

# Innovate:

Issue 08 2013

## Industry collaboration

Africa's first virtual reality mine design centre

## Multidisciplinary initiatives

Landscaping project forms part of new Mining Industry Study Centre  
Reintegrating humankind and nature  
Strategies to combat malaria  
Research contributes to future energy security

## Technical essays

Towards greener pyrotechnics  
Tapping untapped renewable energy  
Diversity in townhouse complexes  
Science in South Africa: The dawn of a renaissance



UNIVERSITEIT VAN PRETORIA  
UNIVERSITY OF PRETORIA  
YUNIBESITHI YA PRETORIA

# Beyond Engineering

**The Graduate School of Technology Management (GSTM) at the University of Pretoria** is the first graduate school of its kind in South Africa and also the largest in Africa.

The GSTM offers internationally recognised postgraduate programmes at honour's, master's and doctoral level. Programmes and research activities relate to the disciplines of technology, engineering and project management for practising engineers and scientists.

The School maintains strong links with industry and government and also developed a good research network with local and international researchers. A strong focus on research ensures relevance to the market in terms of increased competitiveness, optimised product lifecycles and technology transfer. It thus positions technological capabilities within the international context.

A portfolio of continuous education offerings also ensures that the latest knowledge reaches the broader market. For more information on the year programmes and short courses offered by Continuing Education, visit [www.ceatup.co.za](http://www.ceatup.co.za)

## Degree Programmes:

### Masters in Engineering Management (MEM)

The programme provides a range of relevant management education to the engineer in general or functional management. It also focuses on broad base technology utilisation in the business environment.

MEM focuses on the process of value creation, i.e. product and system development, production and operations and the maintenance of systems and related services within a business context. The strategic position of the enterprise in terms of technological capability is paramount. The above-mentioned study areas are key factors distinguishing MEM from other postgraduate and business management degrees.

### Masters in Project Management (MPM)

Provides high-level project management education on the fundamentals of project management as well as integration of projects with a company's strategic intent. MPM also focuses on the people, financial and cost management side of projects,

as well as key elements of procurement and legal aspects of project management. The MPM is accredited by the Global Accreditation Center for Project Management Education Programs (GAC), of the Project Management Institute, USA.

### Honours in Technology Management (MOT) and Masters in Technology Management (MTM)

The objective of the MOT is to provide young engineers and scientists not only with technological capabilities, but also with the ability to manage technology – specialists who not only know how to develop and deploy technology, but also why.

The MTM is aimed at graduate business managers and recent graduates with management and leadership potential to prepare them for leadership roles in business through professional postgraduate education.

For more information on programmes offered by the GSTM, visit [www.up.ac.za/gstm](http://www.up.ac.za/gstm)



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Graduate School of Technology Management

*Innovate* 08: 2013

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**On the cover:**

Africa's first virtual reality mine design centre. See article on page 28.

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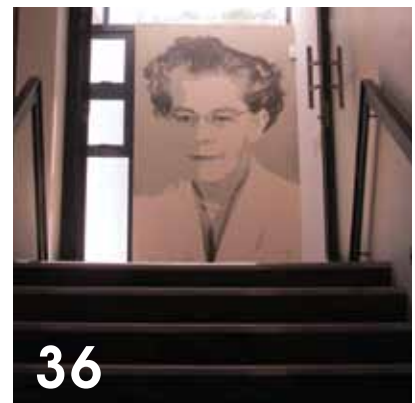


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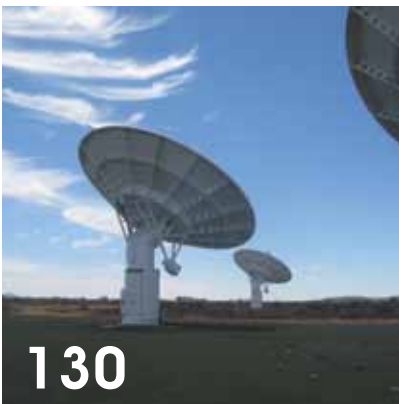
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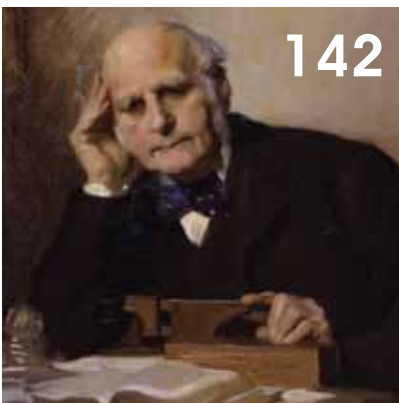
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**ESENTRUM** MINING INDUSTRY STUDY CENTRE

# Hinc lucem et pocula sacra



"In 1209, scholars taking refuge from hostile townsmen in Oxford migrated to Cambridge and settled there." The year 1209 earmarked the establishment of the University of Cambridge, an institution that would later become one of the most famous academic institutions in the world. To date, the names of 89 Nobel Prize winners are affiliated with the University, including famous names such as Rutherford, Thomson, Watson and Crick, Lord Rayleigh and many others.

Year after year, the University of Cambridge is ranked as one of the top-performing universities in the world. The interesting question is, of course, how it succeeded in maintaining this excellent performance for decades, and even centuries. The answer probably lies in the successful establishment of a culture of academic excellence, which is carried over from generation to generation by both academics and students. A combination of top human intellect, globally relevant curricula based on leading research, cutting-edge facilities, a highly efficient global industry network and other contributing factors make this possible.

For other universities in the world, the challenge seems to be to compete with academic institutions such as the University of Cambridge. Is this really possible? I often see competition as a relative concept. Universities should define their own specific academic context in which they need to compete and develop appropriate strategies and strategic roadmaps to reach their academic goals. Universities such as Cambridge should rather be used as role models. The goal should not necessarily be to assimilate the leading universities, but rather to learn from them. Building strong collaborative research networks with these leading universities is of great importance in developing one's own research capabilities.

At the University of Pretoria, the Faculty of Engineering, the Built Environment and Information Technology has a clear vision of the future and how it wants to improve its competitive position. The Faculty's strategic roadmap is built on a combination of its academic excellence, education and research facilities, collaboration with leading international universities, and strong industry networks and support. The high number of research chairs in the various departments in the Faculty

that are sponsored by industry and government is evidence of these role-players' involvement and interest in the research activities of the Faculty. Technological innovation that is relevant to industry and government is a high priority and is strongly supported by the many research initiatives in the various departments and research groups.

In this edition of *Innovate*, you can once again read about some of the leading and interesting research projects that are undertaken in the Faculty. Several hundred academic researchers and postgraduate students, local and foreign, contribute to research. Research findings are diffused in high-ranked international journals and conferences, and attract attention from many other researchers. Industry and government also benefit from this research through the consulting work of academics.

I hope you will again find the contributions in this issue valuable and interesting.

And by the way, in case you were wondering about the meaning of *Hinc lucem et pocula sacra*, it means: From this place, we gain enlightenment and precious knowledge. It is the official motto of the University of Cambridge. And that is what the Faculty of Engineering, the Built Environment and Information Technology at the University of Pretoria strives towards as well! 🍷

Editor  
Tinus Pretorius

# The broadband divide: Where is the digital highway heading?

Janine Smit

“Broadband is no longer a luxury... it is a core infrastructure of the modern economy. Those who have it will prosper, and those who don’t will fall further behind.” This is the unequivocal opinion of Dr Hamadoun Touré, Secretary-General of the International Telecommunication Union (ITU).

It is an opinion shared by many developed countries in the world. Finland is a great leader in this regard, and is advocating for the establishment of broadband as a basic legal right. In the USA, President Barak Obama launched his National Wireless Initiative in 2010. The message is clear: advanced connectivity will deliver major economic benefits everywhere.

The difference between communities with a strong information and communication technology (ICT) infrastructure and those with a weak ICT infrastructure is commonly referred to as the “digital divide”. However, it is not just emerging economies like South Africa that have a digital divide. A 2010 study for the Federal Communications Commission (FCC) in the USA by the Social Science Research Council found that “low-income communities are marginalised without access to broadband – and they know it”.

## What is broadband?

According to the FCC, “broadband” – or high-speed internet access – allows users to access the internet and internet-related services at significantly higher speeds than those available through dial-up internet access services. Broadband speeds vary significantly, depending on the particular type and level of service ordered, and may range from as low as 200 kbps to 30 gigabits per second (Gbps).

## The benefits of broadband

The South African government also realised the benefits of broadband with the publication of the National Broadband Policy by the Minister of Communications in July 2010. The vision of this policy is to ensure universal access to broadband by 2019, ensuring that South Africans are able to access broadband either

individually, or as a household subscribe to a broadband service, or are able to access a broadband service directly or indirectly at a private or public access point. Broadband is recognised as a strategic tool in the building of an information economy and society. Extensive international studies have been performed on the benefits of investing in broadband infrastructure. In every such study, broadband has demonstrated the ability to deliver substantial economic growth, increased employment and vast societal benefits.

The potential benefits will contribute positively to improving the lives of many South African households, for example, by improving communication, and providing access to services, employment and business opportunities.

The impact of broadband can be recognised by the fact that it addresses each one of the eight Millennium Development Goals, which were adopted by the United Nations in 2000 to guide the world’s efforts to alleviate extreme poverty by 2015. As such, broadband plays a role in the following:

- Eradicating extreme poverty and hunger
- Achieving universal primary education
- Promoting gender equality and empowering women
- Reducing child mortality
- Improving maternal health
- Combatting HIV/Aids, malaria and other diseases
- Ensuring environmental sustainability
- Developing a global partnership for development

## ICT RDI Roadmap

The South African Department of Science and Technology (DST)



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“Today, you can tell the rich from the poor by the quality of their internet connections, both within countries and between them.”

– Dr Shashi Tharoor, ITU Broadband Commissioner

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has developed an ICT Research Development and Innovation (RDI) Roadmap to put South Africa on the road to gaining the digital advantage in order to promote economic growth.

The roadmap comprises six key clusters of opportunity that represent areas of significant and attractive market need, to which researchers and policy-makers can feasibly, and with differentiation, respond by building on existing capacity in order to impact on the dimensions of wealth, society and national advantage. These clusters are broadband infrastructure and services, development, sustainability and the environment, grand science, industry applications, and the service economy. Each of these clusters has a number of associated market opportunities, as illustrated in Figure 1.

### Making an impact through research

Prof Sunil Maharaj, Head of both the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria and the SENTECH Chair in Broadband Wireless Multimedia Communications

(BWMC), delivered an expert lecture at the University of Pretoria on 21 August 2013, entitled 'The broadband divide: where is the digital highway going?'

According to Prof Maharaj, there were around 5 000 analogue mobile subscribers in 1980. With the role that the Global System for Mobile Communications (GSM) started to play in digital mobile in 1988, it is predicted that by the end of 2013, there will be approximately seven billion connections in the world. With such spectacular growth in the wireless communications industry, the next challenge is the provision of greater throughput via broadband connections that are both pervasive and affordable.

Today broadband wireless technology is largely based on orthogonal frequency division multiplexing (OFDM) technology. Current challenges in this area include the development of "green radios" due to increased power consumption, the opportunity for spectrum sensing and cognitive radio, the digital divide and the radio frequency spectrum

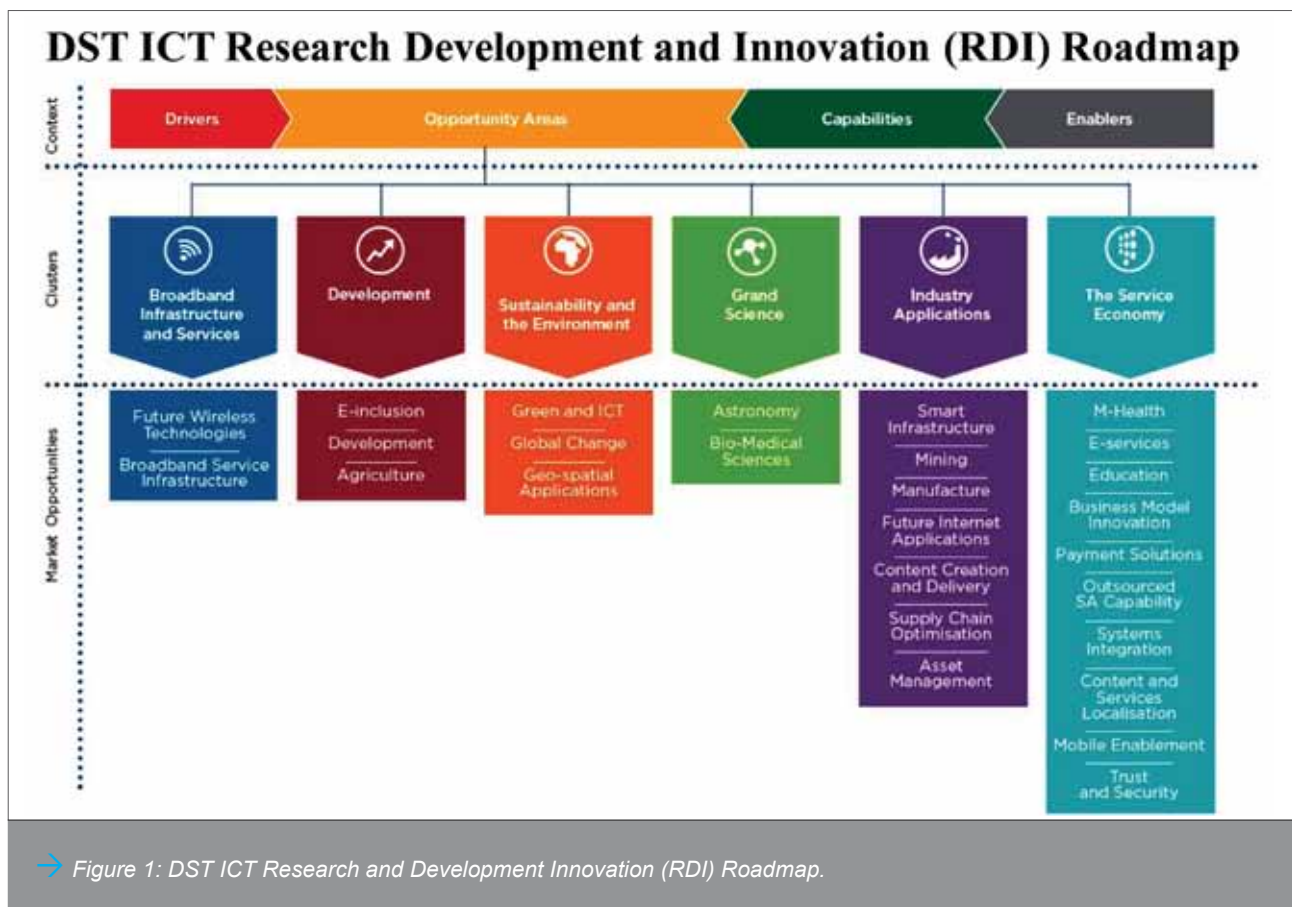
regulatory landscape, and innovation in software applications and localisation.

These challenges are driving the work of the SENTECH Chair in BWMC at the University of Pretoria. Its mission is to participate in cutting-edge research activities in the field of broadband wireless communications, and to deliver world-class research and educational outputs for the benefit of SENTECH, the University of Pretoria, other industry sponsors and South Africa in general.

A number of innovative research projects are currently underway, including the following:

### MIMO channel modelling for indoor wireless communication

This research investigates multiple-input/multiple-output (MIMO) channel modelling for a wideband indoor environment. The theoretical basis of geometric modelling for a typical indoor environment is examined, and a space-time model is formulated. The transmit-and-receive-antenna correlation is then separated and





→ Students in the SENTECH Chair in Broadband Wireless Multimedia Communications participate in forefront research activities in this field.

expressed in terms of antenna element spacing, the scattering parameter, mean angle of arrival and the number of antenna elements employed. These parameters are used to analyse their effect on the capacity for the chosen environment.

### Cognitive radio performance optimisation through spectrum availability prediction

The FCC has predicted that a spectrum shortage may occur in the near future under the current regulatory environment. This impending spectrum shortage is in part due to a rapidly increasing demand for wireless services and inefficient usage of currently licensed bands.

A new paradigm pertaining to wireless spectrum allocation, known as cognitive radio (CR), has been proposed as a potential solution to this problem. This project seeks to contribute to research in the field of CR through an investigation into the effect that a primary user channel occupancy model will have on the performance of a secondary user in a cognitive radio network. This model is important, since it provides secondary users with a basis for channel switching and future channel allocations.

### An offset modulation method used to control the PAPR of an OFDM transmission

Orthogonal frequency division multiplexing (OFDM) has become a very popular method for high data rate communication. However, it is well known that OFDM is plagued by a large peak-to-average power ratio (PAPR) problem.

One of the results of a high PAPR is an inefficient transmitter, which is not desirable. Various methods have been recommended to reduce the PAPR of an OFDM transmission. However, all these methods have a number of drawbacks. This research develops a novel method called offset modulation (OM-OFDM) to control the PAPR of an OFDM signal. The proposed OM-OFDM method does not suffer from a number of the drawbacks experienced by current methods in the field. The BWMC Group has filed a patent for this methodology.

By using the newly applied power performance decision metric, the OM-OFDM method is shown to offer significant performance gains when compared to existing constant envelope (CE)-OFDM (and traditional OFDM transmission methods).

### The future of broadband

In his expert lecture, Prof Maharaj considered whether the end of the road is near in terms of increasing throughput, and posed the question: What will be the next wave? The answer, according to Prof Maharaj, lies in the development of millimetre-Wave (mm-Wave) communications, which could possibly lead to next-generation (5G or 6G) Millimetre Mobile Broadband (MMB). Millimetre-Wave lies at the high end of the microwave frequencies, and has a frequency of 30 GHz ~ 300 GHz. It will enable scientists to explore a new spectrum for mobile broadband communication. Some of the current applications of mm-Wave include radio astronomy, wireless backhauls, intersatellite links, high-resolution radar and security screening.

Through the innovative and internationally relevant research in the field of broadband wireless multimedia communications, Prof Maharaj hopes to contribute to bridging the digital divide, and ensure that the broadband divide does not become the next evil in our society: that our citizens and communities are not disadvantaged due to their lack of access to a high-speed digital connection. 🌐



# Research innovation at the University of Pretoria

Janine Smit

**The University of Pretoria is nationally and internationally recognised for the excellence of its research outputs. Its ambitions and activities are influenced by more than 100 years of learning, scholarship, research and public engagement.**

Over the past 20 years, the University has produced, on average, the highest percentage (14%) of the total South African research output, and has more than 300 National Research Foundation (NRF)-rated researchers among its academic staff – more than 12% of South Africa's NRF-rated researchers. Its consistent performance in research production and postgraduate output is further reflected in the number of journal articles that are listed in the International Scientific Index (ISI) and the International Bibliography of the Social Sciences (IBSS).

Contract research (often referred to as externally funded research), constitutes an important source of

research revenue for the University. It is essentially research that is funded by external sources, including government, foreign funders and industry or commerce.

Typically, these sources of funding include government funding instruments, such as the Technology and Human Resources for Industry Programme (THRIP), the Innovation Fund and the Biotechnology Regional Innovation Centres (BRICs). Industry sources include large corporations, and small and medium enterprises (SMEs), while foreign funders include the European Union Framework programmes, as well as foundations, agencies and collaborative research funds.

## Addressing the need for new knowledge and human capacity

The University's strategic goal over the next 15 years is to raise its international profile by increasingly addressing society's need for new knowledge and human capacity through research.

The provision of human capital will be founded on its research intensity by increasing the output of graduates with higher degrees in both research and professional fields, and replenishing the University's own human capital. The emphasis will be on accelerating knowledge generation by fostering collaboration with government, higher education institutions and the private sector to generate the hybrid spin-offs needed for development. At the same time, key international partners and knowledge networks will be sustained and further developed to strengthen the University's research capacity and linkages.

Areas of existing research strengths will be used as catalysts to develop a pervasive research culture, and cross-cutting research themes of national, regional and/or international relevance will be identified to leverage research capacity and impact. Optimal synergies will also be sought between research and teaching excellence to inform inquiry-led curricula at undergraduate and postgraduate levels, and between research and professional programmes and qualifications to strengthen the identity of the University.

Thus, in addition to equipping its graduates with the attributes necessary for adapting to the demands of the fast-changing world of work, the University will enhance social and economic development by being a university committed to the needs and challenges of its context, and by contributing to the high-level human capital required to address some of the major challenges of our times. As a research-intensive institution, the implications are that it will concentrate on problems of national and/or regional concern in order to maximise local impact, while enhancing its academic stature and



→ Excellent progress has been made with the further development of silicon-based light-emitting devices as part of the Faculty's INSiAVA initiative.

visibility within a highly competitive international world.

