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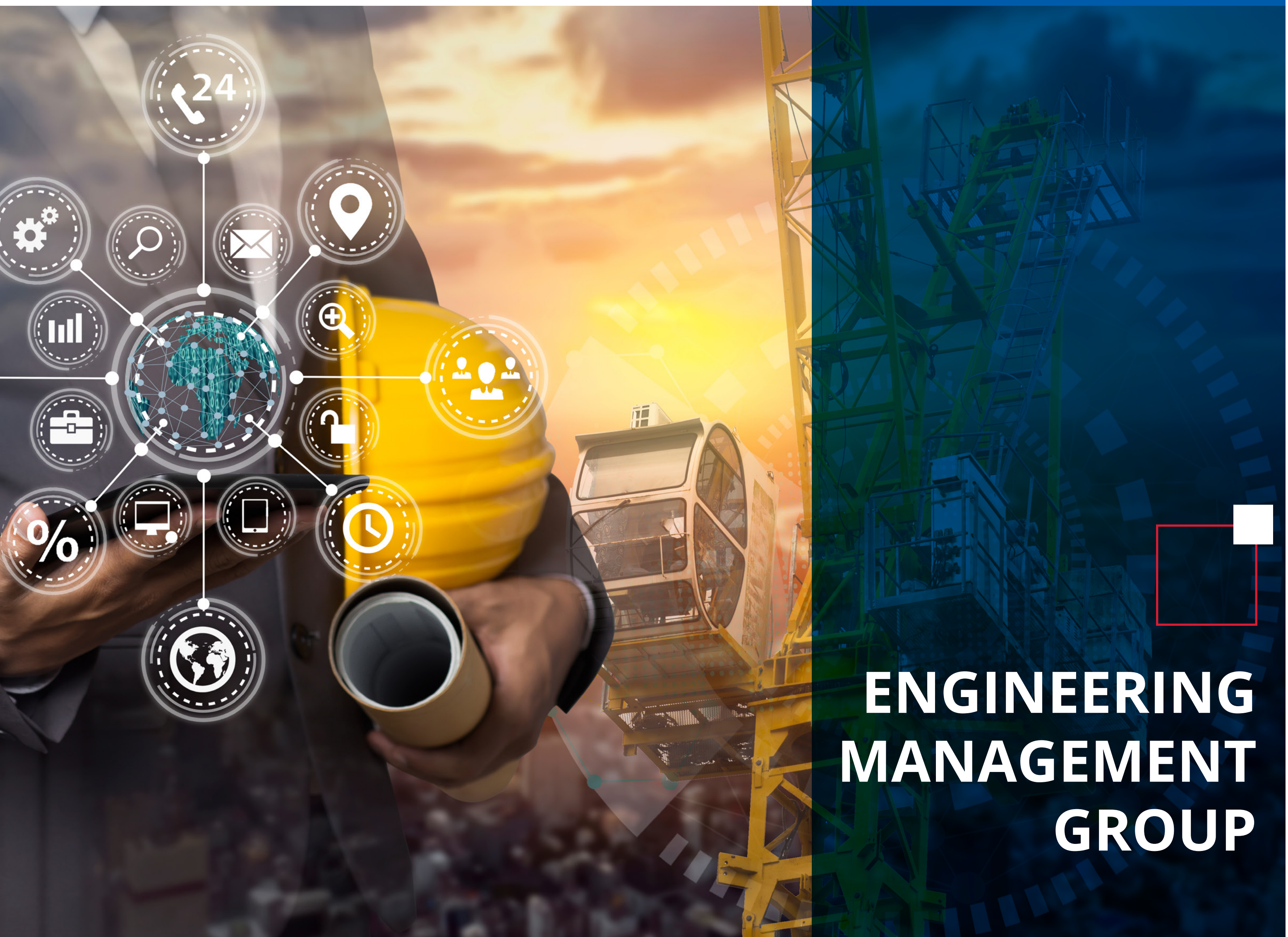
Graduate School of
Technology Management



