environmental engineering and information technology. Prescribed proportions of core, complementary and elective subject modules should be adhered to and thus provide for a balanced education for civil engineer graduates. This is all designed to address the new realities and paradigm shift of the civil engineering working environment, as described in the preceding introduction. The bottom line is that there would not be room for specialist areas like asset maintenance and management in the rather compact under graduate curricula at present.

The development of the desired asset maintenance and management course work should therefore be addressed by putting together such specialist course work and programme at the postgraduate level. The development of new programmes can however be a long and cumbersome route. Not only South African Quality Authority (SAQA), and Engineering Council of Southern Africa (ECSA) requirements have to be met, but also registration and acceptance by the Department of Education. This does not include the hazards of pushing such proposals through the faculty and senate approval systems and procedures at a university. A much shorter route therefore had to be found if the industry's needs were to be met with any resemblance of an appropriate customer care response.

A number of separate courses on aspects of asset maintenance and management and programmes are in existence at present at the post-graduate level, though. Some of these programmes have some areas of commonality with asset maintenance and management, but with a different focus. There is a clear need to integrate and combine asset management systems and technologies into comprehensive short courses, honours and masters degree specialisation programmes. There is a strong management segment needed in asset maintenance and management coursework. Asset managers have to know about financing (long and short term), general management, risk management, people management, safety, health and environmental issues, information management, condition audit systems and quality management. In the civil engineering and fixed asset field there is also a strong technical content needed to deal with aspects such as deterioration modelling, rehabilitation design, materials (not just concrete, steel, asphalt, etc, but new "smart" materials too) and structural analysis of remedial work, condition assessment and description, as well as the actual maintenance management activities. The proposed degree program therefore needs to be designed to strike a balance between appropriate management issues and technical/analytical issues.

3. COURSES AND PROGRAMMES AVAILABLE FOR A POST-GRADUATE DEGREE PROGRAMME.

The approach followed in putting together a specialist masters programme at the University of Pretoria (UP), was to try to use as much as possible existing "off the shelf" modules and short courses and to link it with an existing masters programme. The objective of putting together a comprehensive postgraduate program from existing "off the shelf" modules had to be balanced by a number of operational realities and restrictions. A survey was done in the various schools and departments of the Faculty of Engineering, Built Environment and Information Technology (EBIT) of the University of Pretoria (UP) to see which subject modules or degree programmes would qualify. It was determined that a number of subject modules are

offered in the Department of Construction Economics of the School for the Built Environment which have some relevance to this subject area of asset maintenance and management. It was determined that the focus of these modules was mostly on the facility management aspect of fixed assets (buildings) and due to different lecturing schedules were ruled out as a source for the proposed asset maintenance and management courses.

In the School of Engineering the Department of Mechanical Engineering is offering a masters degree with specialisation in Maintenance Engineering. This is part of the normal masters degree programme with four full year subjects and a field research project needed for attainment of the degree. The subjects offered to choose from are:

- Maintenance Practice
- Reliability Engineering
- Condition based maintenance
- Maintenance operations
- Structural integrity and,
- Tribology

Any four subjects are selected from this list to make up the required credits for the lectured subject content. It is clear that subjects such as Tribology is very specific to mechanical equipment and moving parts and for that reason would not qualify as a subject for a broader asset maintenance and management degree program. Condition based maintenance and structural integrity are also perceived to have a narrow focus and specific to only mechanical equipment and moveable assets.

This masters degree programme in Mechanical Engineering therefore does not have the correct mix of subjects for a combination of fixed and movable asset maintenance and management degree programme. The subjects also lack essential management components, which have been described above as important for asset management practice. A major stumbling block is the fact that these subjects are not modular or offered as semester module subjects, but only as full year subjects, which make compatibility and flexibility with existing infrastructure subject modules in civil engineering problematic.

The Masters programme in Engineering Management (MEM) and Masters in Project Management (PMP) of the Department of Engineering and Technology Management (DETM) in the School of Engineering of the University of Pretoria (UP) are established post-graduate degree programmes offered since 1989. The purpose of the MEM and MPM programmes is to provide management education for the practising engineer, irrespective of under graduate discipline. It is aimed at the engineer pursuing a career in general management or functional management. While the traditional engineering disciplines focus mainly on technology itself, the programme is dedicated to the utilisation of technology within the engineering process in the broader business environment.