Increasing its international profile, through a focus on unique local opportunities and collaborative research, is a primary objective of the University of Pretoria. By strengthening activities in the areas of immediate national need and ensuring that those fields that ultimately affect human welfare are developed, the University will be able to make a significant contribution in overcoming South Africa's challenges and developing human capital in the country.

In general, this means that the University must develop international profiles in areas of importance to developing nations, especially those in Africa. Engineering is one of the broad fields that have been identified. Areas in which capacity should be developed to contribute to addressing some of the major challenges of the developing

world include efficient water use in arid regions, mitigating the impact of climate change, promoting sustainable rural development, sanitation, providing sustainable sources of energy, transport, municipal management, and managing health systems and hospitals.

### Innovation support

The University's research objectives are supported by its Department of Research and Innovation Support (DRIS), which plays an integral role in the practical implementation of the University's research agenda. It provides a range of support services that are aimed at promoting research development and innovation, as well as the protection of intellectual property and the conclusion of licensing agreements to commercialise technologies developed by the University's employees and students.

The University's Contracts and Innovation Support Office within DRIS supports researchers by creating an enabling environment for research, and obtaining funding for research from third parties. It also coordinates processes, systems and structures to facilitate innovation at the University of Pretoria. This includes developing the capacity needed to access market opportunities, and to define and implement routes to market for technological innovations. Furthermore, it develops and coordinates mechanisms to enable the University to take advantage of national innovation funding instruments. It supports researchers in the management of large innovation projects, and provides budgeting guidelines and financial administration support where needed. Finally, it builds strategic networks with other higher education institutions, government agencies and industry partners, as well as strategic international partners.

### Innovation and technology transfer

The main goal of technology transfer (the transfer of technology developed by University researchers to the private sector) is to improve national economic growth through greater technological innovation. Technology transfer contributes directly to technological innovation by supplying the private sector with new technologies that have commercial potential. While businesses look forward to the prospect of receiving new products and services, universities are motivated by the potential income stream from successful licensing agreements, and greater employment opportunities that graduates may have with industry partners.

The legislative environment includes the Technology Innovation Agency Act, Act No. 26 of 2008, and the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008. These acts of Parliament provide South African universities with new intellectual property management protocols.

The University's Technology Transfer Office (TTO) facilitates the transfer of discoveries created using the Univer-

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The University's research objectives are supported by its Department of Research and Innovation Support, which provides a range of support services aimed at promoting research development and innovation, as well as the protection of intellectual property.

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sity resources (physical and human) into new products and services for the public good and benefit. It promotes regional economic growth and job creation, rewards, retains and recruits suitable staff, and builds relationships between faculties and the University's research and innovation community. It also creates, fosters and develops (new) relationships with industry. Furthermore, the TTO generates net royalty income for the inventors and the University, facilitates and generates new funding support for the University and/or faculty from sponsored research funding, consulting opportunities, and donations of money or equipment, and acts as a service centre to the University, faculties, staff and students in all areas related to the protection of intellectual property.

Research and innovation activities often go hand in hand, which is why it is essential for the University to invest in the innovation value chain. Once a scientist declares that he or she has an invention to disclose, the staff of the TTO will determine whether the intellectual property is patentable. "For an invention to be patentable, it should be novel, useful in the field and not obvious," explains Refilwe Ngoato, Technology Transfer Manager.

The first step is to determine that the invention is in fact new. A number of patent analytical tools are used for this purpose, such as that of Thomson Reuters. After this has been established, a patent attorney that is best skilled in that particular field assists with the filing of the patent.

For the filing of a patent, there are two options. A scientist can either file a South African provisional patent, which provides the research team with a

further 12 months to conduct additional research and development, or a Patent Cooperation Treaty (PCT) could be filed, which is an international patent. "Normally new technologies need to be developed further," says Ngoato. In the case of an invention with a high commercial potential, Ngoato advises filing a PCT application, as this provides up to 18 months to do further research and development, conduct market analysis and investigate commercialisation options.

Once a patent has been filed, scientists can proceed with publishing the findings of their research and presenting their research at conferences and symposiums.

According to Prof Stephanie Burton, Vice-Principal: Research and Postgraduate Education, the University of Pretoria, as a research-intensive university, places great emphasis on the impact of research outputs, the publication of research articles in accredited journals, citations and the international recognition of research findings. In South Africa, higher education institutions receive subsidy points from the Department of Higher Education and Training on the basis of their research outputs. This includes publications in journals, books and conference proceedings.

However, to ensure the protection of intellectual property, it is important for scientists to at least obtain a provisional patent before publishing their research. "If one is developing a process or product that will save the world, it is important to take the long-term approach, and appreciate the advantage of sacrificing short-term benefits for long-term gains," she concludes. 📍





# Developing graduates who will change the world

Janine Smit

When questioned about his vision of a typical graduate from the Faculty of Engineering, the Built Environment and Information Technology at the University of Pretoria, Prof Roelf Sandenbergh, Dean of the Faculty, explains that the Faculty strives to develop people with the ability to change the world.

This is very much in line with the University's academic plan and its strategic plan for 2025, which makes provision for teaching excellence as a foundation for research excellence. In this regard, many of the University's strategic decisions and choices regarding academic planning are framed by the consideration of the University's responsibility to develop the high-level skills that are needed for the economy and South African society, as well as a focus on the University's existing areas of strength and international recognition that will complement its research focus.

According to Prof Sandenbergh, it is the objective of staff members in each of the Faculty's 14 departments – spread across four schools – to optimally develop the talent of their students. "It is our foremost task as educators to empower our students to shape the future. In addition to developing the best engineers, architects and computer scientists in the world, we need to ensure that our students are resilient – multifaceted and able to operate 'out there', in industry and society," he said.

"One of the most effective ways of doing this," said Prof Sandenbergh, "is to ensure that the best systems are in place to provide students with the necessary support." This does not only apply to the Faculty's academic structures, but to research and community service as well. "Our research must be focused on the future, and it must be sustainable, with the ultimate goal of changing the world."

"Our teaching concentrates on providing a depth of knowledge that is well rounded and all-encompassing. By integrating new perspectives into existing knowledge, our students are able to create new knowledge, which will enable them to handle the complexities that they will encounter in the workplace as graduates," he remarked. "The challenge is to inspire our students to be exceptional."

In a nutshell, it is the strategy of the Faculty to provide education of the highest quality and to develop the top researchers in their fields in order to deliver graduates who are recognised as the most knowledgeable and competent in the industry.

## Focused on the developmental needs of the country

The Faculty delivers a large percentage of the country's high-level professionals to ensure a sustainable future. It is a leading source of locally relevant and internationally competitive programmes in engineering, the built environment and information technology at both undergraduate and postgraduate level. It offers a wide spectrum of degree programmes and attracts students and staff of a high quality. The Faculty also offers extended programmes to facilitate inclusiveness. It is well resourced in terms of teaching and research facilities, and houses several research centres and institutes. The Faculty maintains close links with industry, which supports both the teaching and research programmes in its four schools. Its multidisciplinary nature facilitates interaction across disciplines in both teaching and research activities to address national and global challenges. Many of the programmes are nationally and internationally accredited and prepare students for leadership positions in the various professions represented in this Faculty.

The School of Engineering is the largest of its kind in the country in terms of student numbers, graduates and research contributions, and offers programmes and research activities in all the major engineering disciplines: chemical, civil, electrical, electronic and computer, industrial and systems, materials science and metallurgical, mechanical and aeronautical, and mining engineering. Based on citations, it is rated by the Institute for Scientific Information (ISI) as the best school





→ *The Faculty teaches its students to deal with the complexities that they will encounter in the workplace.*

of engineering in South Africa. It is also one of only four engineering schools in the country listed in the top 1% of engineering schools in the world. Its research is focused on the developmental needs of the country, and it produces nearly a third of the country's engineering track graduates.

The School for the Built Environment offers programmes in architecture, landscape architecture, interior architecture, town and regional planning, quantity surveying, construction management and real estate, which are accredited both locally and internationally by professional institutions. These programmes cover the entire spectrum of disciplines associated with the built environment, and all have close ties and alignment with the construction industry. Construction projects require the expertise of specialists, and successful physical execution depends on the expertise of those with the appropriate skills and a thorough understanding of the administrative and legal aspects of building developments. Each department in the School is recognised

as one of the leading academic departments of its kind in the country.

The School of Information Technology is unique and the first of its kind in South Africa, where students have the advantage of an integrated approach to information technology (IT), with study programmes and modern laboratories in computer science, informatics and information science.

The Graduate School of Technology Management (GSTM) is the largest school of its kind on the continent and offers formal postgraduate programmes and research activities in the management of technology, engineering management and project management. A strong focus on research ensures relevance to the market in terms of increasing competitiveness, optimising product life cycles, technology transfer and positioning technological abilities within the international context. The school maintains strong links with industry and government and has developed a good local and international research network. A portfolio of continuous

education offerings also ensures that the latest knowledge reaches the broader market.

### **Making an impact through research**

Research is seen as an essential and integral part of the Faculty's activities and is founded on enquiry-based teaching, which leads to research as early as at undergraduate level in the form of group and individual project-based research activities. These develop into more formal courses in research methodology, and basic, as well as applied research at postgraduate level.

The Faculty's researchers concentrate on problems of national and/or regional concern in order to maximise local impact, while enhancing the University's academic stature and visibility in a highly competitive global environment. Its research agenda is aligned with the needs of industry, government and professions with the aim of also making significant contributions internationally.



There is significant support from industry for the Faculty's research activities in the form of sponsorships for research chairs, bursaries for students and funding for expanded facilities like laboratories and research centres.

Research in the Faculty is supported by excellent laboratory and support services, which are further augmented by state-of-the-art teaching and research facilities. Major recent additions to the Faculty's research infrastructure include a geotechnical centrifuge to facilitate research in geotechnical engineering and a wafer prober to make direct evaluation of microchips possible in support of the Faculty's millimetre-Wave spectrum research, with potential application in the Square Kilometre Array (SKA) project.



Departments are encouraged to develop and consolidate research activities and promote the alignment of student research with those of their supervisors, especially in the professional graduate programmes, to increase the quality and impact of research outputs. The quest remains to improve both the participation of staff in research activities and the number and quality of research outputs.

The Faculty's research output is continuing to increase. The number of researchers rated by the National Research Foundation (NRF) is also on the rise.

**NRF ratings for the Faculty in 2011/12**

Rating	Number
A2	1
B1/B2	3
B3	7
C1	12
C2	12
C3	14
Y1	2
Y2	2
<b>Total</b>	<b>53</b>



## Support from industry

The Faculty has a number of industry-sponsored research entities, which make significant contributions to building a research ethos. These include the following:

- The South African Research Chairs Initiative (SARChI) Chair in Fluoro-material Science and Process Integration
- The SARChI Chair in Carbon Technology and Materials
- The SARChI Chair in Artificial Intelligence
- The South African National Energy Development Institute (SANEDI) National Hub for Energy Efficiency and Demand-side Management (EEDSM)
- The Industrial Metals and Minerals Research Institute (IMMRI)
- The South African Institute of Welding (SAIW) Centre for Welding Engineering

The following new industry-sponsored chairs were also established during 2013:

- The Sasol Chair in Health Safety and the Environment
- The Bateman Chair in Minerals Processing
- The Exxaro Chair in Energy Efficiency
- The Chair in Electronic Defence and Radar
- The CBI Electric Low-voltage Chair in Power Electronics

Research in and the development of mobile applications have been strengthened with the establishment of the BlackBerry Apps Laboratory. This forms part of the e-Skills Institute initiative. Other highlights in support of research in the Faculty include the establishment of the African Centre of Excellence for Information Ethics, with the support of the Department of Communications, to further education and research in this field on the African continent. The Eskom Specialist Centre in Plant Asset Management was established in the Department of Mechanical and Aeronautical Engineering as part of the Eskom Power Plant Engineering Institute.

The Faculty also hosts the interfaculty Institutional Research Theme (IRT) on Energy, in which an interdisciplinary approach to energy research is promoted and supported. A research focus area on regenerative and sustainable construction has also been established in the School for the Built Environment.

The further development, application and commercialisation of research are priorities for the Faculty. Excellent progress has been made with the further development of silicon-based light-emitting devices, initiated in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM), and further developed through a joint initiative with the South African Intellectual Property (SAIP) Fund as the INSiAVA initiative.

It has the potential to significantly enhance the performance of electronic devices by using silicon-based light sources for data communication and visual displays.

## Increasing the number of engineering graduates

The Faculty is able to contribute to meeting the national need for more engineers. This has been made possible by the support and investment of government and the University in the future growth of the Faculty. The recently completed teaching and research facilities in the Engineering 3 Building make it possible for the University to accommodate the envisaged growth of its School of Engineering over the next few years, and also contribute to the delivery of engineers to the market who are innovative thinkers.

The School of Engineering subscribes to a new approach to engineering education that aims to teach students the technical fundamentals of their disciplines, as well as non-technical skills. These skills include working in teams, communicating through written or oral presentations, considering their work in the context of society, as well as professional ethics. Instead of emphasising analysis and problem-solving in a theoretical realm, students participate in team-based projects where they go through the cycle of

conceiving, designing, implementing and operating (CDIO).

The growth in student numbers, especially in students from previously disadvantaged groups, is also in line with the University's growth strategy over the next 15 years, which entails planned growth that is realistic and "smart" in terms of the dual focus on areas that will enhance the output of research, while maintaining existing high-quality professional programmes. The focus of the Faculty is to concentrate on increasing the number of graduates in engineering and postgraduate programmes in order to provide the country with these much-needed high-level skills. The University's strategy in this regard is to shift the future shape of the institution in favour of science, engineering and technology, and high-priority disciplines at undergraduate level. This will facilitate the creation of a strong pipeline for postgraduate selection.

## Maintaining a reputation of excellence

Due to its reputation of providing excellent teaching and research, and producing graduates of such a high calibre, the University has been able to increase the support it receives from industry partners in the form of members of advisory boards, funding for research chairs, centres and laboratories, bursaries for students and the placement of graduates.

The Faculty's researchers make a unique contribution to their individual professions, which not only address current challenges, but focus on the future sustainability of both man and machine.

By optimising the use of its resources, the Faculty is confident that it will continue to recruit the best staff and students, and maintain its position of excellence. In this way, it can contribute to the recognition of the University of Pretoria as Africa's leading research-intensive university, recognised internationally for its quality, relevance and impact, as well as for developing people, creating knowledge and making a difference locally and globally. 🌐

# Building an ethical information society in Africa

Anneline du Preez

In May 2012, the African Centre of Excellence for Information Ethics (ACEIE) was established at the University of Pretoria. This collaborative initiative between the South African Department of Communications, the United Nations Education, Scientific and Cultural Organisation (UNESCO) and various universities across Africa is housed by the Department of Information Science in the School of Information Technology and is led by Mr Coetzee Bester.

Information ethics is a descriptive and emancipatory discipline that studies changes in the relationship between people and the world due to information and communication technologies. In Africa, the field provides a unique platform for building an information and knowledge society driven by critical reflection on ethos and values within the African context. It addresses opportunities and challenges unique to the development of African societies.

The establishment of this Centre was necessitated by various converging factors. The rollout of broadband in South Africa and Africa made information more readily available. The recent construction of various submarine cables, including SEACOM, directly contributed to the expansion of broadband capacity on the continent. The growth in communication and information management capacity contributed significantly to the development and management of e-skills, e-governance and information ethics, and the challenges related to these. It was found that students were not properly introduced to information ethics and did not fully understand the concept and purpose as well as the practice of this discipline.

One of the main objectives of ACEIE is to develop a curriculum for teaching information ethics in Africa.

During the first three years of its existence, the Centre will develop a curriculum structure and implement the content at universities in Africa. A group of more than 30 international academics are working together on this pilot project.

According to a memorandum of agreement between the University of Pretoria and the national Department of Communications (who made available R7.4 million over three years), the Centre will also perform the following functions:

- Support the establishment of other ethics centres in Africa through the African Ethics Research Centre Network.
- Convene, coordinate and administer an ethics conference and follow up on the implementation of conference resolutions.
- Facilitate the hosting of Ethics Awards Ceremonies in collaboration with other partners.
- Focus on research and training in information ethics.

Other functions of the Centre include the following:

- Develop short courses for governmental officials in the nine provinces of South Africa.
- Encourage Information Ethics workshops where academics and practitioners can convene

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The national Department of Communications awarded R7.4 million to the Centre to support, inter alia, the establishment of other ethics centres in Africa, to organise conferences, and to support research and training in information ethics.

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→ The African Centre of Excellence for Information Ethics, housed in the Department of Information Science, was established at the University of Pretoria in collaboration with the Department of Communications, UNESCO and various universities across Africa.

in order to exchange knowledge and enhance the practical dynamics of Information Ethics.

- Function as a centre where researchers can come together to endorse key proposals concerning information ethics and its application in African societies, governments and institutions.
- Maintain its collaborative relationships with UNESCO; the E-skills Hub in the Department of Informatics; and the Department of Information Science.

Throughout 2012, various academics were approached to do research on the impact or importance of information ethics in their field of expertise. These academics will have the opportunity to publish their articles in the 2013 *Innovation Journal*, of which a special edition is focused on information ethics. ➔

## Establishing a centre of excellence for information ethics

**In 2007, a group of international academics in the fields of information technology, philosophy and politics formed an academic network to conduct research on information ethics.**

This network is now known as the African Network on Information Ethics (ANIE). It identified a gap in the academic representation of the African continent on the global stage, specifically pertaining to information ethics. It therefore organised events to stimulate research on information ethics in Africa.

The result of these activities and international collaboration led to a partnership with the national Department of Communication, the United Nations Education, Scientific and Culture Organisation (UNESCO) and various universities across Africa.

The collaboration eventually contributed to the establishment of the African Centre of Excellence for Information Ethics (ACEIE) in the Department of Information Science at the University of Pretoria in 2012.

Its purpose is to formally reflect on the activities and history of information ethics in Africa. This reflection should contribute to research on the topic and allow networking with other academics in the field.



# Mining Industry Study Centre provides students with customised facilities

Janine Smit

The University's School of Engineering has embarked on a growth strategy over the last decade to address the shortage of engineering skills in South Africa. This has resulted in a significant increase in the number of engineering students who need to be accommodated.

The development of additional teaching and research facilities through the financial support of both the University of Pretoria and the Department of Higher Education and Training resulted in the construction of the new Engineering 3 Building and parkade on the Hatfield Campus. This development provided additional lecture halls, laboratories, a new access road and entrance, and a parkade for 1 000 cars.

A further development, which forms a vital part of the School's strategy to increase the success of engineering students, is the construction of a study centre, that was officially opened on 31 October 2013. This study centre will provide facilities to support learning, especially groupwork.

Such a facility became a necessity due to the complexity of the students' lecture timetable and their changing demographic profile. There are many students who live far from the campus and travel great distances on a daily basis, and who do not have adequate facilities for study or groupwork at their homes or on campus.

The development of the study centre, situated immediately west of the Engineering 1 Building, was financially supported by Glencore-

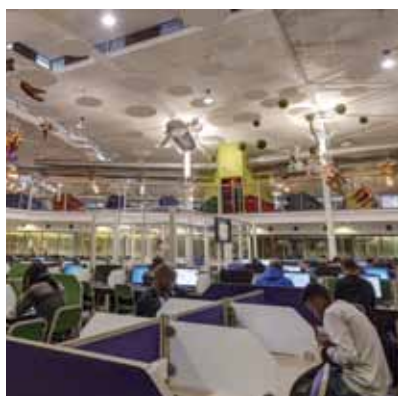
Xstrata and the Anglo American Chairman's Fund. Additional sponsorships were received from CBI Electric (electrical components) and PPC Cement (cement). The contract for the project was allocated to Robenco Construction.

It accommodates 758 students in the following configurations on two levels: On Level 3, there are 252 individual workstations accessible to students on a first-come basis.

There are also 30 conceive, design, implement and operate (CDIO)-type venues where groups of seven students can work in a private cubicle equipped with a table and a flat-screen monitor. These venues are reserved through a computerised booking system. On Level 4, there are 296 cubicle seats without workstations.

The study centre is situated at the University's previous entrance off University Road at the Engineering 2 Building, which was closed when the new entrance to the parkade was constructed.

A new "drop-off-and-go facility" has been constructed at the old entrance, which is convenient for dropping off or picking up students in a safe environment adjacent to the study centre. ➔



# Architectural design of the new Mining Industry Study Centre receives commendation

Renate Steenberg

The University of Pretoria has received a commendation in the Architectural Category of the Steel Awards 2013 of the Southern African Institute of Steel Construction for the architectural design of its new Mining Industry Study Centre.