ENGINEERING MANAGEMENT GROUP

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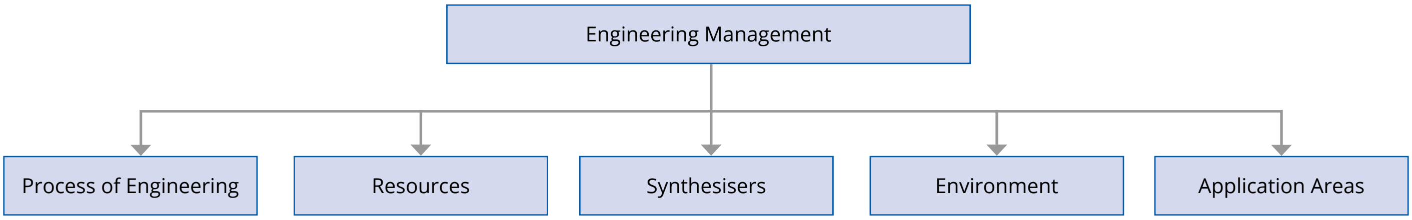
BACKGROUND

Engineering Management (EM) comprises the application of technology and other resources in the process of engineering in order to provide products, systems and services for financial gain in the marketplace. Young engineers and scientists start their careers as specialists. However, they are confronted early in their careers with the challenge to understand and to make a contribution in the total process of engineering. The process of engineering is elegantly described by relating it to the life-cycle of a product or system.

The next diagramme depicts the constituent elements of EM:



Process of Engineering typically includes: Design and Development, Production and Construction, Operations and Support, Upgrades, Phase Out and Dispose of and Recycling.

Resources typically comprise: Technology, People, Money, Information, Facilities and Information.

Synthesisers, *inter alia*, consist of: Strategic and Project Management, Quality and Risk Management and Professional Skills.

Environment could include: Economic, Industrial, Socio-political, Legal and Natural.

Application Areas can include a variety of Industry sectors.

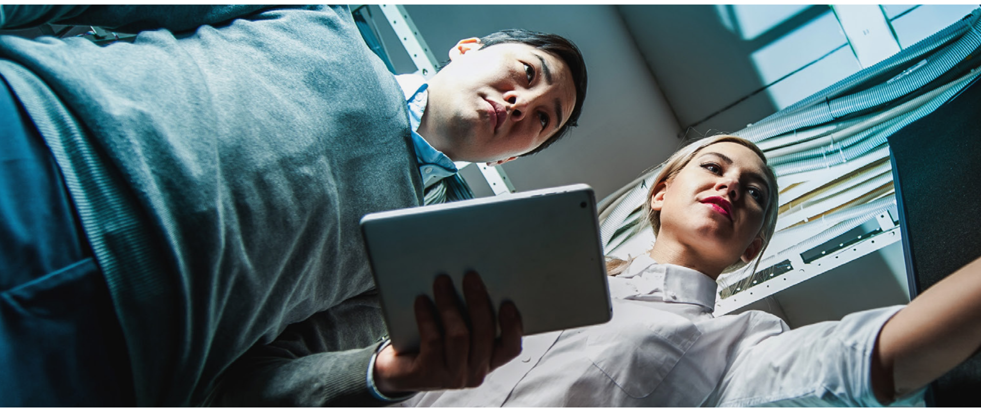
The architecture of the MEM programme is structured around this model. MEM courses and research themes support the model. It is obvious that a variety of research topics can be identified and studied. A systems approach is fundamental to EM.

A course in Systems Engineering (SE) is offered, but the systems approach runs like a golden thread through courses and research in the EM field. Resources relevant to EM are shown and needs to be managed. Synthesisers equip the engineering manager with management knowledge and skills to conceptualise and manage the EM effort. All EM initiatives happens within an environment that should be analysed and adhered to.

EDUCATION AND RESEARCH ALIGNMENT

The alignment of the educational content of the EM programme with the research focus areas of the EM research areas is essential. This practically means that students should rather do research on topics that they master while doing EM courses.

Knowledge areas and potential research topics are described in the remainder of document.



RESEARCH AREAS AND STUDY LEADERS

SYSTEMS ENGINEERING AND RELATED TOPICS

Systems Engineering includes a variety of sub disciplines and topics. Systems Engineering, Systems Thinking and System Dynamics are subsequently described and some research topics listed.