The MEM and MPM curricula are done over two years on a part time basis and are offered as combinations of semester subject modules. The basic outline is briefly summarised in Table 2. A total of 256 SAQA credits are needed for a masters degree. It has a total of 192 SAQA credits making up the core modules while the remaining

64 credits are made up from the domain general modules. It is clear that the MEM and MPM curricula have strong bias towards management and technology management subjects. The MEM and MPM programmes however offer flexibility for the needed "re-packaging" to accommodate a stronger asset maintenance and management content and focus.

Table 2. Standard MEM and MPM Curricula			
	M Eng (Engineering Management) Core Modules	**: M Eng (Project Management) Core Modules**	SAQA Credits
	Systems Engineering and Management	Project Systems Engineering	16
	Production and Operations Management	Introduction to Project Management	16
	People Management	Project Human Resources Management	16
	Financial Management	Project Financial and Cost Management	16
	Technology Management	Project Procurement Management	16
	Maintenance Management	Project Quality Management	16
	Project Management	Legal Aspects of Project Management	16
	Strategic Management	Strategic Management	16
	Thesis	Thesis	64
Domain: General Modules			
	Quality Management	Project Risk Management	16
	Decision Analysis	Project Management Practice	16
	Marketing Management	New Ventures and Entrepreneurship (ELECTIVE)	16
	New Ventures and Entrepreneurship (ELECTIVE)	Engineering Logistics (ELECTIVE)	16
	Engineering Logistics (ELECTIVE)	Marketing Management (ELECTIVE)	16
	Life Cycle Engineering and Safety Health and Environment (SHE) (ELECTIVE)	Life Cycle Engineering and SHE (ELECTIVE)	16
	Information Management (ELECTIVE)	Information Management (ELECTIVE)	16

In the process of discussions with the Department of Engineering and Technology Management (DETM, major industry role-players, such as SPOORNET, SASOL and ISCOR, approached the School of Engineering for a masters programme in asset maintenance and management. Based on the input from these role-players, the MEM and MPM curricula were restructured as shown in Table 3 to offer in effect a Masters degree in Asset Management (MAM) by offering three specialisation domains; asset management (mostly movable asset focus), fixed asset maintenance and management and life cycle engineering. As shown in Table 3, to follow, these three domain areas all have the same core modules as in the original MEM and MPM shown in Table 2. The specialisation or domain specific modules are however different as shown in Table 3.

The domain modules of fixed assets/civil engineering are the only modules, which offer elective modules, which are currently offered in the masters degree programme of the department of Civil and Biosystems Engineering. The domain modules of asset management (movable assets) and life cycle engineering offer specific electives as shown in Table 3. Even though only 64 credits are offered via the domain specific electives in fixed asset management in infrastructure type civil engineering modules there is in effect a stronger bias towards a specialisation field in asset management.

The 64 SAQA credits of the research thesis are also destined to be specific to the asset management area selected by the prospective student. The end result is that a student who wants to specialise in say Railway Asset Management will in effect have a total of 128 SAQA credits specific to the asset management area selected. This is half of the required 256 SAQA credits. The potential civil engineering infrastructure specific modules will be discussed in the next section.

Table 3: Asset Maintenance and Management Specialisation MEM and MPM Curricula

	M Eng (Engineering Management) Core Modules	M Eng (Project Management) Core Modules	SAQA Credits
	Systems Engineering and Management	Project Systems Engineering	16
	Production and Operations Management	Introduction to Project Management	16
	People Management	Project Human Resources Management	16
	Financial Management	Project Financial and Cost Management	16
	Technology Management	Project Procurement Management	16
	Maintenance Management	Project Quality Management	16
	Project Management	Legal Aspects of Project Management	16
	Strategic Management	Strategic Management	16
	Thesis	Thesis	64
Domain: Asset/ Maintenance			
	Life Cycle Engineering and SHE	Life Cycle Engineering and SHE	16
	Asset Management	Asset Management	16
	Risk Management	Risk Management	16
	Reliability Engineering (ELECTIVE)	Reliability Engineering (ELECTIVE)	16
	Engineering Logistics (ELECTIVE)	Engineering Logistics (ELECTIVE)	16
	Information Management (ELECTIVE)	Information Management (ELECTIVE)	16
Domain: Fix Asset Civil			
	Life Cycle Engineering and SHE	Life Cycle Engineering and SHE	16
	Risk Management	Risk Management	16
	Elective module(s) from Civil Engineering	Elective module(s) from Civil Engineering	16 each
	Information Management (ELECTIVE)	Information Management (ELECTIVE)	16
Life-Cycle Management			
	Life Cycle Engineering and SHE	Life Cycle Engineering and SHE	16
	Marketing Management	Marketing Management	16
	Asset Management (ELECTIVE)	Asset Management (ELECTIVE)	16
	Decision Analysis (ELECTIVE)	Decision Analysis (ELECTIVE)	16
	Risk Management (ELECTIVE)	Risk Management (ELECTIVE)	16
	New Ventures and Entrepreneurship (ELECTIVE)	New Ventures and Entrepreneurship (ELECTIVE)	16
	Engineering Logistics (ELECTIVE)	Engineering Logistics (ELECTIVE)	16
	Information Management (ELECTIVE)	Information Management (ELECTIVE)	16