The centre was designed by ARC Architectural Consultants, who were also responsible for the design of the Engineering 3 Building and Parkade. The design utilised an additional 3 000 m<sup>2</sup> of previously unused space at street level beneath the Engineering 1 Building. This newly developed area consists mainly of a large arched roof and mezzanine floor and can accommodate approximately 800 students.

Steel was selected as the preferred structural medium to reduce the additional load that would be added to the existing building in order to undertake the revamp. The team used the principle of compression to limit the amount of additional weight, which ensured that a large portion of the roof's own weight would be transferred to the outer, and independent, pile foundations. The steel roof has spans up to 40 metres and covers an area of 1 700 m<sup>2</sup>. Steel was also used as the primary structural element to support the mezzanine floors.

Steel can be rolled into large sections, which is why this material was used to create a visually aesthetic dome-type roof. This enhanced the overall appearance of the building, since most of the structural steelwork is visible to the public. The use of steel contributed to the aesthetic appearance and shape of the building and helped to achieve the desired appeal of the final building façade.

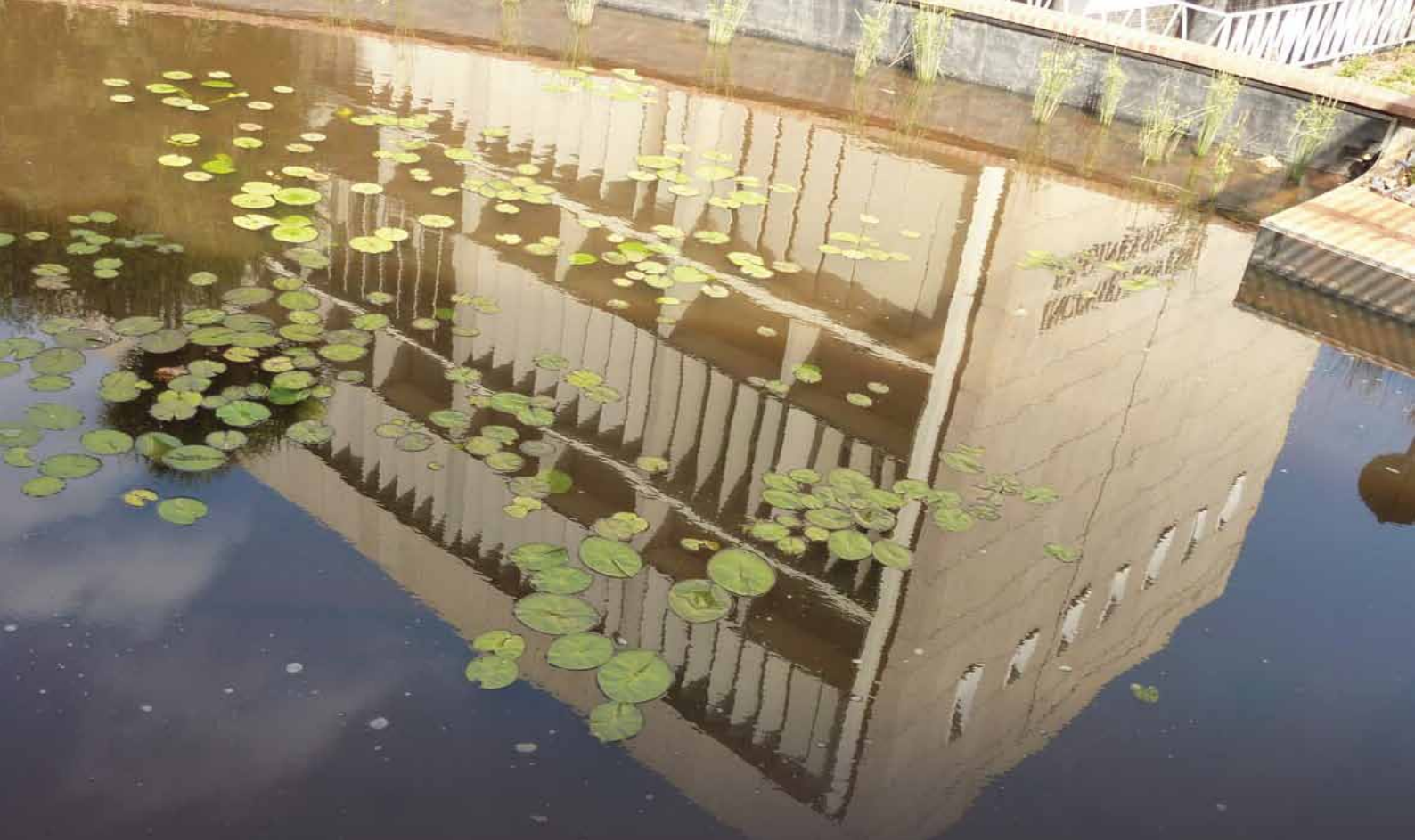
The benefit of steel is that sections can be fabricated off-site. As a result, much of the construction activity on site could be drastically reduced. This played a crucial role in the upgrading of the building. The risk of harming the natural environment and existing plants and trees was minimised due to the less intrusive nature of working with a steel construction.

The steel construction was completed on time and within budget, thus concluding the revamp on a positive note. The University is now equipped with a building that is not only complementary to the landscape, but also provides engineering students with a space in which they can develop their minds and creativity.

\*Some information has been extracted from an article that appeared in *Steel Construction* 37(5), 2013. [+](#)







# Landscaping project produces a sustainable rain garden

Renate Steenberg

The construction of the new Mining Industry Study Centre, immediately west of the Engineering 1 Building, revealed the opportunity for a unique landscaping project, which is one of only a few in the world. This centre is utilised by students who live far from the campus and do not have adequate facilities for study purposes or for groupwork.

With the planning of the study centre facilities for study purposes or for groupwork, the professional team decided to integrate a rain garden into the design of the new building that would use stormwater to create a habitat for a number of fauna and flora species.

## Design considerations

The site consisted of a severely degraded space and roads older than 60 years with impervious surfaces. These surfaces resulted in very poor soil conditions. The area is used extensively by blind students and with the new entrances from the drop-off-and-go facility to the campus and the study centre itself, pedestrian traffic in the area would also increase.

The new building has a large roof of 1700 m<sup>2</sup>, which placed considerable pressure on the existing overloaded stormwater infrastructure. The space also needed to address the requirements of the increasing

number of students at the University. The engineering lecture facilities under the study centre were not waterproofed and a cost-effective solution was required to resolve this. From a design perspective, the symmetry of the buildings was to be retained.

## Opportunities

The site had a number of existing trees that are protected by South African legislation, which were all incorporated into the design. The landform and geology of the site allows for the collection, storage, cleaning and re-use of stormwater. As a result, habitats have been created and the microclimate manipulated to establish various species of fauna and flora. The landscape design showcases the progression of the various professions involved and is an example of a functional, cultural and aesthetic landscape, as well as a living laboratory for research purposes.



## Constraints

The natural water cycle was short-circuited because the evaporation, transpiration and infiltration of water were limited due to impermeable surfaces. Natural infiltration was not possible due to the lack of waterproofing of the lecture halls. Level changes and narrow walkways, which presented challenges for disabled users, also had to be considered. The implementation of symmetry, while retaining existing elements and the character of the building, was an important consideration for the final design. The poor soil conditions due to the impervious surfaces of the roads and the acidification of the soil due to the pine trees that had been planted over the years also posed a challenge to the final design of the project.

## Theory

The landscape design followed the principles of the Sustainable Sites Initiative (SITES), especially with regard to stormwater management and recycling. SITES is an interdisciplinary effort in America that aims to create voluntary national guidelines and performance benchmarks for sustainable land design, construction and maintenance practices.

The design team comprised Neal Dunstan (the University's resident landscape architect) and Jason Sampson (Curator of the Manie van der Schijff Botanical Garden on the Hatfield Campus). They studied the theories of Prof Nigel Dunnet, who specialises

in planting design and vegetation technology at the University of Sheffield in the United Kingdom, as well as those of Andy Clayden, a senior lecturer in landscape architecture at the same university. The design revolves around the concept of a rain garden, which can be defined as an engineered combination of specially selected plants, soil and mulch, designed to collect, retain and clean rainwater that runs off impenetrable surfaces, such as parking lots and rooftops. The benefits of rain gardens include habitat creation, reduced energy usage, pollution control, microclimate manipulation, establishing a sense of place and distinctiveness, developing visually stimulating and dynamically built surroundings, and establishing environmental stewardship.

## Project description

To resolve the issues of the waterproofing and the inadequate

stormwater infrastructure, estimated to cost R8 million if resolved by conventional means, an ultra-violet stable ethylene propylene diene monomer (EPDM) rubber liner, manufactured by Firestone Building Products, was selected to contain the water and prevent water seepage to the lecture halls. EPDM is a synthetic elastomer produced as a co-polymer of ethylene and propylene, with small amounts of a pendant diene (double bonds) in order to cross-link the material. The liner, installed by Belgro Landscaping, was a technical challenge due to the variety of geometric and organic shapes to which it needed to be applied. As a result, the technical director of Firestone EPDM visited the site to render advice and draw up application specifications. This resulted in a variety of changes to the design, the majority of which led to a more viable and cost-effective solution.

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A total of 145 aquatic and terrestrial plant species were used in the spaces in and around the system. The foliage is meant to complement and facilitate the bioremediation potential of the system and keep the water clean, as well as soften the hard lines of the building and create a habitat for wildlife.

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This is the University's first project that truly merges landscape and building, and is one of a few buildings in the world where a rain garden system has been integrated in a building.

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A layer of clay-rich soil-growing medium, which was sourced from the University's Health Sciences Campus, was put on top of the liner. All compost supplied for the project was obtained from the University's waste recycling and composting project. The cost for this phase of the project amounted to around R1,6 million.

### The stormwater system

The system revolves around the collection of stormwater from the roof of the Mining Industry Study Centre and surrounding hard surfaces into vegetated swales. From there, the cleaned water flows into a permanent pond and from there into "tidal ponds". The latter are designed to flood in the rainy season and to be partially dry during the dry season. All excess water from these ponds flows into a 130 m<sup>3</sup> tank positioned under the staircase and ramps on the western side of the study centre.

This water is used for the irrigation of the University's Manie van der Schijff Botanical Garden. Water from the tank is also circulated through the entire system so that the water is never static. The total capacity of the pond system (excluding the tank) is approximately 550 m<sup>3</sup>.

A total of 145 aquatic and terrestrial plant species were used in the spaces in and around the system. The foliage is meant to complement and facilitate the bioremediation potential of the system and keep the water clean, as well as soften the hard lines of the building and create a habitat for wildlife.

The surrounding areas will also house the University's collection of tropical African cycad species (*Encephalartos*). A suitable microclimate has been created to support the plants. At last count, 56 specimens of 22 species have been planted.

The soft landscaping installation was done by Origin Landscapes. Soft landscaping is the process of designing the elements of a landscape that do not involve construction. The range of soft landscape materials includes each layer of the ecological sequence: aquatic plants, semi-aquatic plants, field layer plants (including grasses and herbaceous plants), shrubs and trees.

Existing building materials were re-used as permeable paving, cladding for walls in the ponds, and energy breakers for the stormwater entering the system. New paving blocks from Bosun were sourced from waste material from platinum mining operations. These paving blocks were selected to assist visually impaired users by means of textural changes in the paving, which produce sounds as they tap their canes. All of the rock used in the project was sourced from project excavations on site and from a construction project in Groenkloof.

The customised grooved clay bricks that had previously clad the walls were also retained and used for the funneling of stormwater into the landscape, and to retain the site's heritage value. In order to contain and also prevent access to the deepest water bodies, seating walls

were constructed in organic forms to assist the visually impaired with unobstructed movement. Subtle, low-level LED lighting was added to these walls, also to assist with unobstructed movement.

The lighting in the landscape was reduced to a minimum so that it does not interfere with the natural day-night cycles of the plants, frogs and Tilapia fish, which were introduced into the system for ecological and research purposes by the Curator of the Manie van der Schijff Botanical Garden and the Department of Zoology and Entomology in the Faculty of Natural and Agricultural Sciences.

### Significance

This is the University's first project that truly merges landscape and building, and is one of the very few buildings in the world where a rain garden system has been integrated with a building. The project team has received invitations to present papers from the Ruth Bancroft Botanical Garden and the International Sustainable Campus Network (ISCN) in the USA. The project will also be published in at least three local journals within the next few months, and will be entered into the ISCN and Institute for Landscape Architecture in South Africa (ILASA) awards of excellence.

Landscaping is no longer beautification, but an essential functional and value-adding instrument in solving the many challenges that not only the University, but the urban environments face, working towards the principles of a "resilient city". 🌱







## Africa's first virtual reality mine design centre

Janine Smit

With the establishment of the Virtual Reality (VR) Mine Design Centre at the University of Pretoria's Department of Mining Engineering, the mining industry in South Africa – particularly the training of new mining engineers – will enter a new era.

This is the first centre of its kind in Africa to be housed at a university (and only the second in the southern hemisphere) that provides safe training to students and mine staff on mine safety and other related issues in a simulated mining environment.

This centre was made possible by an R18.8 million sponsorship by Kumba Iron Ore over a period of three years. The company's investment in this groundbreaking form of education, research and development includes the development of open-pit mining-related software modules.

Kumba's VR Mine Design Centre will be able to realistically simulate a range of mining functions, from accident reconstruction and risk analysis, to responding to potential hazards and testing evacuation procedures – all in a low-risk, high-impact learning

environment. It consists of floor-to-ceiling screens, and the VR Simulator will cast 360° 3D images against the dark surrounding panels with cinematic clarity and highly realistic sound effects.

"The mandate from Kumba," says Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering at the University of Pretoria, "was that the new facility had to be highly interactive." Its investment in cutting-edge 3D technology will allow students and staff in the mining industry to move around in a realistic virtual mining world, with an emphasis on surface mining as well.

The applications for a centre like this will transform the way in which mining engineers are currently educated and trained.

According to Prof Webber-Youngman, virtual reality centres in other parts of the world have been highly effective in improving mining productivity and mine design, and most importantly, protecting lives through improved health and safety awareness. “This new facility will take our students beyond the boundaries of traditional education and into experiential learning in a safe and forgiving virtual world,” he says. It is also in line with the University’s current strategy to enhance and increase its facilities to accommodate more engineering students.

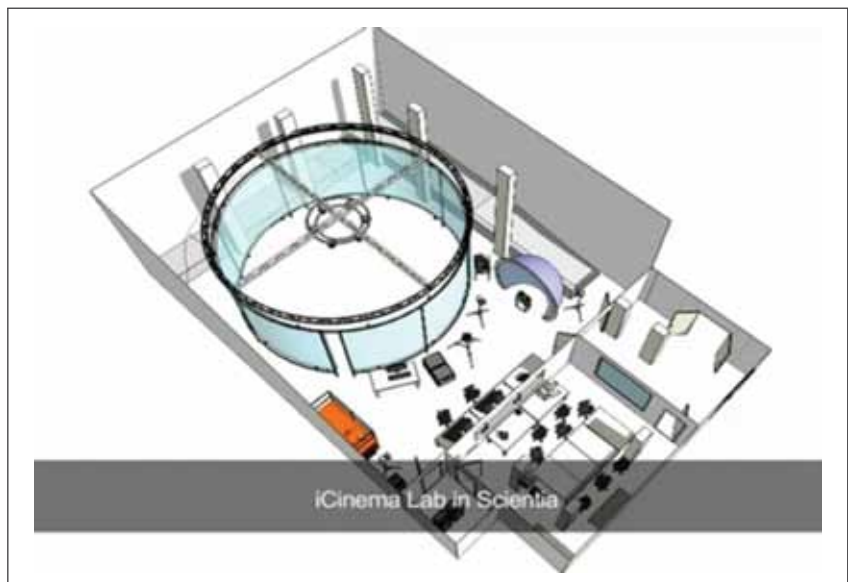
“The Kumba VR Mine Design Centre will simulate high-risk scenarios in a safe and controlled environment where the consequences of any unsafe acts can be powerfully demonstrated without causing any actual loss of life and damage to property,” says Prof Webber-Youngman.

Undergraduate mining students will be able to integrate different conceptual and software modelling techniques, which incorporate geological models, mineral extraction methods, mine planning and design, and mining systems in a VR environment.

Further benefits include the ability to virtually design a complex mining operation from the ground up. The customised design packages will allow trainees to build their understanding of complex mining operations throughout the mine’s life cycle, and show the visual and environmental consequences of their technical decisions.

“By improving the ability of mining engineers to take into account the long-term environmental consequences of their financial and technical decisions in a virtual environment, there will be significant economic, environmental and safety benefits to the industry and surrounding communities in the real world,” says Prof Webber-Youngman.

Virtual reality simulation products have been on the market for the past few years, but have recently



→ *iCinema Lab in Scientia, photo courtesy of Prof Bruce Hebblewhite, Head of the Department of Mining Engineering, University of New South Wales, Sydney, Australia.*



→ *The Kumba Virtual Reality Mine Design Centre will be able to realistically simulate a range of mining functions.*

undergone major improvements in quality and speed. By investing in the VR Mine Design Centre, Kumba is living out its belief that all injuries are preventable, and its commitment to making safety a way of life – both inside and outside the workplace.

Although there has been a downward trend in fatalities in South African mines in the last few years, a lot can still be done to achieve the ‘zero-harm’ objective that is embraced by mining companies. In addition to providing proactive safety

training, VR technology allows for the reconstruction of actual mining incidents for forensic investigation purposes to try and prevent the recurrence of such incidents in the future.

Such a centre therefore has great potential to contribute to achieving this objective, which will have a great impact not only on the activities of mining companies such as Kumba Iron Ore, but to the mining industry as a whole, especially in terms of mine planning and design. ●

# Research contributes to future energy security

Janine Smit

The University of Pretoria's focus on research into energy is holistically designed to be fully multidisciplinary and cuts across a number of departments and faculties at the University. The Institutional Research Theme on Energy (IRT on Energy) forms part of a process initiated at the University in 2010 to identify unique research strengths and support the development of interdisciplinary research groups clustered around these strengths.

By focusing on unique local opportunities and collaborative research, the University will be able to increase its international profile. The primary objective of these research focus areas is on strengthening activities in areas of immediate national need and ensuring that those fields that ultimately affect human welfare are developed. In this way, the University will be able to make a significant contribution to overcoming South Africa's challenges and developing human capital in our country.

The IRT on Energy focuses its research efforts on a number of carefully selected subthemes relevant to South Africa's future energy security, with a specific focus on electricity supply. It supports the relevant government policies and strategies pertaining to the wider energy theme in South Africa in order to ensure that the country is successful in bringing the goals of the Integrated Resource Plan of 2010 to fruition.

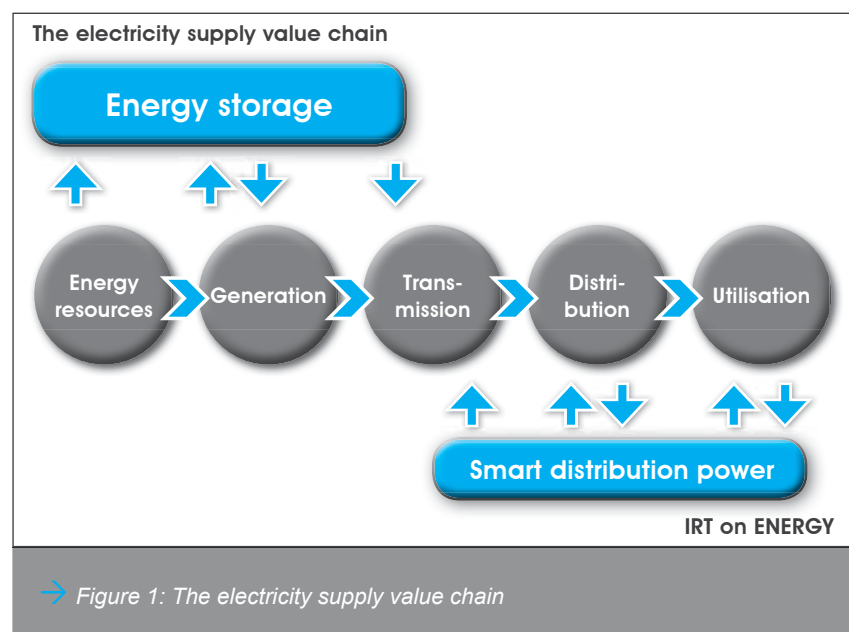
The selection of research subthemes is based on the energy value chain, which includes the influences of

climate awareness and renewable energy sources.