Systems Engineering

Dr Rudolph Oosthuizen

Prof Leon Pretorius

Dr Jörg Lalk

Potential research topics:

- The early phases of SE process, i.e. Problem/Requirement Analysis, Functional Analysis and Design and Conceptual Design.
- Process Analysis and Modelling (primarily IDEF0) in the Technology-based enterprise.
- Information Management/Software (applications) and their interaction with SE.
- Configuration Management in technology-based organisations.
- Product Knowledge Base and related fields.
- Integration and expansion of the Vee model and Systems Hierarchy.
- Systems Architecture and/or Enterprise Architecture.
- Inter-relationship between SE and Project management.
- Relationship between SE and System Dynamics.

Systems Engineering (SE) is about the creation of successful systems. SE focuses on the design and development of the "total system for the total life-cycle", hence the bigger picture. Concepts like holism and synergy are fundamental to a systems approach. SE is applicable to any man-made system. Technical systems and business systems are typically addressed. Various topics related to Systems Engineering or Systems/Product Development, e.g. the application of SE in a specific industry.

For a full list of publications, see:
Dr Oosthuizen (1)(2)
Prof L Pretorius
Dr Lalk

Systems Thinking

Dr Rudolph Oosthuizen

Dr Jörg Lalk

Systems Thinking (ST) has become the new way of dealing with what some refer to as a "holistic view".

The new world is made up of systems, in fact so was the old world, we just never understood that. Pay careful attention to your surroundings; you will regularly hear statements such as "the system is failing us", or "the national health system is not working", or "the political system is a disaster". When asking anybody in any of these spheres what do they mean by "system" most cannot answer.

They cannot answer because firstly they have no idea that in our world everything is connected to everything else, and secondly that a change to one part will (eventually) lead to a change elsewhere, be it positive or negative. Formalising the idea of systems and hence systems thinking allows us to organise our reality (be it in engineering, business or anything else) and importantly, understand the meaning and nature of links between elements making up a system. Once we understand that we actually can recognise patterns of human, machine and scientific behaviour we will have a competitive advantage, be it in business or your personal life.

Charles Dickens said: *"Facts alone are wanted in life. .....You can only form the minds of reasoning.....upon facts.....nothing else will ever be of service"*. Today we know that Charles Dickens could not be more wrong. Our complex world requires much more than just facts, it also requires the ability to understand, work with, and make decisions based on patterns and softer issues. In short, this course will teach you how to solve complex, rapidly changing, and ill-defined problems.

Potential research topics:

- Application of ST in national energy planning: South Africa as a case study
- ST vs. SE: Can they complement each other? (or an integrative framework)
- ST and complexity: Applying ST to solve complex societal problems
- ST processes and tools: A comparative study
- ST in social problems: A case study on racism

System Dynamics

Dr Rudolph Oosthuizen

Prof Leon Pretorius

System Dynamics (SD) as part of a design, simulation and analysis methodology links to systems thinking described previously.

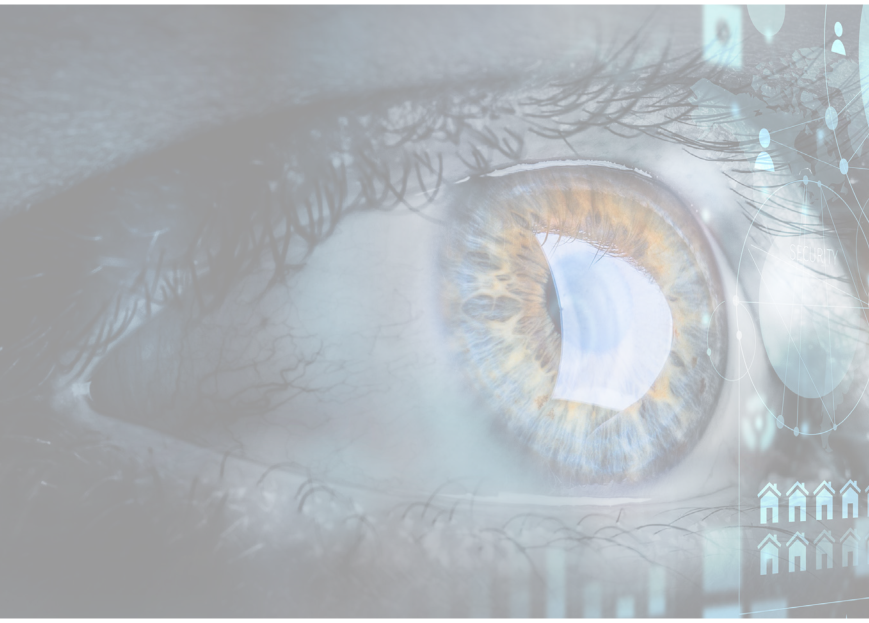
As a field of research many of the original efforts are due to the father of SD, the late Professor JW Forrester from MIT. In the words of Willard R Fey: *"SD philosophy and practice includes the SD methodology for analysing, synthesising, and changing living feedback systems to achieve lasting, improved behavior patterns"*.