4. ELECTIVE MODULES WITH FIXED ASSET SPECIALISATION

The redesigned MEM and MPM programmes as shown in Table 3 clearly indicated FAMM specialisation is feasible. The proposal shown in Table 3 was further refined to cater for the aspect of infrastructure or fixed asset maintenance and management (FAMM) via the expansion of the electives modules. The elective modules were

strengthened with modules with a civil engineering and infrastructure focus. In this way the desired balance between management and technical subject matter was achieved. The proposed fixed asset and maintenance management (FAMM) modules are summarised below. A summary of these modules are given in Appendix A.

- Infrastructure Information Systems (Current Urban Engineering subject module)
- Building maintenance management systems (A new subject module based on Masters thesis by McDulling (2001))
- Water supply management (Currently a short course now converted to a fully fledged subject module)
- Deterioration and maintenance of structural concrete (A recently developed post graduate subject module)
- Road rehabilitation technology and Pavement design are existing modules in the Transportation Engineering specialisation field)
- Environmental Management (Current post-graduate module offered by Chemical Engineering and Urban Engineering)
- Integrated Development Planning (Current post-graduate module in Urban Engineering offered by department of Town and Regional Planning)
- Urban Restructuring (Current post-graduate module in Urban Engineering offered by department of Town and Regional Planning)
- Maintenance Special (Current flexible Urban Engineering subject to address specific needs)

These "off the shelf" civil engineering subject modules are in most cases already offered in the post-graduate civil engineering programme of other specialist areas such as structural engineering, transportation engineering, water engineering and urban engineering. These subject modules offer the opportunity to specialise in specific areas such as building and structures, transportation infrastructure, water infrastructure and urban infrastructure, as well as an integrated approach to a portfolio of such fixed asset infrastructure. The Integrated Infrastructure Management Model (IIMM) mentioned in the introduction is such an example, which can also be offered as a module in due course. The FAMM "flavour" is further strengthened by the capstone research project, which can have a focus on a specific fixed asset management area.

There are a number of short courses, which have been developed specifically for the Railways environment by the Chair in Railway Engineering of Spoornet. These current short courses are briefly as follows:

- **Introduction to Multi Disciplinary Concepts in Railway Engineering**
  This course will introduce multi-disciplinary aspects of railway engineering. It covers the principles applicable to each railway-engineering field as well as a general background on how a railway transport system operates. It will develop an appreciation for the complexities of and multi-disciplinary inter relationships of the railway system

- **Advance Concepts in Railway Infrastructure Maintenance**
  This course provides detailed concepts used in railway infrastructure maintenance. It covers the best practice philosophies used in railway infrastructure maintenance to the different railway-engineering fields. It

develops an integrated approach to assist in maintenance resource optimisation.

- **Best Practice for Wheel and Rail Management**
  The course is based on the manual published by the International Heavy Haul Association (IHHA) in 2001. It draws on information presented to 16 international IHHA conferences and technical sessions between 1978 and 2000. All this was integrated with the latest knowledge with the aid of the IHHA's International Review Panel under the guidance of its Technical Review Committee. The course assist in investigating the root course of wheel and rail damage, understanding the wheel/rail the system and provides a system approach to wheel and rail management.

The chair in railway engineering is also currently in a process of developing additional courses that will be presented in 2004. These courses are briefly discussed below.