## Energy research focus areas

The IRT on Energy addresses the following subthemes:

- **Energy production:** There is a specific emphasis on clean coal, as well as nuclear and renewable energy technologies, such as solar and wind.
- **Energy distribution:** Two notable aspects that are addressed are smart grids and energy storage. Both these areas are growing in importance, as the contribution of renewables with their inherent random availability impact on the stability of the national grid.
- **Energy optimisation:** This is an area in which the University is particularly well placed, with its hosting of the South African National Energy Development Institute's (SANEDI) National Hub for Energy Efficiency and Demand-side Management. Specific areas being researched include thermal and process optimisation, energy efficiency,



→ Figure 1: The electricity supply value chain



demand-side management and plant lifetime extension.

- **Advanced materials:** In many instances, new energy technologies call for unique material attributes, notably in high-temperature applications. The University is particularly well positioned for such research thanks to direct spin-offs from research the University conducted for the former pebble-bed modular reactor project. Research projects include those involving silicon carbide (SiC), ceramics and high-temperature materials.
- **Policy, economics and society:** With the ever-increasing complexity of energy technologies, it has become mandatory to ensure that chosen energy sources not only fulfil their required energy production goals, but do so in a sustainable and economic manner. Research projects include those related to techno-economic modelling, project management, systems engineering and societal impacts.
- **Environment:** No argument for sustainable energy can be made without a serious focus on the environmental impacts of the chosen energy sources. The University is quite active in this field and has made some unique contributions in the minimisation and management of nuclear waste and reducing the carbon footprint.

### Departmental collaboration

A number of departments from the faculties of Engineering, the Built Environment and Information Technology, Natural and Agricultural Sciences, and Economic and Management Sciences make valuable research contributions towards the goals of the IRT on Energy.

These include Mechanical and Aeronautical Engineering, Electrical, Electronic and Computer Engineering, Materials Science and Metallurgical Engineering, Chemical Engineering, Physics, Chemistry and Economics, as well as the Graduate School for Technology Management and the Institute for Technological Innovation.

The IRT on Energy is a three-year initiative, which was launched in 2012 with funding from the University. A total of 10 new projects were funded in the first year, with nine of these projects continuing in the second year. In addition, four new projects were initiated. Current research projects include the following:

- Heat exchanger optimisation
- Energy efficiency
- Chemical process integration
- Smart grid optimisation
- Energy system assessment and modelling
- Silicon carbide for nuclear applications
- Glassy carbon physics
- Energy optimisation in renewable energy systems
- Electrical double-layer vanadium batteries
- Solar energy studies on carbon-based composites for energy storage
- Renewable and electrical lighting systems
- Nuclear waste minimisation
- Artificial photosynthesis

### Concentrated solar power and the development of solar fuel

Two important initiatives related to solar energy form part of the IRT on Energy.

The first initiative is the Clean Energy Research Centre and a project on concentrated solar power, which developed from research initiated in the Department of Mechanical and

Aeronautical Engineering. A total of 15 students (including seven PhD candidates) are currently involved in research pertaining to concentrated solar power. Collaboration in this regard is taking place with the Solar Thermal Energy Research Group (STERG) at Stellenbosch University and the Livermore Software Technology Corporation in the USA.

The second initiative, in collaboration with Prof Egmont Rohwer in the Department of Chemistry, involves the development of solar fuel from CO<sub>2</sub>. This is known as CO<sub>2</sub> cracking. In an attempt to reduce the human CO<sub>2</sub> footprint, the research team proposes using solar energy to convert atmospheric or technical CO<sub>2</sub> and water into methanol, a liquid fuel that is easy to store and transport using readily existing technology.

Other activities in which the IRT on Energy has been involved include the research and postgraduate programmes of the Eskom Power Plant Engineering Institute (EPPEI) Specialist Centre in Plant Asset Management in the Department of Mechanical and Aeronautical Engineering, as well as participation in the 5th International Conference on Applied Energy that was presented on the University's Hatfield Campus in collaboration with the SANEDI National Hub for Energy Efficiency and Demand-side Management from 1 to 4 July 2013.

According to Prof Tinus Pretorius, leader of the IRT on Energy, focus areas for future research will concentrate on the national and global energy crisis, and will include aspects such as renewable energy (storage and grid integration), nuclear materials, energy efficiency and energy modelling. ➔



# M&V for energy-efficiency projects

Anneline du Preez

South Africa's energy crisis has brought about several research initiatives in the quest for an effective long-term solution to the problem. At the University of Pretoria, the South African National Energy Development Institute (SANEDI) National Hub for Energy Efficiency and Demand-side Management (EEDSM) focuses on producing high-quality master's and doctoral graduates to meet the needs of an expanding and sustainable energy industry.

The SANEDI Energy Hub was established in 2008, and is a joint initiative between the University, and the national Department of Science and Technology and the former Department of Minerals and Energy. Prof Xiaohua Xia, an A-rated researcher in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria, is the Director of the Hub.

In recent years, Prof Xia's research group has made continuous contributions to the National EEDSM programme by conducting research activities on measurement and verification (M&V), energy system modelling, and management and optimisation. M&V is the process of using measurement to reliably determine actual savings created within an individual facility by an energy management programme. As the M&V activities offer continuous and informative feedback from EEDSM projects, the energy regulation utility is able to manage energy budgets and enhance the financing for energy efficiency projects.

An article entitled "Mathematical description for the measurement and verification of energy efficiency improvement", developed by Prof Xia and his colleague, Prof Jiangfeng Zhang, has recently been published in an international peer-reviewed energy journal. This was the world's first paper to present a mathematical description of the energy efficiency M&V problem and bring the basic M&V concepts, propositions, techniques and methodology into a scientific framework. In this paper, the mathematical definitions for baseline and baseline adjustment are given. In addition, the M&V plan development is formulated as an M&V modelling problem.

This approach provides a fruitful source of research problems by which an optimal M&V plan under various practical constraints can be determined.

As a case study of developing an optimal M&V plan, another article, entitled "Optimal sampling plan for clean development mechanism energy efficiency lighting projects", has also been published by Prof Xia, Prof Zhang and a PhD candidate, Mr Xianming Ye. This work proposes metering cost minimisation models for handling the M&V uncertainties with minimal metering costs under the case study of energy-efficient lighting projects.

By using the proposed optimisation model, the overall accuracy of the project can be maintained by sacrificing the confidence/precision criteria of the groups with high uncertainty, while improving the accuracy in the groups with low uncertainty. The metering costs are then minimised by optimising the sample size of each group. The proposed model largely reduces the metering costs of the sampling, while still maintaining the accuracy requirements of the project.

The research on this topic ultimately culminated in the publication of a book, *Energy efficiency measurement & verification practices*. This M&V case study book summarises the success stories and also lessons learnt in M&V best practice in South Africa during the past 10 years. The book is a collection of papers on various energy efficiency M&V projects. It was written by the most experienced M&V professionals in South Africa and was edited by Prof Xia and Prof Zhang. [🔗](#)

# Informatics: A unique discipline and a valued qualification

Prof Alta van der Merwe

## What is informatics exactly?

This is a question that is often asked by colleagues who are not familiar with information technology (IT)-related disciplines, who are curious about what exactly happens in the Department of Informatics (also referred to as information systems at other universities).

To answer this question, one should consider the different schools of thought addressing Informatics. The first school of thought holds a narrow view, where Informatics is referred to as the collection, classification, storage, retrieval and dissemination of recorded knowledge. However, informatics is also defined as the science of information, the practice of information processing, and the engineering of information systems. Informatics is also concerned with the structure, algorithms, behaviour and interactions of natural and artificial systems that store, process, access and communicate information. In addition, it studies human-computer interaction and how an interface can be built to maximise user efficiency. It also develops its own conceptual and theoretical foundations and utilises foundations developed in other fields.

Many practical problems in society that are complex to solve are referred to as “wicket problems”. The domain of informatics focuses on some of these problems, and uses computing to solve them. Examples include privacy and security in computing, health care, education and poverty alleviation, as well as sustainable development and other challenges in managing our environment. Due to the nature of solutions that include technology, applications in informatics are computer-based. Informatics also enhances existing solutions and systems with tools and techniques from fields such as communication, mathematics, multimedia and human-computer interaction design. Informatics differs from sister domains such as computer science and computer engineering, where solutions and studies in informatics include a strong focus on the human use of computing.

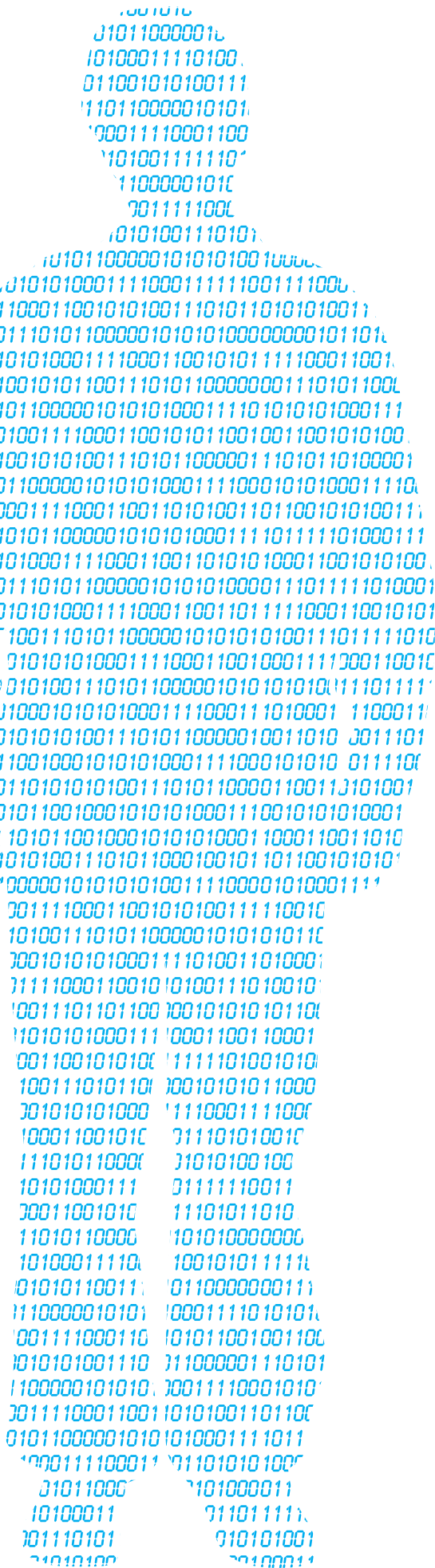
Informatics is a relatively new field. The first journal articles published

in the 1970s focused on information systems-related topics. By the turn of the century, there were still numerous discussions on the nature of informatics and the value of research in this domain. Davis (2000) argued that the field of information systems is now mature enough to become a reference discipline, embracing enough foundational theory for other disciplines. Davis highlighted the fact that all the top universities in the world already have an information systems or informatics department, and that there is at least one journal, the *MIS Quarterly*, that survived 25 years. The major conference in the field, the International Conference on Information Systems (ICIS), is 20 years old, while there is also an acknowledged international society, namely the Association for Information Systems.

The Informatics Department at the University of Pretoria educates informaticians to design, build, implement and secure information systems that meet human, organisational and societal needs. These students combine skills from the programme with their own unique personal and professional interests to foster innovation in information and technology in the private, public and non-profit sectors.

One emerging field in which informatics plays an important role is that of data science. Hal Varian (2013), chief economist of Google, states that “the ability to take data – to be able to understand it, process it, extract value from it, visualise it and communicate it – is going to be a hugely important skill in the next decades, not only at the professional level, but even at the educational level for elementary school kids, for high school kids and for college kids”.

His view supports the fact that informatics – as a discipline within the more traditional fields, such



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## Informatics studies human-computer interaction and how to build an interface to maximise user efficiency.

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as data science – adds facets such as stakeholder and systems requirements elicitation, storyboarding and communication, data analysis, processes and value chains, as well as systems architecture and integration.

At the University of Pretoria, the Department of Informatics is proud of the fact that its graduates are popular in industry and are offered competitive salaries after receiving their bachelors or honours degrees. Through the Department's quest for excellence, it has received Accreditation Board for Engineering and Technology (ABET) accreditation – the only Informatics/Information Systems department in Africa to have received this international accreditation. Many of the Department's alumni are in leadership positions in the foremost companies in the world. Positive feedback is regularly received on the value that these individuals gained from their education at the University of Pretoria.

The Department's research focus areas include information systems in education, IT management and information and communication technology (ICT) for development. Its strengths in these focus areas are the first-class solutions that the Department provides, specifically in the South African domain, where technology is considered from an innovative perspective. The Department believes in contributing and being involved on an international level. Staff members deliver presentations at conferences, organise conferences, and act as reviewers and panellists internationally. The Department is extremely proud that nearly 70% of its staff members have PhD degrees, which enables it to grow its postgraduate base and produce more peer-reviewed articles. 📌

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## Project Day

On 23 October 2013, the Department of Informatics hosted its annual Project Day for final-year BCom (Informatics) students. Twenty groups took part in the exhibition, which was held in the Rautenbach Hall on the Hatfield Campus. As in previous years, each group of four to five students designed a business information system for a real-life client. These projects ranged from the design of a trailer manufacturing management system, to point-of-sales systems, an online shuttle service management system, a construction plant management system, a panelbeater quoting and administration system, an online electronic device management system and a soil-mixing and sales management system.

# Alumnus showcases talent for innovative design

Renate Steenberg

The architectural firm of alumnus, Pieter Mathews, who graduated with a BArch degree from the University of Pretoria in 1991, was responsible for the expansion of the Elizabeth C Steijn Hall at the Afrikaanse Hoër Meisieskool Pretoria (AHMP).

With the expansion of the Elizabeth C Steijn Hall, Mathews & Associates Architects combined the legacy of the old with the progression of the new. The original hall was commissioned in the late 1950s by Ms Steijn herself, who was the school's principal from 1945 to 1962. The design of the hall purposely moved away from the designs of other buildings on the school's grounds and its modernistic influences were clearly visible.

Due to the growing number of learners, a larger school hall became necessary. The school decided to approach Mathews & Associates Architects to design a hall that would honour the heritage of the old hall and meet the school's current needs. Pieter Mathews was supported in this project by one of the office's architects assistants, Philip du Toit, also an alumnus of the University. The school is the oldest Afrikaans school in Pretoria, which meant that it was important that the design incorporated elements of the old building.

Art is very important to the school and there are a number of significant sculptures and other pieces of art on the school grounds. Existing pieces such as Elly Holm's "Bokkie" and new pieces such as Willem Boshoff's "Kompasroos" are part of the design. The amalgamation of old and new is particularly evident in the re-use of the original foyer's parquet floor, the original front door and the original, unplastered structure beams.

Mathews & Associates Architects is based in Pretoria and their projects have received numerous accolades.

Two of the most prominent were the Nellmapius Bridge and the Baobab Toll Plaza, both on the N1. The Nellmapius Bridge concept was exhibited at the 2012 Venice Biennale. The company also won a competition to design one of the types of the new Tshwane Rapid Transit (TRT) stations in the historically sensitive areas of Pretoria, called the Memory Box. Construction of this project is underway.

According to Mathews, his studio masters at the University of Pretoria, Prof Karel Bakker, Prof Roger Fisher and Prof Schalk le Roux, had a great influence on him, and encouraged him to work abroad.

He went to London where he was employed at Bruce Gillbreth Architects, an American practice, but later moved to Triad, a British practice, where he felt more comfortable with their world view, after which he travelled around the globe. In his final year of study, Mathews received the Gold Fields of South Africa Scholarship for Architecture, as well as the David Haddon Prize for office practice.



The amalgamation of old and new is particularly evident in the re-use of the original foyer's parquet floor, the original front door and the original, unplastered structure beams.



Photo: Carla Crafford



Photos courtesy of Mathews & Associates Architects, unless otherwise indicated.

→ Mathews & Associates was responsible for the expansion of the Elizabeth C Steijn Hall at the Afrikaanse Hoër Meisieskool Pretoria.

In November 1995, he joined forces with Jacques Gerber and formed Mathews & Gerber Architects. The business was pitched as a youthful practice, helping young couples to build on a budget and realise their dream homes. They found a gap in the market and received extensive media coverage. However, the recession forced Mathews to become involved in building for himself and for clients, which had the positive impact of gaining valuable direct experience of hands-on building.

He built six houses during this time, of which four were featured in the *Digest of SA Architecture*, *Architecture SA*, *De Kat* and *House & Leisure*. In October 2000, Mathews & Gerber went their separate ways and Mathews & Associates

Architects was founded with Thomas Gouws and Anton Smit as associates. When Thomas Gouws left in 2002, Liam Purnell was appointed senior associate.

Mathews received many enquiries about Mathews & Associates Architects' use of unconventional finishing and texturing methods from the public and decided to publish a book. He approached traditional local publishing channels, but they turned him down, saying that there was no market in South Africa for books of this nature.

Mathews established Visual Books and published *Architecture* with the backing of one of the leading local building materials producers, Lafarge Cement, in 2003. The book was very successful and Mathews received the Pretoria Institute for

Architecture (PIA) President's Award for *Architecture* in 2005. His second book, *Detail Housed*, followed in 2007. In 2009, Mathews was also the publishing manager for *Construction Primer* by Hans Wegelin, now prescribed at most tertiary institutions.

In 2012, the Department of Architecture acknowledged his contribution to the Department with the Zero Hour credential. Recently, the design of the Elizabeth C Steijn Hall received a Merit Award from the PIA. The firm also designed a new sport clubhouse for AHMP, which received an Honourable Mention from the PIA. He is a former board member of the South African Institute of Architects (SAIA) and is currently President of the PIA, as well as convenor for Cool Capital. ●

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Among the company's prominent projects are the Nellmapius Bridge on the N1 just outside Centurion and the design of one of the types of the new Tshwane Rapid Transit (TRT) stations.

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Photo courtesy of Aveng Grinaker-LTA.



# Leading architectural education

The **Department of Architecture**, at the **University of Pretoria**, presents undergraduate and postgraduate programmes in architecture, interior architecture and landscape architecture. The design professions of the built environment compliment one another by collaboratively designing and realising space. The Department offers students an interdisciplinary learning environment and a unique opportunity to engage with lecturers and peers from these related spatial design disciplines. All three disciplines require both creative and rational innovators to design worthwhile environments for users.

The Department endorses a formal training that is academically and theoretically grounded and technologically informed. At the core of the curriculum is a studio-based culture, through which skills in design, theory, communication and management are developed. Discipline specific studios and modules are introduced from the second year of study. Graduates from this Department are highly regarded, both locally and abroad. Through a commitment to innovation, the Department promotes a sustainable and prospering South African society.

## Interior Architecture



The Programme in Interior Architecture empowers students to design sustainable, meaningful and beautiful places within the context of architectural space. Graduates possess the theoretical and technical knowledge to engage critically with proposed or existing structures. Designers of interior environments shape the relationship between space, object and user. They follow a human-centred approach and perform spatial design and research services across various scales and typologies. Graduates work as designers in the built environment and related fields such as exhibition, lighting, product and stage design. The programme offers students the opportunity to become specialists in interior design within an interdisciplinary learning environment.

### Programme structure

The following are studio based programmes with professional outcomes (admission by selection):

<b>BSc(Int)</b>	3 years full-time
<b>BInt(Hons)</b>	1 year full-time
<b>MInt(Prof)</b>	1 year full-time

## Landscape Architecture



Landscapes are the represented expressions of the dynamic interaction between the technological and cultural activities of human societies with the physical environment. Landscape architecture is a profession and academic discipline concerned with the design of rural and urban outside places on various scales informed by this interaction. It considers change over time and mediates art and science; artefact and nature; city and region; and private and public interests. Landscape architects therefore synthesise knowledge from the humanities and the sciences to sustainably design meaningful and beautiful places that are grounded in material and immaterial culture, and ecology of their local contexts.

### Programme structure

The following are studio based programmes with professional outcomes (admission by selection):

<b>BSc(LArch)</b>	3 years full-time
<b>BL(Hons)</b>	1 year full-time
<b>ML(Prof)</b>	1 year full-time



**UNIVERSITEIT VAN PRETORIA**  
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 Faculty of Engineering, Built Environment and  
 Information Technology

# Physical, chemical and biological strategies to combat malaria

Mthokozisi M Sibanda, Prof Walter W Focke, Heino M Heyman and Prof Lyn-Marie Birkholtz

In sub-Saharan Africa, the entomological inoculation rates (the number of bites by infectious mosquitoes per person per unit time) can reach levels of more than a thousand infective bites per person per year. Research conducted by scientists at the University of Pretoria, under the auspices of the faculty research theme (FRT) Sustainable Malaria Control, focuses on the elimination of malaria and the promotion of health.