The goals in this SD research domain are:

- To obtain and contribute to the fundamental knowledge of systems thinking and system dynamics as applied in the engineering system, business enterprise and technology management domain;
- To apply the general system dynamics process in various areas of the organisation to be able to model and address socio-technical problems in these types of organisational systems.

Some current research topics addressed in the research group for systems energy and innovation include:

- Assessment of a systems approach to sustainable eHealth implementation in resource constrained environments;
- Modeling and assessing sustainability of energy and other natural resources technology in developing socio technical contexts;
- Risk management dynamics and decision making in supply chain planning, product development;
- Requirements engineering dynamics;
- Project dynamics and other similar complex business and technology systems;
- Dynamics of technology and entrepreneurship, etc.



Technology is often seen as the engine of economic growth. Michael Porter confirms this in his statement:

"An upgrading economy demands a steadily rising level of technology. Technological change, in the broadest sense of the term, accounts for much of economic growth".

Technology Management

Dr Petrus Letaba

Prof Tinus Pretorius

Prof Elma van der Lingen

The management of technology is therefore an important function within any organisation, whether it be as a core resource of technology-based companies or as a support resource in service organisations. Technology, in different formats and in many different applications, is present over the whole lifecycle of projects and its activities. Gregory (1995) identified the typical technology management activities as Identification, Selection, Acquisition, Exploitation and Protection.

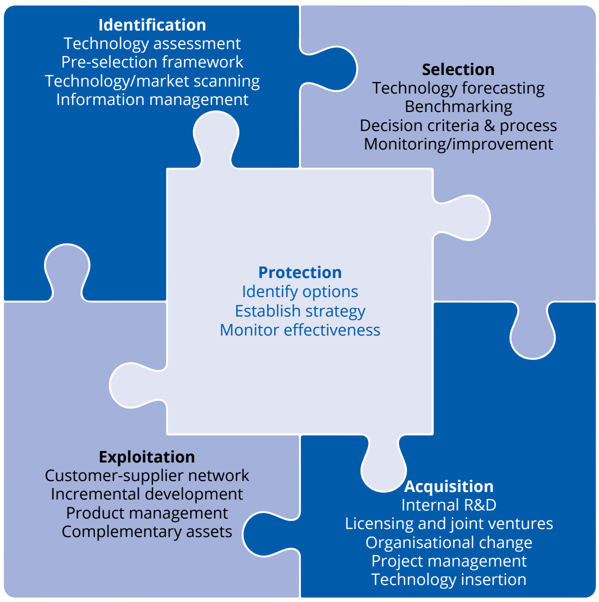
Many different methods and tools/frameworks were developed to assist organisations in the execution of their technology management activities and the search for new ones continues as the business environment keeps changing because of new emerging and disruptive technologies.

Therefore, the main research question of the theme is: How can technology shape the competitiveness of organisations?

Researchers thus ask questions such as:

- How can we assess current and emerging technologies?
- How can we forecast future technology landscapes?
- How can we select new technologies that will add value to the organisation?
- What processes do we need to acquire and transfer new technologies (including R&D)?
- How should we exploit and protect our technologies for optimal utilisation?
- What methods and tools can we use to perform the various technology management functions?