- **Geotechnical Aspects for Railway Engineering**

  The course will cover the principles and functions of the layered track foundation system, its drainage and failure modes and how it relates to track performance. Various case studies will be included. The course will provide fundamentals to the railway track substructure and problems and solutions related to its interaction with the track.

- **Railway Asset Management**

The course introduces the general principles of railway asset management. The course will cover the key aspects of the management of a railway asset having a life cycle and the relationship between railway asset management as part of a system and of the business plan

It will develop an understanding of the appropriateness of the design of the railway system that the maintenance engineer and or manager is managing to the existing and future business needs together with the development of life cycle maintenance plans and the ability to adapt it to changing business requirements. This course is developed in conjunction with Spoornet and the International Union of Railways (UIC).

These short courses form part of a portfolio of Railway specific multi- disciplinary courses, which are designed to develop into a fully-fledged Railways Asset Management (RAM) course described above. The RAM course will pitch at a masters degree level and has the support of the international railways fraternity. The proposed MEM and MPM courses as described in Table 3 should therefore be seen as the first step in an evolutionary step to develop the proposed international RAM masters degree.

5. SUMMARY AND CONCLUSION

The civil engineering industry has experienced a paradigm shift in recent years in a number of ways. One of the most significant ways has been an appreciation of the full life cycle cost and associated maintenance and management of civil engineering fixed asset infrastructure. The need for education and training in the emerging area of asset and maintenance management has been expressed by various role-players and stake-holders in this field. No existing purpose built under graduate or post graduate or short course on this specific niche area is currently available in SA. This paper explained how the immediate need can be addressed by following a course of identification of "off the shelf" subjects and modules to be linked with an existing post-graduate masters programme. The masters programme in engineering management (MEM) and project management (MPM) offered by the Department of Engineering and Technology Management (ETM) of the University of Pretoria (UP) were identified as the most appropriate vehicle to package and link relevant civil engineering infrastructure subject modules to address the expressed need for FAMM education.

The repackaged MEM and MPM programmes as a specialist masters in asset management strike the correct balance between management modules and technical modules to address the required asset maintenance and management education and training needs. This was also achieved within the restrictions and practical problems faced with the institutional set up and the processes to get new educational products onto the market whilst meeting regulatory standards and specifications associated with the higher education environment. The MAM program is acknowledged as clearly not a "greenfields" product development, but it managed to meet at least 80% of the current educational needs in this field. It is also acknowledged that this proposed MAM may not address all the needs for training and education of all role-players in full yet. The proposed specialist asset maintenance and management MEM and MPM degrees do offer opportunity for inclusion of other fields of interest, such as specialist Railway Asset management (RAM) courses. courses and continued education courses forming part of an evolutionary developed RAM portfolio of courses also offer the opportunity for the development of specialist interest areas.

The specialist domain in asset maintenance and management of the MEM and MPM degree programmes are already on offer from 2003 via the School of Engineering under the co-ordination of the Department of Engineering and Technology Management (ETM) and co-operation of the Department of Civil and Biosystems Engineering and the Spoornet Chair in Railways Engineering at UP.

6. REFERENCE LIST

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APPENDIX A
SELECTION OF SUBJECT MODULE DESCRIPTIONS

CONDITION BASED MAINTENANCE
Key aspects: The importance and principles of condition based maintenance. Condition based maintenance techniques with focus on vibration, oil and temperature monitoring. Vibration monitoring – Theoretical principles, Transducers, Measurement instrumentation, Signal processing, Interpretation of results, Acoustical/Shock wave monitoring, Oil monitoring – Spectroscopic analysis, Ferrographic analysis, microscopic particle analysis, Tribology monitoring – Theoretical principles of infrared thermography, Applications, Avoidance of pitfalls, Implementing condition based maintenance.

DETERIORATION AND MAINTENANCE OF CONCRETE
This module highlights the principles for appropriate selection of materials and techniques for repair, maintenance and strengthening of civil engineering structures. Case studies. Investigation and diagnosis. Corrosion of reinforcement. Alkali-aggregate reaction, sulphate attack. Physical degradation. Repair materials. Protective systems. Systems for repair.