This FRT forms part of a process initiated by the University to identify the unique research strengths of the institution and to support the development of strong multidisciplinary research groups clustered around these identified strengths. These research themes, of which Sustainable Malaria Control is one, are designed to recognise and foster excellence in research. They are led by acknowledged international leaders in their specific disciplines across more than one faculty.

The researchers involved in investigating malaria vector control strategies are Mthokozisi Sibanda and Prof Walter Focke of the Department of Chemical Engineering, Heino Heyman of the Department of Plant Sciences, and Prof Lyn-Marie Birkholtz of the Department of Biochemistry. The latter two researchers are associated with the University's Faculty of Natural and Agricultural Sciences.

According to research, it is estimated that existing interventions can only reduce the annual inoculation rate by an order of magnitude, which suggests that the current interventions recommended by the World Health Organisation (WHO) might not suffice in achieving the goal of eliminating malaria in Africa. The problem is compounded by mosquito vectors that develop multiple-resistance mechanisms to pyrethroids. Effective vector control methods suppress vector populations to a bare minimum. This reduces the capacity of the mosquito to transmit the malaria parasite. The pesticide DDT has been shown to be an effective chemical in achieving this. The goal, however, is to find an alternative technology that is more cost-effective and efficient than DDT.

## An integrated approach

Malaria is a parasitic disease that is mostly confined to tropical areas.

It is transmitted by the female *anopheles* mosquito, and results in approximately 250 million clinical cases of malaria and nearly a million deaths annually. Malaria is particularly prevalent in sub-Saharan Africa, where it affects mostly pregnant women and children under five years of age. The WHO recommends an integrated approach that combines clinical control of the malaria parasite along with the use of long-life insecticide-treated nets and indoor residual spraying. Since mosquitoes are the vectors in malaria transmission, decreasing their population could lead to a reduction in malaria morbidity and mortality.

## Vector elimination

Techniques currently in use to eliminate the mosquito vector include aerial spraying (ultra-low volume spraying), larviciding, the biological control of the mosquito ovum, larvae and adults, environmental control and sterilising the male mosquito.

Ultra-low volume spraying is a process of applying the minimum effective volume of an undiluted formulation of insecticide. Ultra-low volume is the favoured aerial spray method used worldwide for mosquito adulticide control. It is used in areas where the mosquitoes are predominantly exophilic. It is expensive to operate and the insecticides currently in use do not have a long residual period. In an article published in the *Journal of the American Mosquito Control Association* in 1996, authors Mount, Terry and Haile report that small-scale tests using a small, fixed-wing, single-engine aircraft equipped with high-volume spray systems that are modified to allow ultra-low volume applications showed satisfactory mortality rates of various mosquito species (89–100%).

The mosquito life cycle has four stages, of which three are spent in

a stagnant aquatic environment. Destroying the larvae, either chemically or biologically, while in the aquatic environment is an effective vector control method. The earliest chemical larvicide, cupric acetoarsenite, was successfully used to eradicate *Anopheles gambiae* in Brazil before World War II. Temephos, an organophosphate larvicide, is much safer to use than arsenic but also kills mosquito predators.

Recently, insect growth regulators have been implemented as larvicides. Insect growth regulators work by binding onto larvae hormone receptors, preventing the insects from reaching the next stage of development. A significant advantage of an insect growth regulator is that it is target-specific and has shown a good margin of safety on non-target organisms. However, these agents may be toxic to immature stages of other aquatic insects.

Biological agents, such as parasites, pathogens and predators, can be used to target various life stages of the mosquito. Bacteria, fungi, viruses and fish have been employed to decrease the mosquito larvae populations. These agents are inexpensive to implement, and safe to humans and non-target organisms. They therefore provide a potentially environmentally friendly option. Fish feeding on mosquito larvae include *Gambus affinis* and *Gambus Holbrook*. They have been used for many generations in malaria-endemic regions.

According to an article in the *Journal of Vector Borne Diseases* in 2003, author PK Mittal reports that pathogenic bacteria, such as *Bacillus thuringiensis* var. *israelensis* (Bti) and *Bacillus sphaericus* (Bs) have been shown to be highly effective in controlling mosquito larvae at very low doses.

Some fungi have been used to control mosquito larvae and adults. Such entomopathogenic fungi (for example, the aquatic *Coelomomyces* sp. and soil fungi *Beauveria bassiana*) can kill *Anopheles gambiae* through tarsal contact. Unlike other mosquito biocontrol agents, such as bacteria, microsporidia and viruses, the fungi can infect and kill without being ingested. The spores germinate on the insect cuticle, and this is followed by penetration and growth into the mosquito hemolymph within one to two weeks. Very low concentrations of spores suffice. This has been shown to reduce malaria transmission by up to 90% as soon as the mosquitoes become infected with the fungus after ingesting *Plasmodia*. Transgenic fungi that can produce antimalarial peptides in the mid-gut of the mosquito have also been reported.

The basic rationale of environmental management is to eliminate all possible mosquito breeding sites. Environmental management was used extensively before the advent of DDT and provided a single effective way of fighting malaria. Environmental management has been applied in four distinct epidemiological settings: malaria in forest areas, rural malaria attributable to water resources development and management, rural malaria attributable to wetlands, rivers, coastlands and non-agricultural man-made habitats, and urban areas. Research by Keiser, Singer and Utzinger, published in *Lancet Infectious Diseases*, shows that environmental control can reduce the risk of malaria transmission by 88%.

When a female mosquito mates with an infertile male, she becomes infertile for the rest of her lifespan. Sterilisation of male mosquitoes is achieved by exposing male pupae-stage or adult mosquitoes to high-energy ionising

radiation. This causes damage to germ cells making them sterile. Sustained release of large numbers of sterile males (outnumbering the fertile native males) over a period of time that covers several generations of the target population, will lead to a gradual decrease in the productive capacity of the mosquitoes. Eventually, so few fertile insects remain that no fecund mating events occur and the population is eliminated. Sterile insect technique (SIT) is usually initiated when the number of mosquitoes reaches a seasonal minimum, for example, at the end of winter.

### Preventing mosquito bites

Preventative measures to combat malaria include the use of long-life insecticide-treated nets (LLITNs), the use of repellents and attractants, and the careful design of human settlements.

African countries favour LLITN programmes, as they are inexpensive and, unlike indoor residual spraying (IRS) programmes, are easy to implement. The downside of LLITN is that protection is only offered during sleeping time. Washing gradually diminishes the insecticidal activity of the nets. The effectiveness of LLITNs is thus limited by the need to wash the nets from time to time.

Before the advent of DDT and pyrethroids in the 1950s and 1970s respectively, researchers focused on diverting the female mosquitoes from human beings. This could be done by attracting or repelling them. With the initial perceived success of DDT and pyrethroid insecticides, research in this field became subdued. However, recently, with the controversy arising from the use of DDT and the emergence of resistance to pyrethroids, there is renewed interest in alternative control methods.

The mechanisms whereby repellents function are not clearly understood. They include chemical products with an offensive smell or taste to mosquitoes. Plant-derived compounds with repellence properties are most likely chemicals that are produced in defence against insects that

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The basic rationale of environmental management is to eliminate all possible mosquito breeding sites. It was used extensively before the advent of DDT and provided a single effective way of fighting malaria.

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pose a threat to the plant itself. These chemicals can be grouped into different categories, based on the functional groups present. They include nitrogen-containing compounds, terpenoids, phenolics, proteinase inhibitors and growth regulators. These compounds are generally produced to fight off a broad spectrum of insects, and are thus also effective against mosquitoes. Plants with better repellent properties fall into distinct families, with the *Poaceae* family (citronella-based) being the pre-eminent one. Species of *Lamiaceae*, *Fabaceae* and *Asteraceae* also show promising results. The future potential is thus very clear as these families cover large numbers of plant species, many of which have not yet been researched.

Prior to the extensive use of synthetically produced repellents, aromatic/essential oils were commonly used. The military was a significant consumer of these oils. Soldiers were issued with creams containing citronella, camphor and paraffin. Numerous essential oil-producing plants from the *Lamiaceae*, *Poaceae*, *Rutaceae* and *Myrtaceae* families have very well-known repellent activity. Synthetic products that have been used as repellents include Indalone, dimethylphthalate 2-ethyl-1, 3-hexane diol (Rutgers 612) and *N,N*-diethyl-*m*-toluamide (DEET). DEET is by far the most effective and widely used repellent.

Attractants present an option for controlling mosquito vector populations via mosquito traps. Host-seeking female mosquitoes are guided by attractant odours released by their target. In an article published in *PLoS ONE*, the open access peer-reviewed journal of the Public Library of Science, in 2010, authors Okumu et al. state that *Anopheles gambiae* is attracted to the ammonia, lactic acid and other carboxylic acids naturally present in the body odour and sweat produced by warm-blooded animals.

According to an article published in the journal *Chemical Senses* in 2001 by authors Smallegange, Qiu, Van Loon and Takken, blends of these compounds attract more mosquitoes

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Careful design of human settlements effectively reduces the spread of malaria. In malaria-endemic cases, transmission can be reduced by covering the windows and doors of human dwellings with thin muslin.

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than individual compounds applied in isolation, suggesting synergistic interactions. Blends of lactic acid, carboxylic acids and ammonia were shown to be attractive in laboratory tests and field tests. However, relative to human sweat, these blends are still less attractive. This implies that there are additional compounds, yet to be discovered, with synergistic activity for attracting mosquitoes. Research conducted by Mboera, Takken and Sambu, published in the *Bulletin of Entomological Research* in 2000, shows that carbon dioxide also plays an important role in mosquito host-seeking behaviour. In field tests, mosquito trap catches increased with the addition of CO<sub>2</sub> to the odour blend. *Anopheles gambiae* apparently prefers to attack its victims on the feet and ankles. It is attracted to this particular area because of the odour emitted by the feet. This odour is produced by *Brevibacterium linens*, which survives in the humid and warm clefts between the toes. The odour resembles that of limburger cheese. Bart Knols, in his book *Cheese, dogs and pills to end malaria* (2012), confirmed the attractiveness of limburger cheese to *Anopheles gambiae*.

An alternative technique that prevents a mosquito from locating its blood host is to disable its odour receptors. Mark Stopfer, in his book *Malaria: Mosquitoes bamboozled* (2011), described three classes of odour receptor disruptors. Inhibitors such as hexanol and butanol have the ability to block CO<sub>2</sub> receptors in mosquitoes. Secondly, irritators such as 2-butanone can be used to simulate CO<sub>2</sub>, and thus has the ability to distract mosquitoes from human beings. Lastly, blinders such as 2,3-butanedione cause prolonged activation of CO<sub>2</sub> sensory neurons,

thereby disabling the ability of the mosquito to sense CO<sub>2</sub> coming from humans.

According to an article published in *Trends in Parasitology* in 2002, authors Lindsay, Emmerson and Charlwood found that the careful design of human settlements effectively reduces the spread of malaria. In malaria-endemic areas, transmission was reduced by up to 96% by covering the windows and doors of human dwellings with thin muslin. The most efficient vectors in Africa are superbly adapted to feeding on human beings and are able to enter a human dwelling in search of a blood meal. *Anopheles gambiae* is attracted to the human odour coming from an abode. It flies upwards as soon as it meets an obstacle such as the wall of a dwelling.

If there is an opening in the roof, such as open eaves, the vector will use this as an entry point. Closing the eaves and installing a ceiling or a net screen is beneficial, as it reduces the house entry of mosquitoes. In an article published in the journal *Tropical Medicine and International Health* in 2003, authors Lindsay, Jawara, Paine, Pinder, Walraven and Emerson show that house entry by mosquitoes was reduced by 59% with a ceiling and 37% when the eaves were closed.

#### [Killing mosquitoes after they have bitten](#)

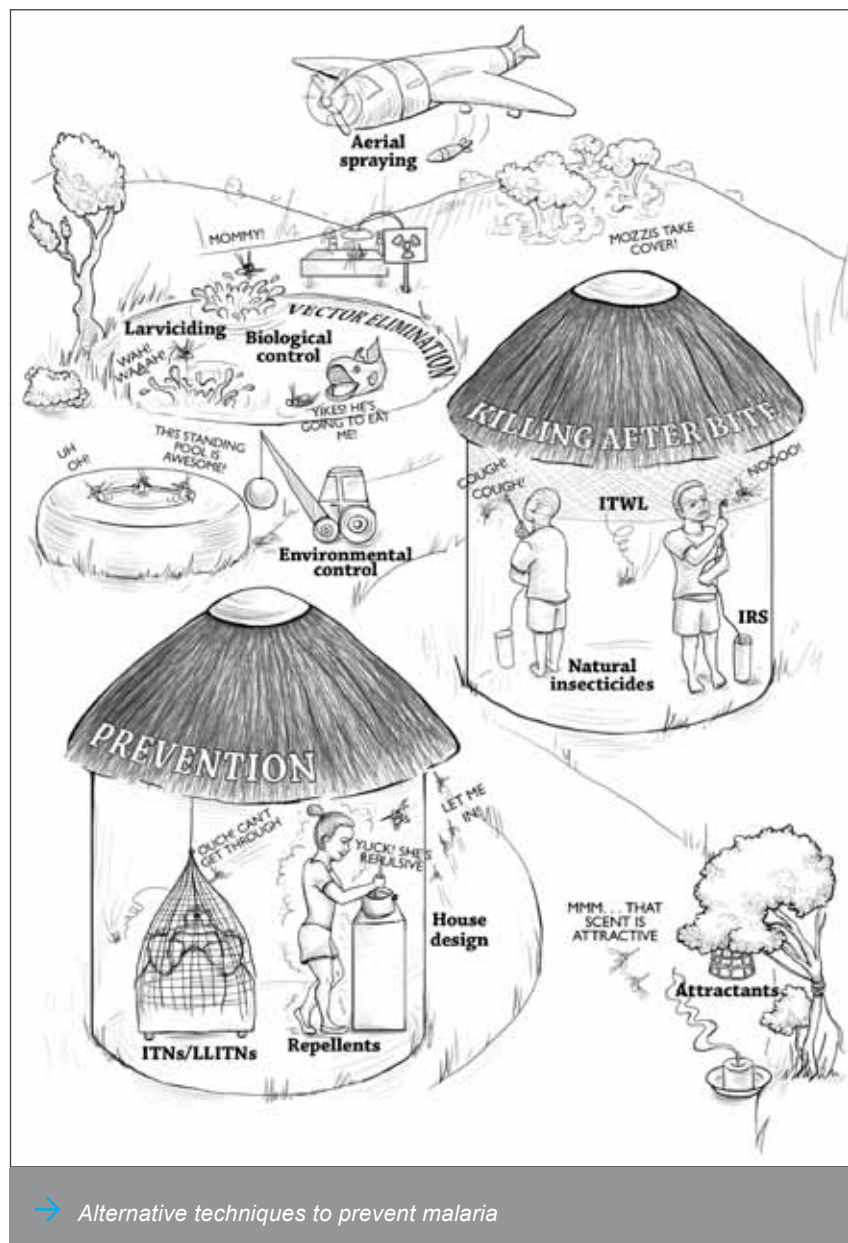
Strategies are also implemented to combat malaria by killing mosquitoes after they have bitten. Such techniques include the use of indoor residual spray and insecticide-treated wall linings. The WHO promotes the use of these two methods as a primary operational vector control intervention to prevent malaria

transmission. Indoor residual spray is deemed particularly effective and is widely applied in southern Africa. The WHO has approved 12 insecticides for use in indoor residual spraying. Six of the insecticides are classified as pyrethroids (alphacypermethrin, betacyfluthrin, bifenthrin, deltamethrin, etofenprox and lamdacyhalothrin), three as organophosphates (malathion, fenitrothion and pirimiphos-methyl), two as carbamates (propoxur and bendiocarb). The last one is DDT.

DDT is the most preferred pesticide for indoor residual spraying because it has an efficacy of 12 months or more, while the rest of the insecticides have an efficacy of up to six months. The longer-lasting efficacy of DDT provides a low-cost option, as one spray cycle per annum is sufficient, while two or more spray cycles may be required for the alternative insecticides.

In South Africa, DDT was temporarily replaced with deltamethrin between 1996 and 1999. However, DDT was reintroduced in 2000 when malaria transmission reached epidemic proportions. The failure of the pyrethroid was attributed to the return of *Anopheles funestus* strains. This major mosquito vector showed resistance to pyrethroids, but remained fully susceptible to DDT. The stabilisation of DDT alternatives for indoor residual spraying includes formulations based on micro-encapsulated insecticides that have been tested with great success. These results show that shielding the insecticides from the outside environment stabilises them against premature degradation.

However, the higher costs associated with such formulations may limit their widespread implementation as replacements for DDT. Recent work suggests that the precipitation of insecticides on low-cost phosphogypsum and the co-intercalation of the insecticides in organo-clays can provide significantly improved stabilisation of selected WHO-approved insecticides. Replacing synthetic with natural insecticides offers



advantages and novel possibilities. These include different modes of action and the prevention of rapid degradation in the environment. Research into natural insecticides subsided during the early 1970s with the successful synthesis of pyrethroids (synthetic equivalent of the natural insecticide pyrethrum). Pyrethrum itself is a potent natural insecticide, but is unstable in ultraviolet light and at high temperatures.

However, there is renewed interest in natural insecticides as green alternatives. Research into natural mosquito adulticides has been limited and the commercial exploitation of natural insecticides is uncommon in the market.

A problem is posed by the fact that the residual effect of these botanicals tends to be very short. For example, in the case of azadirachtin, it only lasts between four and eight days in the field. The essential oils of five plant species – caraway, celery, Chinese star anise, long pepper and zedoary – all showed significant effectiveness against pyrethroid-resistant *Anopheles aegypti* strains. The effectiveness of these oils against the pyrethroid-resistant strains is a major discovery, as it highlighted the potential utility of essential oils in prone areas that display a resistance to insecticides. Indoor residual spray depends heavily on the use of DDT. In addition to this, insecticide dusting is a problem in indoor residual spraying. Insecticide-treated wall linings (ITWLs) have



→ The scientists involved in research on physical, chemical and biological strategies to combat malaria (from left) are Heino Heyman, Prof Lyn-Marie Birkholtz, Prof Walter Focke and Mthokozisi Sibanda.

been proposed as a safer alternative to indoor residual spraying. So far, the most advanced product is based on woven shade cloth made from polyethylene with 50% shading and treated with deltamethrin 4.4 g a.i./kg material. The type of treatment is similar to Type 2 LLITNs (the insecticide being included in the fibre itself). This product was developed and manufactured by Durable Activated Residual Textiles South Africa (DART).

Field test results show that ITWL nets are generally acceptable in a range of community settings. However, these wall linings were produced using labour intensive fabric weaving or knitting methods. Prof Focke and PhD student Mthokozisi Sibanda have developed inexpensive linings that are produced by extruding insecticide impregnated polyethylene directly into a net format. The results of preliminary field trials on these nets have been presented at two international malaria conferences.

Results indicate that the use of these pyrethroid-impregnated indoor linings is potentially as successful as indoor residual spraying. This new and

potentially safe method might be a more sustainable approach for vector control.

### Acknowledgements

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Faculty of Engineering, Built Environment and  
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# Reintegrating humankind and nature

Anneline du Preez

The concept of sustainability grew from a set of diverse but equally valid and often interlinked streams of thought. These streams of thought are the products of larger societal concerns that came to shape the agendas of governments, business and civil society after World War II.





→ Researchers in the Department of Construction Economics are developing frameworks for sustainable construction and the development of human settlements.

Since then, ecological systems have been challenged to keep meeting the increasing demands made by human needs. This challenge has reached critical dimensions. Responses to the crisis have laid the foundations for different sustainability paradigms, also in the built environment.

The work of Prof Chrisna du Plessis of the Department of Construction Economics in the School for the Built Environment focuses on developing the principles and guiding frameworks for the practices of sustainable construction and human settlement development from within the different sustainability paradigms. She has identified three such paradigms.

The first of these evolved in public policy. It was driven by the United Nations and was based on developing a set of common criteria, indicators and strategies through international consensus. The second paradigm has its roots in the private sector, as businesses responded to the risks, pressures and opportunities of an environmental agenda. Both these paradigms can be criticised

for perpetuating the structures of society that created the crisis in the first place.

The third paradigm, however, calls for profound and radical changes to the structures of society, including the dominant world view, in order for the earth to remain fit for human habitation. This paradigm underlies concepts such as transformative resilience and regenerative design and development. It holds that human development needs can only be met sustainably if ecological conditions are such that all of life can flourish and continue to evolve.

The regenerative sustainability paradigm represents a shift to a holistic living systems world view. This paradigm attempts to address the dysfunctional human-nature relationship by entering into a co-creative partnership with nature.