Because of the nature of technology management, the interface with the field of knowledge management through technology and knowledge intelligence is obvious.



Source: Gregory (1995)

For full list of publications, see:
Dr Letaba
Prof Pretorius
Prof van der Lingen

Engineering Asset Management

Prof Joe Amadi-Echendu

From the Stone Age and all of human history, engineered assets have provided impetus, and continue to provide the means for enhancing the way we live.

Engineered assets make up our built environment; from personalised smart and mobile devices, home/office appliances, industrial plants and public infrastructure into more complex and sophisticated functional systems. They include all man-made artifacts such as components, equipment, facilities, infrastructure, hardware and software tools, and cyber-physical systems that are deployed in all aspects of human endeavour. Engineered assets complement, supplement and in many situations, directly replace humans in numerous laborious and dangerous tasks. The management of an engineered asset such as an airplane, an electricity substation, an earthmoving machine, a telecommunications satellite, space station, or a water and sewerage treatment plant requires the integration of knowledge across many traditional and emerging disciplines. From a research viewpoint, the grand challenge is to formalise methods for the management of the wide range of engineered assets based on unambiguous, coherent, consistent, logical and multidisciplinary body of knowledge. The wide ranging areas of research broadly include (i) asset acquisition and investment decisions; (ii) asset operation, maintenance and retirement; (iii) condition, risk, resilience, and vulnerability assessments; (iv) performance evaluation and sustainability of assets and asset systems; (v) effects, impacts and influences of technologies and innovation on the management of assets.

Maintenance Management

Prof Joe Amadi-Echendu

Prof Krige Visser

Maintenance management can be regarded as "all activities of management that determine the maintenance objectives, strategies and responsibilities and implementation of them by means of maintenance planning, organisation and control, and the improvement of maintenance activities and processes".

Strategic maintenance management and disciplined execution of maintenance tasks is critical to provide value during the operations phase of the asset life cycle.

Maintenance is crucial in ensuring that electricity networks, water reticulation systems, sewerage treatment plants and communication systems are functioning properly, especially in rural areas of South Africa. Government objectives for social upliftment of all communities in South Africa will not be achieved if public physical assets are dysfunctional.

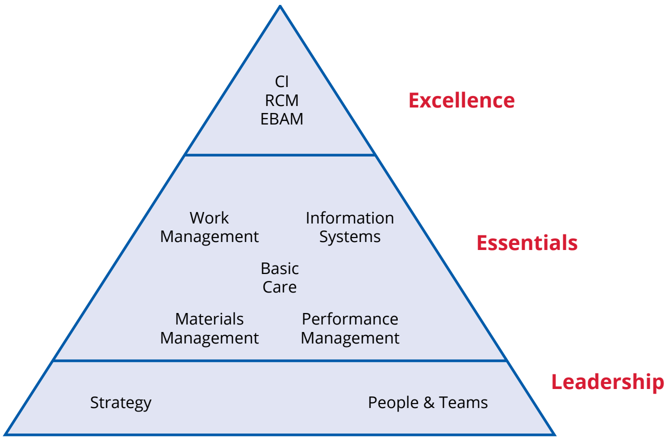
A crucial aspect of maintenance planning is to select cost-effective maintenance tactics, e.g. use-based, condition-based, failure-based or fault-finding. Optimum maintenance intervention (often replacement) intervals should also be determined from failure history if available or from data provided by original equipment manufacturers (OEMs).

Campbell and Reyes-Picknell provide a model for the overall maintenance management function. This model for maintenance excellence defines three levels of maturity and ten elements that can be used to measure an organisation's journey to excellence in maintenance management.

Maintenance management excellence is achieved through competent people and effective teams, good strategy deployment and some essential functions as shown for the second level. Continuous Improvement (CI), Reliability-centred Maintenance (RCM) and Evidence-based Asset Management (EBAM) are applied by mature maintenance organisations.

Potential research topics:

- To what extent have new maintenance technologies been implemented and used in South African manufacturing industries, e.g. e-maintenance, self-maintenance, lean



Source: Campbell & Reyes-Picknell (2014)

maintenance, green maintenance and digitisation?