FINANCIAL MANAGEMENT
The course objective is to provide the student with a thorough understanding and knowledge about the role and functioning of financial management in order to achieve the objective of the firm. The course is student centred. Consequently students should continuously strive towards a high level of self-activity. Study-units should be studies by students beforehand. During class discussions the emphasis will fall on problems and obscurities which may arise from the study material. The syllabus of the course is the following: Understanding corporate annual financial reports. Financial statement analysis. The time value of money. Risk and rates of return. Valuation. Capital investment decisions. The required rate of return and long-term financing. Capital structure decisions. Long-term financing instruments. Short-term financing instruments. Current asset management.

INFORMATION MANAGEMENT
Students will learn how to be effective exploiters of computer/communications technologies now and in the future. Focus will be placed on IT resources (computers and microelectronics, networks, software, data and people) and alternative approaches to managing them; the opportunity and pitfalls associated with these technologies; and what the user-manager and the systems professional need to know to make effective use of these technologies. Students will also learn how to manage relationships between IT professional (the IT department) and end users (the business). Furthermore attention will be given to IT in very broad terms, including traditional data processing and management information systems, as well as enterprise resource planning systems, electronic commerce data resource warehousing and data mining, managerial support systems, groupware, artificial intelligence applications, and so forth.

INFRASTRUCTURE INFORMATION SYSTEMS
Information technology and administration applied to civil engineering infrastructure management. Topics include process design, data structure design, geographical information and information systems.

INTEGRATED DEVELOPMENT PLANNING
Introduction to development and development planning theories; the integrated development planning process; policy, legal and institutional frameworks for integrated development planning in South Africa; implementation of integrated development plans; integrated development planning case studies; simulated integrated development planning exercise.

LIFE CYCLE SYSTEMS ANALYSIS
Introduction to life cycle assessment as a decision support tool in business practices. Integration of environmental, economic and technical aspects for design and management decision-making. ISO 14040 principles and framework for life cycle analyses of product, process and service systems. Defining system boundaries and functional units. Life cycle inventory databases and data quality analysis. Life cycle impact assessment procedures. Environmental comparison metrics and weighting options. A case study in the automotive value chain of South Africa to apply the principles of life cycle systems analysis**.**

MAINTENANCE MANAGEMENT
Framework for Maintenance Management, Models in Maintenance Management (Reliability, Maintainability and Availability), Maintenance Planning, Organisation of Maintenance Resources, Leading in the Maintenance Environment, Control of the Maintenance Function, Current Strategies for Maintenance Management, Computerised Maintenance Management Information Systems (CMMS)

MAINTENANCE SPECIAL
Arranged in consultation with the Head of Department, usually following a week-long short module in the field of urban engineering.

PAVEMENT DESIGN
Design philosophy in First and Third World environments; characterising and use of pavement materials; drainage; systems approach to layout, geometric and pavement design; stresses and strains in pavements; mechanistic design methods and elasto-plastic behaviour; economic analysis; designing pavements for streets, gravel and paved roads, runways, and industrial areas.

PEOPLE MANAGEMENT
This subject consists of two parts:
Managing Organisational Behaviour -
This is the management of individual and group behaviour in organisational performance. The following will be addressed: Individual and group performance.
Team development and group dynamics. Conflict management and negotiations Stress management, Leadership, Organisational communication, Change management.
Human Resource Management -
Human resource systems and processes will be addressed: Recruitment, selection and placement, diversity in the workplace, motivation and job satisfaction, performance management, training, career development, labour relations.

PROJECT MANAGEMENT
The nature of projects and project management. The project life cycle and project phases. Organisational aspects of project management. Project teams and roles. Processes and methodologies for planning and control – initiating the project. Scope planning, Scope definition and the WBS. Scope management and work authorisation. Scheduling; PERT, CPM. Resource planning, cost estimates and project budgeting. The control process. Performance analysis: earned value, BCWS, BCWP, ACWP and performance indices.

Project closure: evaluation, reporting and termination. Project management information systems. Reasons for project successes and failures and continuing improvement. Theory of Constraints Project Management.

QUALITY MANAGEMENT
This introductory course aims to give a managerial perspective on Quality. Topics that are covered include the following: Evolution of Quality. Philosophy and principles of Total Quality Management (TQM). Implementation of TQM. International Standards like ISO

9000, 14000 and 18000. Business processes and the reengineering thereof. Quality Function Deployment. Concurrent Engineering. Quality Tools and Techniques. Test and Evaluation and audits.