It aims to restore and regenerate the global social-ecological system through a set of localised ecological design and engineering practices, which are rooted in the social-ecological narratives and context.

However, this paradigm still has to be tested at scale and as a fully integrated system of physical, cultural and visionary inventions. Currently the regenerative paradigm seems to offer a way for humans to engage with nature in two significant ways. It will build the adaptive capacity to survive the perturbations of global change and increase the regenerative capacity of the world to create conditions under which humans and others can thrive. Prof Du Plessis, with fellow members of the Think Tank on Resilient Urban Systems in Transition (TRUST), is investigating the theoretical and practical implications of this paradigm for urban systems. Their work can be followed on <http://trustsa.weebly.com/>.

Prof Du Plessis's work has been recognised by the University of Salford, UK, when it presented her with an Alumni Achievement Award (similar to the University of Pretoria's Laureate Awards) in 2012. She also received an Outstanding Reviewer Award from the Emerald Literati Network. 📍



# Novel redesign of welded pressure leach autoclaves for the platinum industry

Prof Madeleine du Toit, Joseph Owen Roux and David Shklaz

The base metals refinery of a major platinum producer in South Africa refines converter matte-containing base metals and platinum group metals (PGMs) using a five-stage hydrometallurgical process. The second-stage leach produces a PGM-rich residue through the extraction of copper and any remaining base metals from the first-stage leach solid residue material.

Leaching is performed in a high-pressure autoclave, under highly oxidising conditions in a concentrated  $H_2SO_4$  solution at a temperature of 150 °C. The original design utilised a heavy-walled carbon steel shell with lead lining and two layers of acid bricks. These autoclaves were heavy, maintenance-intensive and prone to catastrophic failure. A radical redesign using duplex SAF 2205 stainless steel<sup>1</sup> was proposed, eliminating the need for lead and brick lining and substantially reducing the wall thickness requirements. The first duplex stainless steel unit has been in continuous operation for more than 78 months.

## Background

Impala Platinum Limited (Implats) is one of the world's leading producers of PGMs, with operations in the Bushveld Complex in South Africa and the Great Dyke in Zimbabwe. The Implats Base Metals Refinery (BMR) processes ore that contains base metals and PGMs supplied to the refinery in the form of converter matte. At the BMR, five separate leaching steps are used to refine the matte, yielding a PGM-rich concentrate (which is processed further at the platinum metals refinery), nickel in briquette or powder form, copper cathodes and cobalt powder.

The second-stage leach process at the BMR produces a PGM-rich residue through the extraction of copper and any remaining base metals from the first-stage leach solid residue material. The PGM-rich residue is further processed in the third-stage leach. The second-stage leaching process is performed in autoclaves operating at a design pressure of 1070 kPag and a temperature of between 120 and 140 °C. Concentrated  $H_2SO_4$  is added to the feed to produce a solution with a free-acid content.

Oxygen is passed into the first and second compartments of the autoclave.

As a result of the aggressive, highly oxidising conditions in the autoclave, the original autoclave design for the second-stage leach utilised a three-layer configuration, consisting of a heavy carbon steel shell (with a wall thickness of 40 mm), a lead lining and two layers of acid bricks. The bricks acted as a wear-resistant material and ensured a low surface temperature at the skin of the lead lining, whereas the lead lining acted as a corrosion barrier to protect the steel shell from acid corrosion.

The bricks were layered with mortar to ensure that they were held firmly in position, while preventing the penetration of the corrosive solution between the bricks. The total thickness of the lead lining and the two layers of bricks was between 200 and 250 mm. The bricks and the lead lining, if damaged, had to be replaced immediately, as contact between the acidic solution and the carbon steel shell resulted in rapid corrosive attack. The autoclave also utilised a vertical partition wall made up of two brick layers, which created four buffer zones (compartments) for the different stages of the process. An agitator was installed inside the autoclave, which increased the leach efficiency. During the agitation process, vibrations were created in the autoclave shell, which could cause damage to the bricks and liners.

Vessels of this type had become the industry standard for this application and had been in use in the platinum industry for many years.

## Limitations of the original autoclave design

The original second-stage leach autoclave design exhibited several

1. SAF 2205, also known as Sandvik SAF 2205, is a Sandvik-owned trademark for a 22Cr duplex (ferritic-austenitic) stainless steel. SAF derives from Sandvik Austenite Ferrite.



→ Installation of the completed second-stage leach autoclave at the BMR in June 2007.

problems that caused reduced productivity levels and efficiency in operation. The main concerns were the following:

- The autoclaves required extensive maintenance due to bricks collapsing at the nozzles and partition walls, necessitating frequent maintenance intervals to avoid the deterioration of the main shell, and underperformance due to the collapse of the partition walls.
- As a result of frequent collapses, the brick composite material contaminated the final product, further reducing productivity.
- Each vessel was costly to manufacture and required a substantial capital investment.
- The duration of manufacture was lengthy. This was further exacerbated by the need to have the brick lining installed in situ.
- Due to the heavy design of the autoclave, heavy lifting equipment was required. This increased the installation costs of the vessel.
- Bricklaying involves manpower working in confined spaces under hazardous conditions, thus necessitating the implementation

of special precautions, the use of breathing apparatus and special equipment to comply with the Occupational Health and Safety Act and other statutory requirements.

- Workers installing the lead lining were exposed to extremely hazardous conditions. The use of lead is governed by specific regulations, and is restricted in several countries around the world. South Africa has promulgated Lead Regulations that control the use and application of lead in the National Occupational Health and Safety Act.
- When the vessel is decommissioned, strict procedures have to be adhered to when disposing of it. Due to the heavy weight of the autoclave and the brick lining, it is not feasible to lift the vessel as a whole unit. The bricks have to be removed, and the vessel has to be rotated and heated above the melting point of lead to allow the molten lead to flow out through the nozzles. This required a specialised and highly skilled workforce.
- Since the brick lining tends to swell, it was essential to ensure

that the manufacturer maintained strict out-of-round control so that the permissible tolerances were not exceeded. It was common to have 0.5% out-of-round on the brick lining, whereas the code of construction on pressurised equipment limited the out-of-round to 1% of the diameter size. This necessitated additional manufacturing jigs, spiders and temporary bracing to maintain circularity within permissible tolerances.

- The vessel has four compartments with a large agitator to mix the product. It was common for this agitator to have a run-out that induced vibrations, thus weakening and cracking the mortar and causing the brickwork to collapse.
- The vessel had to be placed on a heavy foundation that would withstand the weight of the shell, lead lining and the two layers of brick linings.

### Finding an innovative solution

The solution that had to be found would have to be one that would ensure the safety of personnel on the

→ Table 1: The typical chemical composition of SAF 2205 (weight percentage, balance Fe)

Chromium (Cr)	Nickel (Ni)	Carbon (C)	Manganese (Mn)	Silicon (Si)	Nitrogen (N)	Molybdenum (Mo)
21–23%	4.5–6.5%	0.03 max	2.0 max	1.0 max	0.08–0.20	2.5–3.5

plant, limit pollution and environmental degradation at the end of the vessel's operating life, provide cost-saving advantages throughout the life cycle of the vessel and yield an autoclave design that is easy to operate and maintain.

Available literature suggested the use of titanium, titanium clad or superduplex stainless steel autoclaves as alternatives to brick and lead-lined autoclaves in applications involving long-term exposure to operating conditions similar to those in the second-stage leach autoclave at the BMR. These materials are, however, expensive, difficult to fabricate and often not readily available. The use of a more general-purpose duplex stainless steel, known as SAF 2205, but also referred to as EN 1.4462 (according to EN 10088 and EN 10028<sup>2</sup>) and S31803 (according to ASTM A240<sup>3</sup>), was therefore investigated. SAF 2205 is a highly alloyed duplex stainless steel of Swedish origin, with a typical chemical composition as shown in Table 1.

SAF 2205 displays excellent corrosion resistance in a wide range of environments, resists localised corrosion, is highly resistant to intergranular corrosion and is not susceptible to chloride stress corrosion cracking. It has a hardness of 8 on the Mohs scale<sup>4</sup>. SAF 2205 stainless steel is a high-strength alloy, with a typical yield strength of 520 MPa and an ultimate tensile strength of 760 MPa. For comparison purposes, the brick lining used until recently at the BMR has a typical hardness of Mohs 9, but without any tensile mechanical strength. SAF 2205 material is readily available, and has a dual-phase ferritic-austenitic structure, which ensures the good mechanical properties and excellent corrosion resistance required in this application.

Samples of SAF 2205 and a lower-alloyed AISI 316 L stainless steel<sup>5</sup>

were placed into an original second-stage leach autoclave in a region of the partition wall where the agitating effect was at a maximum. The AISI 316 L stainless steel samples rapidly deteriorated in this environment, which is in agreement with available literature. However, the SAF 2205 samples did not show any evidence of wear or chemical attack. This suggested that SAF 2205 is compatible with the environment inside the second-stage leach autoclave.

### Redesign of the second-stage leach autoclave

On completion of the successful in situ trials, the second-stage leach autoclave was completely redesigned using SAF 2205 duplex stainless steel as construction material. This design takes into consideration the recent improvements in technology in duplex stainless steel products. The newly designed autoclave does not require any lead or brick lining, and the first installed vessel has already been in continuous operation for more than 78 months (with one minor design change to the partition walls). The main advantages of the newly designed autoclave are that downtime

is minimised, allowing for reduced maintenance servicing, working volume is increased substantially, which minimises batch-time processing and increases the output of the plant, and the internal components can be easily adjusted according to process requirements.

The product, the adjustable internal baffles and the agitators have been patented, in addition to a registration deed for the utilisation of duplex materials without the need for additional brick layers (which would have been necessary as a corrosion barrier in the conventional autoclave design). Table 2 compares the brick-lined autoclave (old) to the solid SAF 2205 (new), in terms of weight and the efficient working volume of the vessels, which are from the same outer dimensions.

The vessel shell is manufactured from SAF 2205 plates, which are formed in circular sections, assembled in an abutting end-to-end arrangement and welded to form an elongated cylindrical body. The plates are stepped and welded in a staggered array to increase rigidity and to avoid a continuous circumferential seam.

→ Table 2: Comparison of brick-lined and SAF 2205 autoclaves

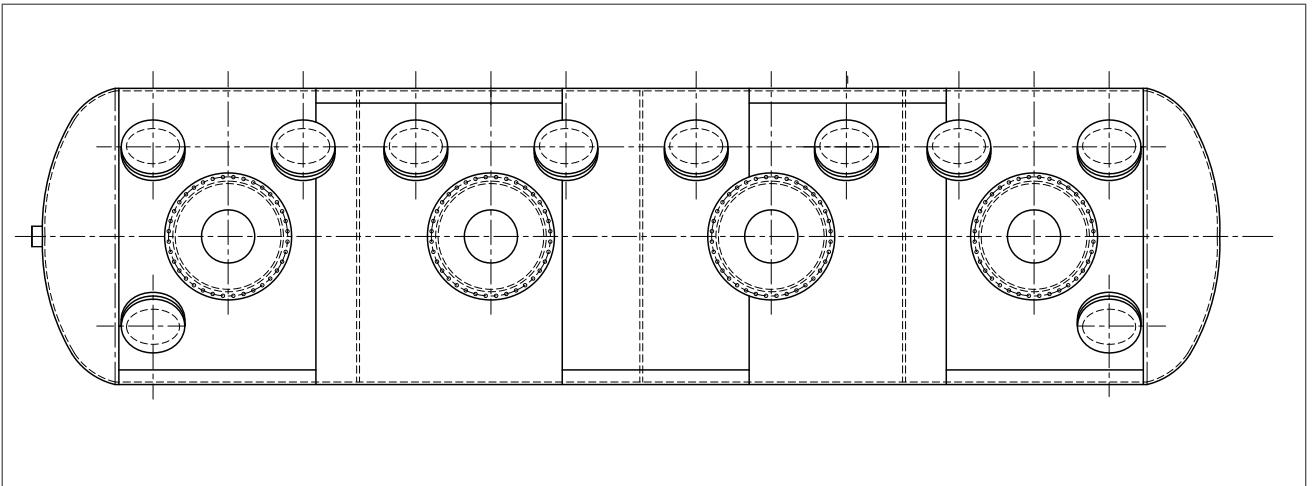
Property	Brick autoclave	SAF 2205 autoclave
Construction material	BS 1501–1510430A	SAF 2205
<b>Before bricking</b>		
Shell thickness	40 mm upper 25 mm lower	22 mm throughout
Dish head thickness	25 mm	16 mm
Brick lining	Yes	N/A
Lead	Yes	N/A
<b>After bricking</b>		
Pass partition width	345 mm brick	30 mm SAF 2205
Vessel weight (empty)	83 620 kg	19 183 kg
Working volume	53.70 m <sup>3</sup>	78.58 m <sup>3</sup>

2. EN refers to the European Standards, developed by the European Committee for Standardization (CEN).

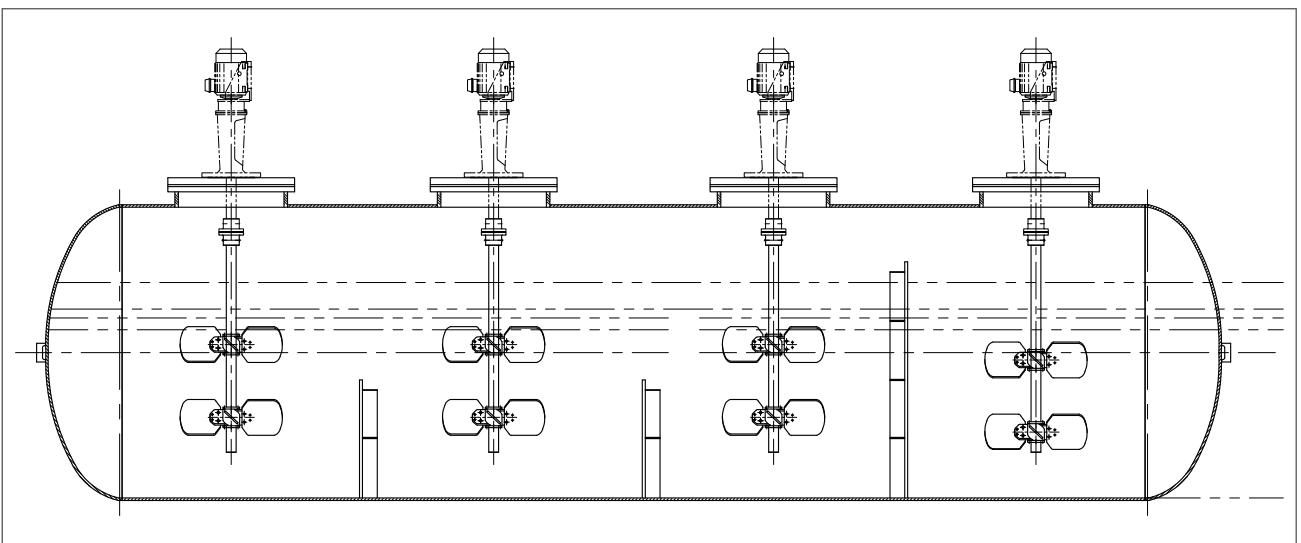
3. Standards developed by ASTM International, formerly known as the American Society for Testing and Materials (ASTM).

4. A scale developed by German mineralogist Friedrich Mohs to compare the hardness or scratch resistance of minerals.

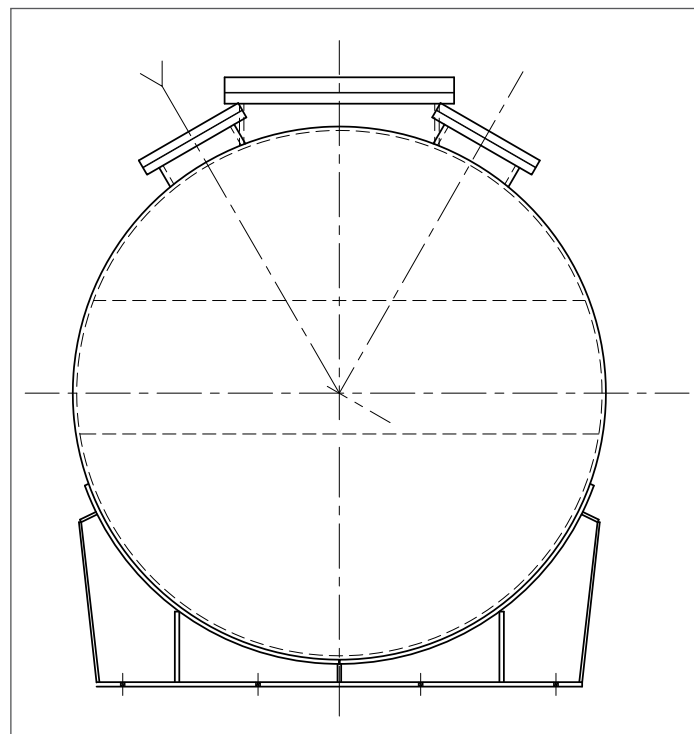
5. A standardisation system developed by the American Iron and Steel Institute (AISI).



→ Figure 1: Top view of the redesigned second-stage leach autoclave



→ Figure 2: Autoclave with agitators



→ Figure 3: Side view of the redesigned second-stage leach autoclave

Strict quality control was maintained during all stages of fabrication. The dished ends were hot-formed and welded to the cylindrical body to form the vessel. Several manhole and nozzle openings were included for access and for connections to the process piping. The nozzles were hot-formed and welded to the vessel body using partial penetration fillet welds. Figure 1 shows the top view of the autoclave. Figure 2 is an elevation drawing, and Figure 3 is a side view.

A number of internal baffles with adjusting of baffle height based on process requirements were installed in order to generate compartments. Hydrofoil agitators were installed to ensure proper mixing during the leaching process. The agitator profile has been optimised regarding performance and energy consumption. The outer diameter of the blades are smaller than the agitator nozzle, which enables removing of the entire agitator through the flange without the need of dismantling in the autoclave.

Finite Element Method (FEM) analysis was carried out for all the

components subjected to cyclic stresses to demonstrate the integrity of the elements and to prove that the operating stresses in the shell and other elements do not exceed the maximum permissible stresses allowable for the construction material.

### Benefits of the new autoclave design

After more than 78 months in service in the same environment and under the same operating conditions as used for the original brick and lead-lined autoclaves, the first solid duplex stainless steel autoclave showed no signs of corrosion and the leaching process proceeded normally. The throughput was, however, significantly increased due to the larger open volume in the autoclave. The elimination of the brick lining also removed the risk of brick collapse as a result of the agitation action. The maintenance requirements of the newly designed vessels were substantially reduced.

In the older version of the autoclave, the use of lead substances made for

a hazardous and dangerous working environment. Eliminating the use of lead in the redesigned autoclave therefore provides for a safer working environment during the manufacture of the vessel, as well as for plant operators, and also during disposal of the vessel at the end of its operating life.

Furthermore, from an environmental point of view, toxic and harmful lead substances have been eliminated and replaced with more environmentally sustainable duplex stainless steel. The new material ensures a longer lifespan owing to the fact that the duplex stainless steel is resistant to corrosion in the solution used in the leach process.

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# Using multi-source GPS data to characterise multi-day driving patterns and fuel use

Prof Christo Venter and Prof Johan W Joubert

The use of global positioning system (GPS) technologies for collecting travel data is growing rapidly throughout the world. As GPS technologies improve, a number of shifts are occurring in their application. Data collection periods are also increasing beyond the traditional one-day survey, as respondents carry GPS devices for up to a week. This provides rich data on the day-to-day repetitiveness and variability of travel without adding to respondent burden.

The South African National Roads Agency Limited (SANRAL) has recently completed a major upgrade of 185 km of freeway infrastructure in Gauteng. The Gauteng Freeway Improvement Project (GFIP) was aimed at relieving congestion, improving traffic management through Intelligent Transport Systems deployment, and improving traffic safety on the province's extensive freeway network.

In a research project conducted to characterise multi-day driving patterns and fuel use, GPS data from commercial fleets was combined with project-specific, mobile GPS sources to analyse and compare private and commercial vehicle traffic in the same area. The purpose of the research project is to help improve the state of travel demand modelling in South Africa.

A three-day GPS survey of a sample of car drivers in Gauteng provided detailed information on the daily movements of these individuals. This information was used to extract the activity chain information needed for the simulation of travel plans using the Multi-agent Transport Simulation (MATSim) toolkit, which allows for large-scale transportation simulations. The same individuals will be resurveyed at one-year intervals to study long-term behaviour changes.