- To what extent have different industries like processing, mining, energy, transport, communications, oil and gas, assembly plants, etc. have advanced or progressed to support the 4th industrial revolution, i.e. Industry 4.0?
- Which methods and tools are used in industry by maintenance managers and planners to select intervention intervals for used-based maintenance, periodic condition-based maintenance, and fault-finding maintenance to minimise the total cost of maintenance or total cost of ownership?

For full list of publications, see:
Prof Amadi-Echendu (1)(2)(3)
Prof Visser

Risk Management

Dr Schalk Grobbelaar

Prof Leon Pretorius

Prof Krige Visser

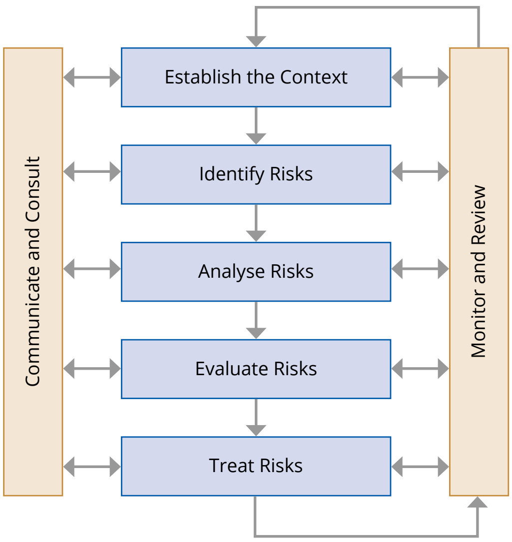
Risk is defined by the ISO 31000 Risk Management Standard as "the effect of uncertainty on objectives". Project risk is defined by the PMI as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective".

Risk exists in the business enterprise and projects because of uncertainty and risk management is therefore about reducing uncertainty in the enterprise or project to an acceptable level. Risk management is applied in various areas of the enterprise, e.g. business and financial risk, operational risk, safety, environmental and health risk, and project risk. The goal of project risk management is to deliver a project on time, within budget, and with acceptable quality or performance.

A conceptual model for risk management is provided by the International Standards Organisation. It covers the main steps of the process, the interaction with stakeholders through communication and consultation, and the way in which monitoring, and review is required during all steps of the process. The first step of the process defines the scope and context since a risk assessment is not done in isolation of the environment of the business or project. A risk team needs to be assembled within the business or project to perform the steps of the risk management process. The analysis and evaluation steps determine the risk value of each risk event and identifies the critical risks. The treatment phase defines suitable 'controls' that reduces the probability or consequence of an event.

Potential research topics in risk management are:

- Comparison of alternative analysis methods or tools for different risk analysis requirements.
- Probability and consequence estimation and elicitation techniques in risk measurement and parameter estimation for probability distributions in risk simulation.
- Investigation of monitoring and control effectiveness in project risk management.



Source: ISO 31000 (2009)

For full list of publications, see:
Dr Grobbelaar (1)(2)

Dr Jörg Lalk

Dr George Alex Thopil

Prof David Walwyn

Energy Studies and Technologies

This field of study and research is discussed in detail in a separate brochure by the Energy Systems Analysis Group of the GSTM led by Dr Jörg Lalk (refer details within energy research brochure).

For full list of publications, see:
Dr Thopil
Dr Lalk
Prof Walwyn (1)(2)

Sustainability

Dr George Alex Thopil

Sustainability in the most general form means, creating the ability to continue a mentioned act or process, without being an impediment to continuity while performing the said act or process.

The concept of sustainability can be applied at the largest of levels (such as the planet) to the smallest levels (such as a micro-organism). Both levels are essential for life to be sustainable. The very same principles can be applied to everyday life including functioning of organisations, businesses and even the economy.

Considering how complex modern day functioning is, comprehending, planning and implementing sustainability requires complex and multi-disciplinary solutions using flexible frameworks. Multiple frameworks exist currently, that can be used for analysing sustainability. Devising sustainable solutions very often need to take into account multiple facets of society or organisations.

These facets include social, technical, economic, environmental and policy aspects. Additionally sustainability requires an understanding of the short, medium and long term eventualities that could occur.