RESEARCH PROJECT

A research project on a topic of the student's choice from any of the courses offered. The work takes place under the supervision of a project adviser. In addition to the satisfactory completion of the report itself, the student also has to prepare and present a paper based on the project at a final year symposium held during November each year. Evaluation is based on report content as well as presentation.

RISK MANAGEMENT

Introduction to project decision making and risk management. The need: illustrative case studies. Nature and sources of project risk. Probability analysis, impact analysis. Risk management standards and guidelines. The generic process of Project Risk Management (PRM). The nature of uncertainty. Project selection under uncertainty. Choosing a project strategy. Relationship between risk management and decision making. Modeling and simulation. Risk preference. Judgement under uncertainty. Cost and schedule risk. Technical risk (nature dependent on domain). Specifics of individual phases of PRM (project definition, the process, risk identification, ownership issues, risk estimation, risk evaluation, response development, project planning). Risk efficiency and the value of risk management. Risk allocation and insurance. Risk communication. Organizing for risk management. Documentation requirements. Application software. Decision making and risk management in practice.

ROAD REHABILITATION TECHNOLOGY

Development of road management systems and application to existing street and road networks. Evaluation
of, and measurements on existing facilities. Maintenance management. Recycling of materials. Design methods for upgrading, re-construction and strengthening of the existing road infrastructure. Prerequisite: Pavement Design

SAFETY, HEALTH & ENVIRONMENT

In any engineering practise, the engineer at some stage in his career becomes involved in the various aspects of managing a project. Apart from the general issues of management, namely planning, organising, leading and control, the manager is confronted with various issues of which safety, health and the environment forms an integral part of his daily tasks. It is therefore very important that the engineer in charge of a large project would have a very sound basic knowledge of SHE related issues. It is therefore important that he can apply the various principles relating to it, not only to the advantages of the company, but also to the advantage of the safety and health of the employees and the preservation of the environment. Topics include: Safety and Health management planning, the Occupational Safety and Health Act, the framework of accountability, systems and procedures to handle regulations, permits and licences, third party inspection, the systematic approach to environmental management on projects, environmental impact assessments, strategic environmental assessments, pragmatic environmental impact statement, World Bank standards, approaches to integration and the phased project life cycle.

STRATEGIC MANAGEMENT

The objective with this module is to stimulate strategic thinking and the development of strategic decision making skills amongst students in the field of strategic management in an engineering environment. In this module the following topics are addressed:
Concepts and Practice of Strategy: An historical background serves as introduction. Classical concepts and misconceptions in strategic and operational management work are given.
The Process of Strategic Management: The work content and structure of strategic

management are discussed. A schematic model of the process is developed.
Formulation of Strategy: This section gives a statement of the work to be done in formulation of strategy. The following aspects are covered: The company mission. External environment. Environmental forecasting. The company SWOT analysis. Formulating objectives and grand strategies. Strategic analysis and choice.
Implementation of Strategy: In the concluding part of the course attention is given to implementation through business functions, structure, leadership and culture, rewards, control mechanisms for measuring, evaluating and corrective actions.

SYSTEMS ENGINEERING
This course provides students with an insight into the development of products and systems from a holistic point of view. This point of view is necessary because of global competition, the growing complexity of the technologies available and the increasing sophistication of the end user. It is particularly necessary in the case of complex and large-scale systems where the development is highly multi-disciplinary in nature.

The course focuses on the management of the engineering effort required to bring new products and systems into being so that they are cost-effective, as opposed to engineering design or project management. It provides the student with a top-down approach: From needs analysis to synthesis to design specification; from conceptualization to detailed design; from total system requirements to component requirements; from prototype to production. The hierarchical nature of systems and time-phased baseline development concepts are used to simplify the management problem. The holistic approach considers design for aspects such as reliability, serviceability, user friendliness, producibility and affordability.

URBAN RESTRUCTURING
Definition of and rationale for urban restructuring; urban processes and outcomes; problems in urban areas, such as the decline of the inner city, edge city development, housing and services backlog, the dysfunctional Apartheid cityscape and dependence on private motor car use; types of intervention (i.e. spatial, economic and institutional) to ensure urban restructuring; policy and legislation for urban restructuring in South Africa; international case studies; impact of global economy on South Africa’s cities; simulated exercise in urban restructuring.