## Obtaining GPS data

Data for commercial traffic was obtained from a commercial fleet management provider that continuously tracks the movements of 42 000 vehicles, while data for private car users was obtained from a panel of 720 drivers, whose multi-day driving activity was tracked using mobile passive GPS loggers. The study was therefore able to determine whether the subsample of drivers who are freeway users differed from the true population of freeway users in the area.

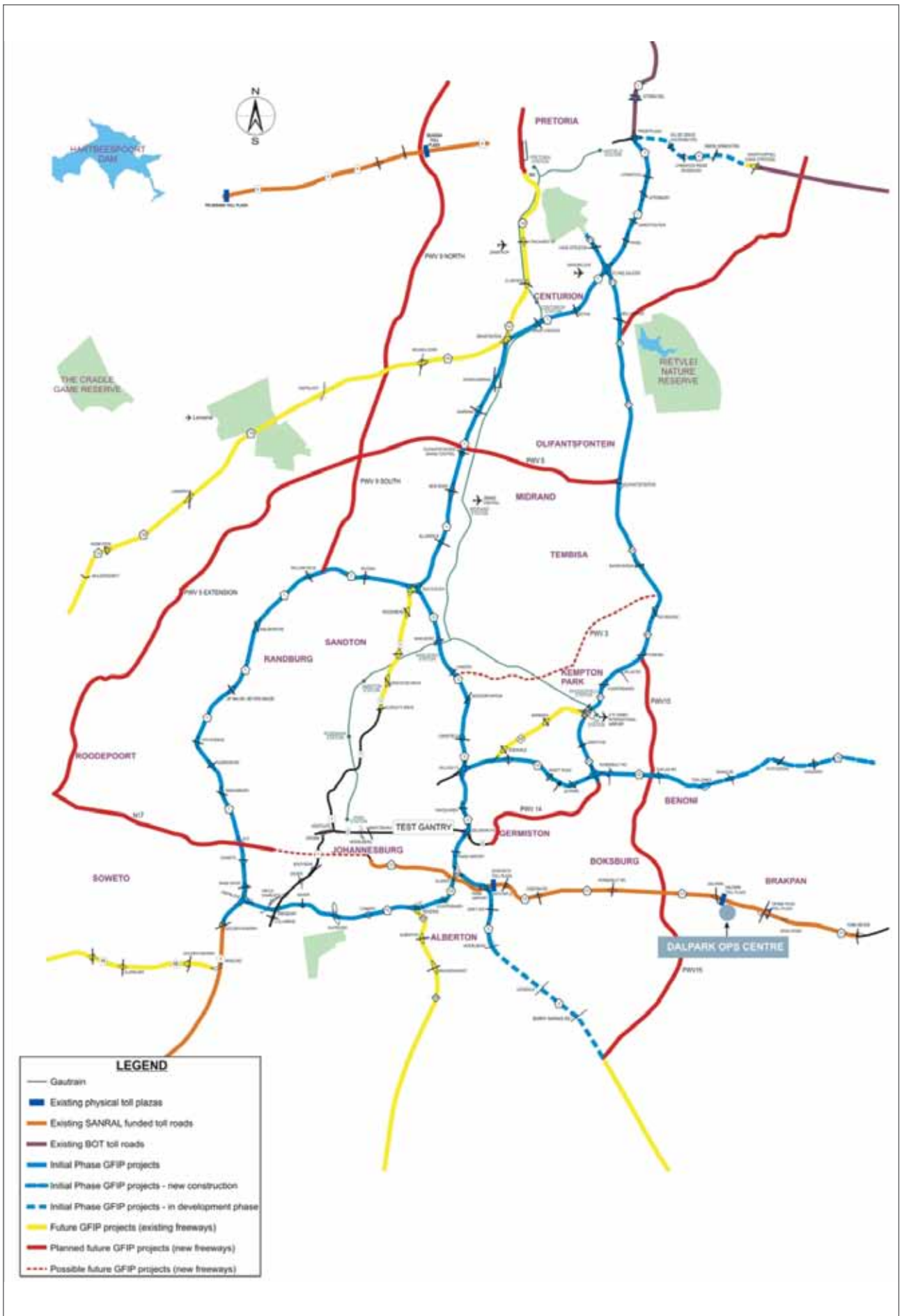
The GPS data obtained was downloaded and processed using purpose-built software for filtering, smoothing and geographic information system (GIS) matching of trips and routes. It was then analysed and the driving behaviour of the two driver populations compared in terms of the total distance travelled, spatial patterns and temporal variation. The detailed nature of the GPS data also permitted the estimation of fuel consumption at a very disaggregate level (by link and time of day), and the identification of differences between user groups, which have significant implications for transport and energy policy.

## Daily vehicle kilometres of travel

The results of the average daily vehicle kilometres of travel (VKT) for different income groups in the private car sample are depicted in Figure 2. Consistent with travel behaviour theory, the lowest travel activity occurred in the lowest income category, with an average daily distance travelled of about 20 km. The mid-range income group was found to have the highest driving activity. The VKT was found to reduce again by about 20% for higher income groups.

The reasons for these trends can be found in the fact that low-income drivers cannot always afford to travel long distances. High-income users can afford to travel long distances, but also have maximum choice of housing and employment location. They seem to use this flexibility to improve their proximity to jobs and other activities. Medium-income drivers seem to be worst off. While they can afford to travel long distances, they also seem less able to avoid them.

For commercial vehicles, the VKT was much higher. On average, intra-provincial vehicles travel 165 km per activity chain, which increases to 532 km per activity chain for inter-provincial vehicles. The average number of activities per chain was



→ Figure 1: Freeway network in Gauteng, South Africa (Source: South African National Roads Agency Ltd)



9.2 for intra-provincial vehicles and 8.6 for inter-provincial vehicles. With transport costs making up a sizable proportion of total logistics costs, companies aim to maximise their fleet utilisation. Activity chains with a high number of activities are indicative of such optimisation efforts.

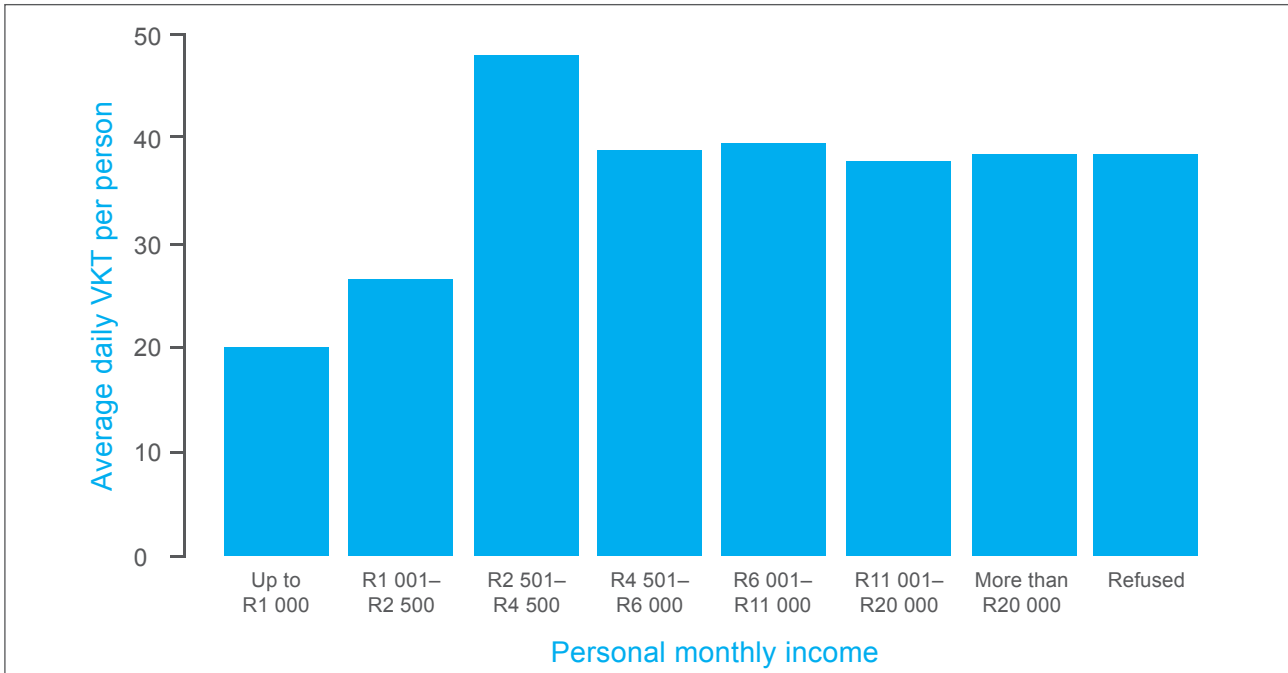
### Road type and time of day

Figure 3 categorises the VKT for different income groups by the type

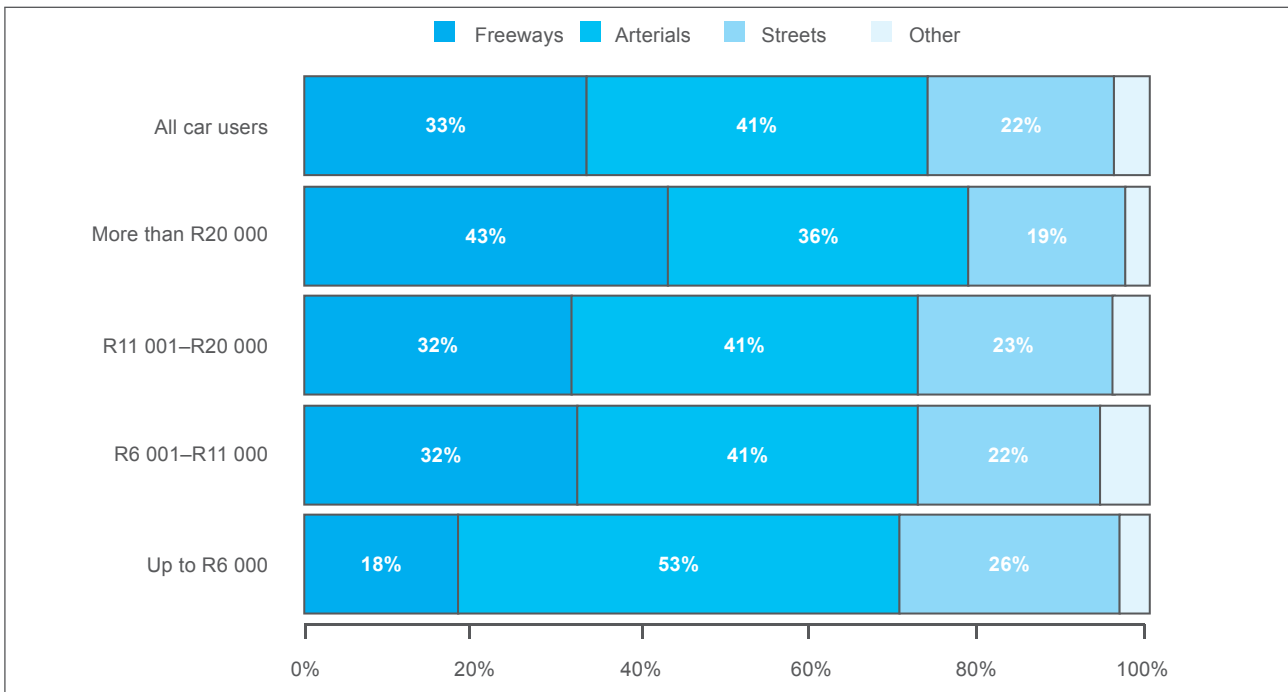
of road on which travel occurs. Overall, about a third of private car use in Gauteng occurs on the freeway network, and only 22% on the street network. There is a clear relationship between personal income and the type of road used. Freeway use rises with income, with the most affluent drivers spending more than twice the proportion of kilometres on freeways than the lowest income category. This is most likely related to the fact that the freeway network is designed to serve

the commuting needs of higher-income drivers better than those of lower-income neighbourhoods.

In comparison, private cars and commercial vehicles differ in their use of road types. It was found that private cars and intraprovincial commercial vehicles spend similar proportions of their VKT on the freeways, while commercial vehicles make greater use of arterial roads and less use of local streets.



→ Figure 2: Average daily VKT of private car users, by income category



→ Figure 3: Distribution of daily VKT of private car users per road type

In contrast, interprovincial vehicles undertake more long-haul trips and show higher VKT on the freeway and arterial network.

Table 1 shows the share of freeway VKT by private and commercial vehicles throughout the day. Time-of-day patterns are important, as fuel consumption varies with speed and congestion levels. Higher-income drivers tend to concentrate more of their freeway travel in the peak periods, while low-income drivers make more use of shoulder and off-peak periods. Average travel speeds are marginally lower in the peak than in the off-peak periods, and much lower on arterial and local streets.

### Day-to-day variability

Recent research has focused on the day-to-day variability of travel, arguing that habit and variability are important dimensions of travel behaviour. Multi-day GPS data is useful to determine the regularity and variability of travel, at both aggregate and route level.

To measure the general level of variability in daily travel activity, a coefficient of variation (CoV) for the daily VKT for each vehicle was calculated.

A CoV value of zero corresponds to no variation. The larger the CoV for

a vehicle, the more the daily travel varied from day to day. For private vehicles, the GPS records across three consecutive weekdays were used. For commercial vehicles, three consecutive weekdays were arbitrarily chosen, with typical traffic patterns, to calculate the CoV.

The average CoV was shown to vary between vehicle classes, and also within each class. The most important finding is that day-to-day variation is higher for private vehicles than for commercial vehicles, and that, among private vehicles, the highest variability is found in the lower-income groups.

For interprovincial commercial vehicles, the CoV varied between 0 and 1.73, with a median of 0.54 and a mean of 0.60. The behaviour of intraprovincial vehicles was more consistent, with a lower median of 0.39 and a mean of 0.47. The fact that commercial vehicles often perform routine deliveries may explain the low variation. The average CoV for private cars, across all income groups, varied between 0 and 1.59, with a median of 0.69 and a mean of 0.70, which was significantly higher than the day-to-day variation of commercial vehicles.

A second measure of variability looks at the day-to-day variation at the route level. The researchers found that only 47% of freeway users in the sample

used the same freeway section on more than one day. The rest showed no repetition in their route choices.

### Estimating disaggregate fuel consumption patterns

In order to estimate fuel consumption at the level of the individual vehicle, link and time of day, the following model was used:

$$c_{nkt} = d_{nk} \cdot b_n \cdot f(v_{nkt}) / 100$$

Where:

- $c_{nkt}$  = litres of fuel consumed by vehicle  $n$  on link  $k$  at time  $t$
- $d_{nk}$  = distance travelled by vehicle  $n$  on link  $k$  (in kilometres)
- $b_n$  = base fuel consumption rate for vehicle  $n$  (in litres per 100 km)
- $f(v_{nkt})$  = fuel efficiency adjustment factor for vehicle  $n$  travelling at speed

Fuel consumption is thus dependent on the type of vehicle, the link distance and the travel speed. Consequently, fuel consumption would vary by the type of road used and the time of day (depending on congestion levels).

Table 2 shows the results of the fuel calculations by user group and road type. Fuel consumption rates are highest on streets, followed by freeways and then arterials. Fuel consumption is slightly higher during

→ Table 1: Time-of-day distribution of VKT and speed on Gauteng roads

	Morning and afternoon peaks (06:00–10:00 and 14:00–18:00)	Off-peak (05:00–06:00, 10:00–14:00 and 18:00–21:00)	Night (21:00–05:00)	Total
<b>Percentage of VKT on freeways by time of day</b>				
<b>Private car users</b>				
Income <sup>1</sup> up to R6 000	47%	39%	14%	100%
R6 001 to R11 000	54%	35%	11%	100%
R11 001 to R20 000	61%	34%	5%	100%
R20 001 and up	59%	35%	6%	100%
Refused to answer/ Did not know	52%	42%	6%	100%
<b>Commercial vehicles</b>				
Intraprovincial heavy vehicles	50%	44%	6%	100%
Interprovincial heavy vehicles	50%	44%	6%	100%
<b>Average speed per road type (km/h)</b>				
Freeways	87.5	97.1	--	--
Arterials	46.5	47.9	--	--
Streets	37.9	39.4	--	--

1. Personal monthly income reported in GPS survey. The dash indicates values that are not estimated.

off-peak periods, but the difference is negligible for cars and trucks. Trucks have much higher fuel consumption rates than passenger vehicles, but contribute only 12% to the total fuel bill. Among car users, drivers in the highest income group have the highest fuel consumption rates due to their use of larger, less fuel-efficient vehicles. Drivers in the lowest income bracket also have high fuel consumption rates.

A “recovery ratio” was also calculated, which is relevant to the road financing debate, as fuel tax revenues contributed by a group are proportional to their total fuel consumption. If fuel levies are seen as a user payment for road use, these revenues should be on par with the amount of road use. A recovery ratio of less than 1.0 indicates that a group contributes less fuel taxes than their share of VKT demands. This is the case for car users. Commercial vehicles pay about two and a half times their share of VKT. Among car users, higher-income drivers tend to have recovery ratios above 1.0. The exception is drivers in the lowest income group. This suggests that they are doubly penalised. Not only do they consume more fuel per kilometre by travelling on more congested streets, but their taxes go towards upgrading other parts of the network (arterials and freeways) that are used more frequently by other drivers.

## Conclusion

The study found that high congestion and low speeds on residential streets lead to higher fuel use and higher taxation. Improving local street networks would be an effective method of reducing energy consumption and travel expenditure. Further research is needed to accurately identify and allocate benefits and costs, relating not only to fuel costs, but also to multiplier effects and intangible benefits, such as reliability and safety. These factors influence the acceptability and fairness of road funding mechanisms, which are under pressure worldwide.

## Acknowledgements

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→ Table 2: Fuel consumption rates and recovery ratios per user group in Gauteng

	Average fuel consumption rate (litres/100 km)					Recovery ratio (percentage of fuel consumed / percentage of VKT)		
	Freeways	Arterials	Streets	Peak	Off-peak	Freeways	Arterials	Streets
<b>Private car users</b>								
Income <sup>1</sup> up to R6 000	8.78	9.33	10.91	9.64	9.66	0.87	0.92	1.08
R6 001 to R11 000	9.12	8.93	9.54	9.05	9.25	0.90	0.88	0.94
R11 001 to R20 000	8.67	8.67	9.33	8.76	8.94	0.86	0.86	0.92
R20 001 and over	10.19	9.85	10.21	10.02	10.12	1.01	0.97	1.01
Refuse to answer/ Did not know	9.57	9.10	9.74	9.32	9.51	0.95	0.90	0.96
<b>All car users</b>	<b>9.30</b>	<b>9.14</b>	<b>9.92</b>	<b>9.34</b>	<b>9.45</b>	<b>0.92</b>	<b>0.90</b>	<b>0.98</b>
<b>Commercial vehicles</b>								
Intraprovincial	24.35	25.04		25.40	24.15	2.41	2.48	
Interprovincial	24.37	25.06		24.83	24.49	2.41	2.48	
<b>All commercial vehicles</b>	<b>24.36</b>	<b>25.05</b>		<b>25.09</b>	<b>24.34</b>	<b>2.41</b>	<b>2.48</b>	
<b>Total: All vehicles</b>	<b>10.30</b>	<b>10.02</b>		<b>10.11</b>	<b>10.12</b>	<b>1.02</b>	<b>0.99</b>	

<sup>2</sup> Personal monthly income reported in GPS survey.

# Talent management in the mining industries of developing nations

Juan Jorge

**Talent management is and will continue to be a limiting growth factor for the mining industry. Top-performing global mining and related companies from developing nations share a common pool of engineers and technical staff who compose a “value chain”. This value chain allows for the conception, design, construction, operation and expansion of a mineral-extracting enterprise.**

Historically, Africa and South America have been a source of raw material for developed nations. For the last few decades, China – with its insatiable need for commodities – has driven growth in these regions by causing effects ranging from a rise in the price of these commodities to direct infrastructure investments.

Roger Agnelli, former CEO of the Brazilian mining company, Vale, recently gave an address at the Sloan School of Business of the Massachusetts Institute of Technology (MIT). Vale is the world’s largest producer of iron ore. Agnelli stated that “Africa will be home to the ‘next battle for natural resources’, given its potential for agricultural and industrial development, as well as its relatively close proximity to Asia”. He further detailed that “the only continent that can compete with South America with regard to natural resources is Africa”.

One pertinent example of the commodities push is the mining sector, which has helped to shape large companies in developing nations. This sector comprises companies that extract minerals from the ground, contractors who build

the services and installations, and consultants who design the projects. Companies such as these, which have emerged from developing nations, have become increasingly globalised and are currently competing with established mining entities from developed nations that have realised shortcomings regarding their future competitiveness. Demographic shifts mainly led to a shortage of talented individuals in the workforce.