The GSTM currently conducts research in the areas of energy and environmental sustainability as well as water related sustainability. The issues of sustainability link closely with systems and life cycle approaches.

Potential research topics are:

- Energy sustainability
- Environmental sustainability
- Water sustainability

For full list of publications, see:
Dr Thopil

Production and Operations Management

Dr Hilda Chikwanda

All value in society is generated by transforming one set of things into other different things. Without such transformations, there would be no wealth creation and no rationale for business. Production involves transformation of raw material (input) into desired product or service (output) by adding economic value.

Operations management is the design and management of transformation processes used to convert inputs into outputs that customers want and are willing to pay for. It concerns the management of production systems. Production and Operations Management is about applying business organisation and management concepts in creation of goods and services that meet the needs of customers.

Our research aims to tackle industry and society's challenges in a world that increasingly merges technology with humanity. Working with students we are eager to solve problems for the present and for the future. Using a holistic approach, we address today's most pressing operational challenges (strategic issues of designing operations and tactical issues of executing processes) to make things work better, faster and cheaper. Through projects and research, students and the team work toward innovative solutions to motivate lasting change and business impact. The research program in Operations Management aims to train students to develop scientific solutions to the problems currently being faced by operations. It trains students to apply empirical techniques and theoretical analysis to advance our understanding of how work and processes are, or should be, organised and managed. A wide variety of research methods are employed.

Research in Operations Management covers a broad range of topics as found in (but not limited to):

- Manufacturing and Service operations
- Strategic and International operations
- Logistics and Supply chain management
- Inventory control and management
- Project Management and Scheduling
- New product development and Quality management

For full list of publications, see:
Prof Chikwanda

Technology and data driven decision making

Dr Schalk Grobbelaar

We find ourselves in the fourth industrial revolution where the Internet of Things (IoT) drives data-driven decision making. Smartphones, intelligent sensors, edge computing, cloud computing and artificial intelligence has become part of our daily lives.

For organisations to remain competitive in this fast-paced environment, they need to be agile and competent in data science. From a technology and innovation management perspective, organisations need to prepare themselves to be competitive in this environment. This requires technical and management skills.

Research in this area studies the application of data science tools and the management of this technology and its innovations.

Typical research questions in this area include:

- What are the research patterns in a specific field of study, and where are there gaps that require more attention?
- How can data science be used to make better predictions of the future?
- How do organisations improve their data-driven decision-making capabilities?
- How do organisations integrate data-driven decision making into strategic decision making?
- How do organisations sustainably and ethically apply these technologies?
- How should society/organisations manage the potential risks of these technologies?

By researching these aspects, organisations/society will be enabled to sustainably and ethically use these technologies to improve competitiveness.

For full list of publications, see:
Dr Grobbelaar (1)(2)

CONTACT US

Prof David Walwyn
Room 4 (4-18)
4th Floor
Engineering 2 Building
University of Pretoria

Email: david.walwyn@up.ac.za

Prof Elma van der Lingen
Room 4-4
4th Floor
Engineering 2 Building
University of Pretoria

Email: elma.vanderlingen@up.ac.za

Prof Hilda Chikwanda
Room 4-12
4th Floor
Engineering 2 Building
University of Pretoria

Email: hilda.chikwanda@up.ac.za

Prof Joe Amadi-Echendu
Room 4-19.1
4th Floor
Engineering 2 Building
University of Pretoria

Email: joe.amadi-echendu@up.ac.za

Dr George Alex Thopil
Room 4-16
4th Floor
Engineering 2 Building
University of Pretoria

Email: george.alexthopil@up.ac.za

Dr Schalk Grobbelaar
Room 4-10
4th Floor
Engineering 2 Building
University of Pretoria

Email: schalk.grobbelaar@up.ac.za

Dr Rudolph Oosthuizen
Room 4-15
4th Floor
Engineering 2 Building
University of Pretoria

Email: siebert.benade@up.ac.za

Prof Krige Visser
Email: krige.visser@up.ac.za

Prof Leon Pretorius
Email: leon.pretorius@up.ac.za

Prof Tinus Pretorius
Email: tinus.pretorius@up.ac.za

Dr Jörg Lalk
Email: jorg.lalk@up.ac.za