Research conducted on this topic aimed to obtain a better understanding of the talent management of engineers and technical staff in global mining companies and associated services in developing countries.

A secondary objective of the research project was to determine how talent management ranks as a strategic priority, as well as to identify the tools and guidelines used to support this strategy. The researcher also attempted to determine if successful practices were applied, and to identify difficulties experienced in leading companies in this sector.



## Developing a conceptual method to manage talent in the mining industry

Data was gathered using survey research, as well as phenomenological and narrative research. A survey was used, as it provides quantitative or numeric descriptions of trends, attitudes or opinions of a population by studying a sample of the population. The sample was composed of randomly selected individuals of a representative list of global mining companies and associated services from developing nations. The identification of key role-players allowed for the acquisition of the essence of human experiences about a phenomenon as described by participants. This was achieved by means of unstructured interviews in which the interviewed subjects presented their views and experiences regarding this phenomenon.

An existing bibliography was utilised to guide the research and characterise the results. In a recent study on the six principles of effective global talent management by G Stahl et al., published in the *MIT Sloan Management Review*, the two major talent management theories that have been developed up to now are outlined. These are the differential approach, closely related to McKinsey & Company's early ideas, and the inclusive approach, which is related to Schiemann's ACE approach, which considers alignment, capabilities and engagement (ACE).

According to Stahl et al. (2012:26), many companies place a great deal of emphasis on high-potential employees. This is despite the fact that the practice of sorting employees based on their performance and potential has generated much criticism. This is known as the differential approach. Companies favouring this approach focus most of the rewards, incentives and attention on their top talent (A players), give less recognition, financial rewards and development attention to the bulk of the other employees (B players) and work aggressively to weed out employees who don't meet performance expectations and are deemed to have little potential (C players).

Stahl et al. (2012:26) observe that some companies prefer a more inclusive approach and attempt to address the needs of employees at all levels of the organisation. With this approach, talent management tactics used for different groups are based on an assessment of how best to leverage the value that each group of employees can contribute to the company.

Stahl et al. (2012) explain that hybrids of these two philosophies are applied in practice with the intention of bringing out the most positive aspects of each individual.

Through the use of the survey as research methodology, the researcher was able to generalise the results obtained through a quantifiable

description of attitudes regarding talent management in top-performing global mining and associated services companies from developing nations.

LinkedIn, which boasts one of the largest professional social networks available today, with more than 147 million members, was used as the database for the selection of individuals. In order to obtain a 90% confidence level and a 10% sampling error, and considering an estimated 15% response rate, the researcher sent out 286 survey questionnaires.

As a degree of complexity is associated with talent management, an interpretive form of data collection was implemented concurrently with the quantitative data collection in order to understand this phenomenon and the perceptions of individuals in organisations. Semi-structured interviews, consisting of mostly open-ended questions, made up the core of the qualitative data collection. Five key individuals were purposefully identified on the basis of their professional trajectory and location.

## Results of the survey

The survey had an overall response rate of 26%, with engineers responding to 28% of the requests and managers and human resource (HR) officials responding to 24% of the requests. The companies represented in this survey illustrated an acute awareness of what talent management is, as well as its importance.

→ Northern Cape province: The primary crusher structure at the new Kumani Mine near Kathu.  
Photo: Graeme Williams – MediaClubSouthAfrica.com



→ *Historically, Africa and South America have been a source of raw material for developed nations.*

These companies also shared the view that talent management is strategically important when designing an organisation's business plan. However, only a fifth of the companies indicated that they manage their business and talent management strategies concurrently.

The survey covered three possible role-players in talent management: the unit manager, the direct manager or supervisor and HR officials. With the exception of the selection process of potential employees, in which HR officials seem to play a slightly more predominant role, direct supervisors or managers have the most important role to play in the retention, development and growth of employees within a company. This implies that a technical person is responsible for most of the talent management activities in these organisations.

The surveyed organisations seem to show characteristics of the approaches of both McKinsey & Company and Schiemann.

In terms of the McKinsey approach, a talent mindset seems to dominate organisations, especially at management level. In terms of creating a value proposition for

employees, growth and development seem to be a priority and companies tend to incorporate some of the aspects of wealth and reward.

In terms of Schiemann's ACE model, organisations seem to be making an effort in trying to obtain alignment, create a company culture and encourage teamwork. However, managers in these organisations do not see this as a practical way of enhancing their employees' efficiency. These organisations make use of marked capability-enhancing initiatives, but do not seem to be doing as well in obtaining employee engagement.

A total of 74% of the respondents have worked with three or more different nationalities in the past year, showing considerable exposure to different cultures, as well as a growing probability of having a more heterogeneous work environment. Although the majority of respondents believe that cultural diversity is considered in their organisation's talent management strategy, only a third of them believe that this is done with considerable emphasis. Talent management efforts seem to be efficient in terms of the identification, recruitment, development and retention of employees of different cultures.

The majority of respondents agreed that the short duration and remoteness of projects are important factors affecting turnover in their organisations. These organisations seem to be retaining employees successfully under these conditions by implementing a financial stimulus, strict health and safety procedures, training, limited exposure periods, and encouraging frequent trips home.

Overall, respondents believe that their talent management activities are well adapted to their working conditions and environments, indicating that talent management is either developed in-house or adapted.

According to staff respondents, the most important concept in the talent management programmes is development. Growth, development and a good corporate image are aspects at which these organisations are excelling. The respondents also consider these factors to be important and believe that the organisations are mostly practising a Schiemann-like approach that considers multicultural aspects. The direct manager or supervisor was pointed out as the single most important person in the retention and development of staff. In contrast to the abovementioned general population, the most

important aspects were identified for engineers. Engineers regard development as the most important element when judging a talent management programme. They consider the programme in which they participate to lean towards the Schiemann approach, in which multicultural aspects are covered. The biggest concerns of these engineers seem to be the lack of growth and development opportunities, as well as exciting work opportunities.

HR officials, managers and engineers also differ in their perceptions of opportunities to grow and develop, as well as their perceptions of exciting work opportunities. Furthermore, HR officials and managers differ in their understanding of exposing engineers to more exciting opportunities because managers believe that there is a reduced need for growth opportunities. This differentiates their perceptions from those of HR officials and those of engineers.

Engineers consider it important to be exposed to multicultural aspects. Although their managers generally agree with them on this matter, HR officials seem to be of the opinion that more multicultural aspects and a more defined Schiemann approach should be implemented than is actually the case in practice.

The personal interviews confirmed the survey results in terms of the surveyed organisations not having a clear-cut McKinsey “star-guided” strategy or a pure Schiemann team approach. These organisations seem to use a mix of the two philosophies, with more emphasis on some aspects. Most of these strategies are developed in-house.

In terms of the important aspects that should be present in a talent management strategy, managers and HR officials tend to have a balanced perception of the need to recruit and retain talent. Managers, however, think it is less important to develop staff. This fact and the role that managers play in all phases of talent management should be considered in order to improve talent management.

Managers need to be aware that they are the most important piece in the talent management puzzle.

## Recommendations

It was found that an awareness of talent management seems to be a matter that is familiar to all the organisations that participated in the research. This accentuated awareness is a reflection of the strategic priority talent management has in these organisations, which has come to limit the time frames and viability of some projects in the recent past. Such an awareness has pushed for the development and adaptation of general talent management theories in respondents’ realities and work environments. The implemented strategies drew mostly on Schiemann’s ACE approach, as well as McKinsey & Company’s “star-guided” approach.

The perception of some of the respondents shows that there is a high degree of satisfaction with regard to the talent management initiatives in place in the various organisations. This satisfaction points to the fact that specifically oriented and purposefully designed talent management strategies, which attend to the cultural and work environment conditions, are created in-house and not directly translated from the generic bibliography used in this research.

However, these organisations have three main shortcomings: a homogenous, but steadily changing internal culture, a geographical fragmentation of the talent management strategy, and the extent to which technical managers are responsible for talent management.

The fact that the organisations that participated in this research have recently been involved in globalisation initiatives would be the most important factor behind a generally homogenous work environment. The geographical fragmentation in talent management strategies is demonstrated in the number of engineers (approximately half of those surveyed) who participate in such initiatives, the lack of consistency in implementing a teamwork culture, and having

employees selectively aligned to the company’s objectives and goals.

Direct managers need to play an important role in overcoming the abovementioned shortcomings. In the organisations that participated in this survey, these roles are mostly exercised by people with an outstanding technical career, but who are not necessarily managers with people management expertise or training. As a general rule, these managers do not completely visualise the important role they have to play in the development and retention of staff.

The key to growth and competitiveness in terms of an efficient talent management strategy revolves around the manager’s ability to assume a leading role in talent management. They are there because they have mastered the technical and financial aspects of the company, but they should consider the human aspect of their business in order to be sustainable.

In order to overcome present shortcomings, talent management initiatives and managers will need to focus on accentuating training and offering more challenging and exciting work for engineers, with appropriate tools in a system guided by a general strategy. 📌

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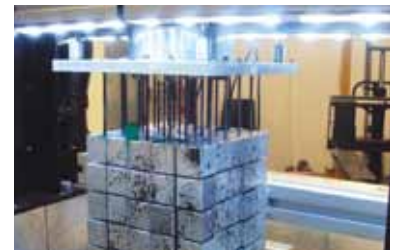
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**Centrifuge:** The Department houses the largest civil engineering centrifuge in the southern hemisphere, accelerating scale models to investigate the behaviour of complex geotechnical problems such as the formation of sinkholes.



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# An inside look at the stresses due to lateral forces in Tubular Modular Track

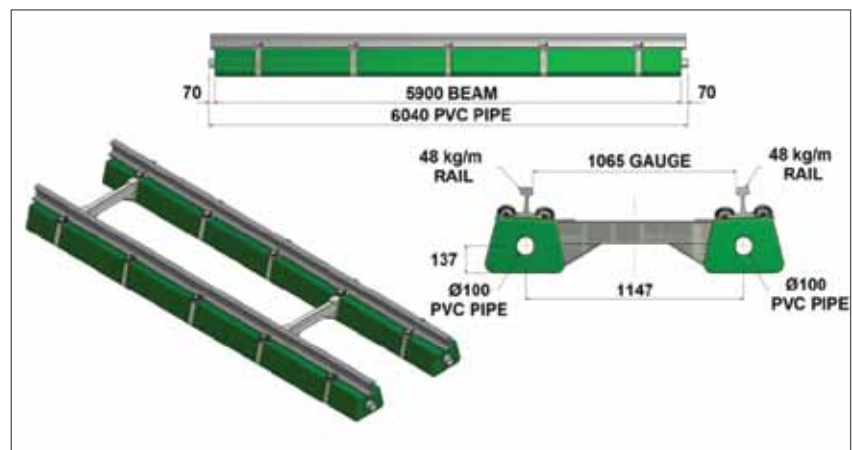
Brendan van Schoor and Prof Hannes Gräbe

The Tubular Modular Track (TMT) system is a relatively new innovation in railway technology. It is a non-ballasted track structure that provides a more stable and reliable track system. It also requires less maintenance. Improvements in railway track structures in South Africa, such as the TMT system, will succeed in satisfying the need for higher capacity, and faster, safer and more economic public transport systems.

The TMT system was developed in South Africa and has been implemented since 1989. It was originally used in the mining industry, but also has applications in the passenger and freight transport sectors, as it provides a stable and low-maintenance track. A TMT module is commonly 5.9 m in length and consists of two parallel steel rails held in place by Pandrol fastening clips on parallel, reinforced concrete beams. To maintain the gauge (the spacing between the rails), gauge bars connect the concrete beams at

A moving train induces complex loading on a railway track. The resultant force can be divided into three separate components: a vertical, a longitudinal and a lateral force component (see Figure 2).

The focus of the study was on the lateral forces induced on the track and on the behaviour of the gauge bar, when subjected to train loading. Four factors contribute to the resulting lateral force on the track: the lateral force of the wheel flange pressing on the outer rail, the lateral force due



→ Figure 1: Tubular Modular Track module

approximately every 3 m, depending on the specific application, axle load and whether it is on a curved or straight section of track.

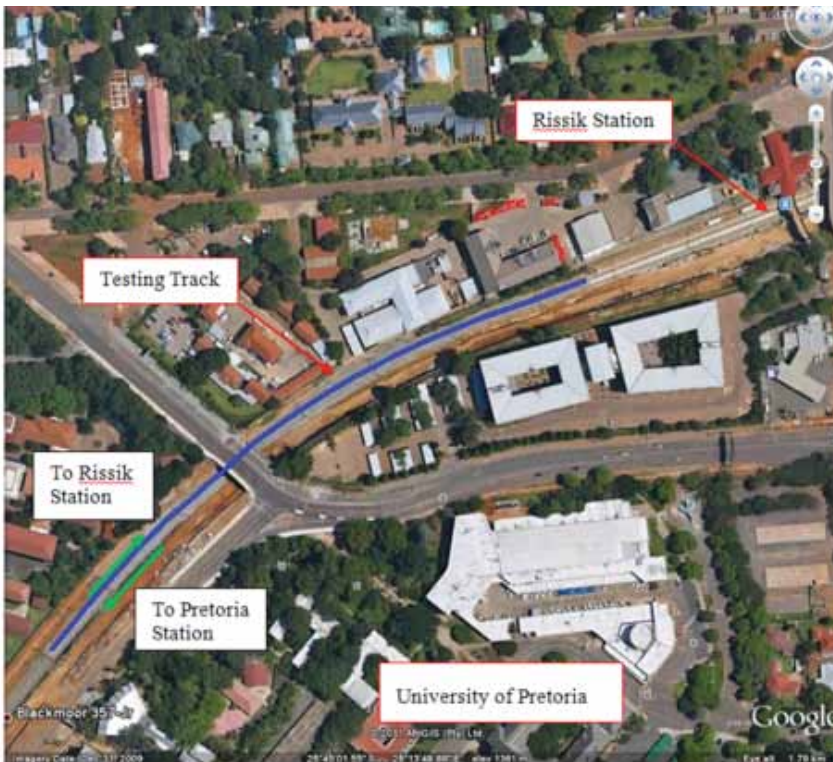
A research project implemented by the University of Pretoria focused on the strains and stresses experienced by the gauge bar in three different sections along the track structure: a transitional curve, a circular curve and a tangent section of track.

The testing was done by installing strain gauges at different positions on the gauge bars on an active line of the Passenger Rail Agency of South Africa (PRASA) in Hatfield, Pretoria, to the west of the Rissik Street station.

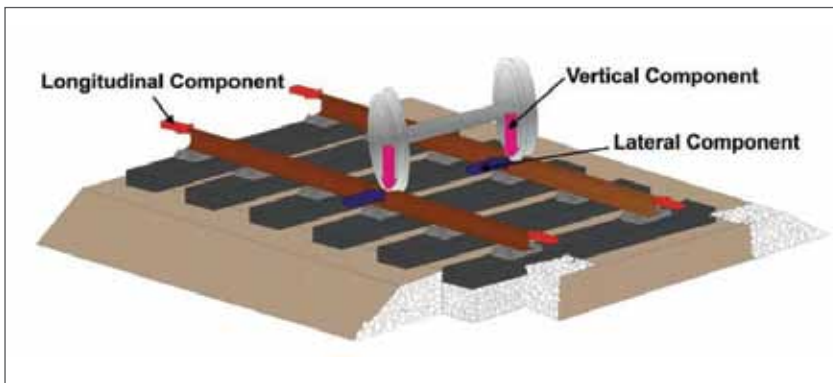
to centrifugal force, a component for crosswind, and dynamic lateral forces.

By determining the strains and stresses induced by lateral forces in the gauge bar at different sections of the TMT test section, and investigating the strains and stresses throughout the top of the gauge bar of a TMT system, the researchers were able to confirm how the results can be optimised to enhance the performance of the TMT system with regard to the gauge bar.

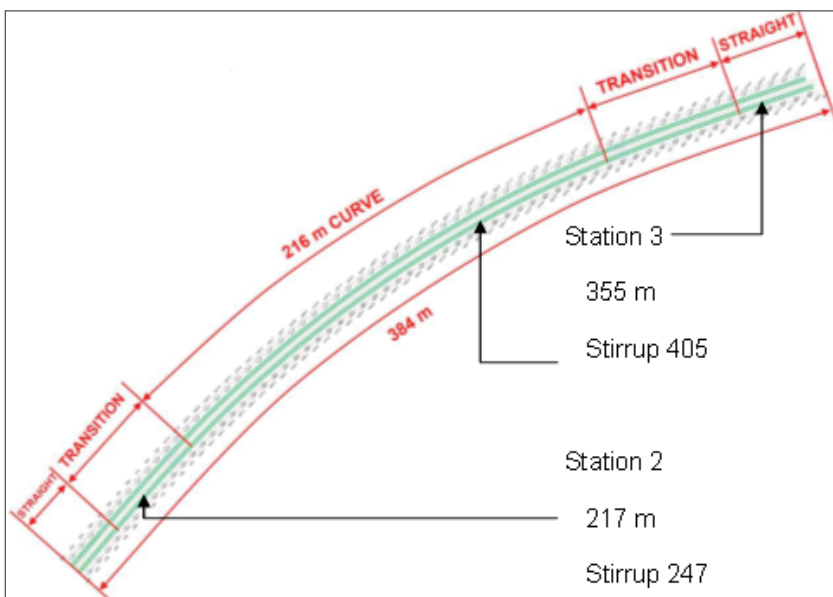
Three gauge bars were used for the testing: one on the tangent portion of the track, one in the transitional curve and one in the circular curve (see Figure 3). Installing them at different



→ Aerial photograph of the testing site.



→ Figure 2: Schematic illustration of forces acting on track structures



→ Figure 3: Track layout showing the testing stations

sections enabled the researchers to identify the portion of the track in which the highest lateral forces were generated.

Strain gauges were installed at different positions along a gauge bar in each of the abovementioned sections of the track (see Figure 4). As the trains passed the test section, the strains could be measured and recorded.

Typical results obtained from the strain gauge readings are illustrated in Figure 5, which shows the strains of all seven strain gauges of one gauge bar as a single train passes. Positive values indicate compression and negative values indicate tension. The highest peak values coincide with the wheels of the motorised coaches (weighing 60 metric tons) and the lower peaks represent the carriages (weighing 30 metric tons).

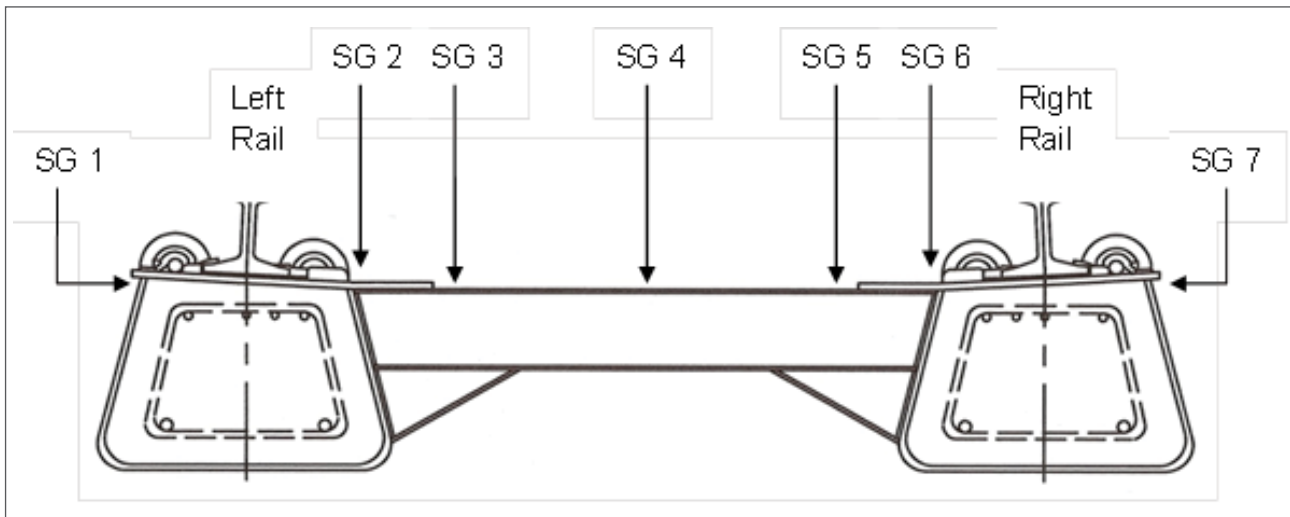
The strains measured were used to calculate the stresses throughout the top of the gauge bar and are indicated as maximum calculated stresses in Figure 6.

### Research findings

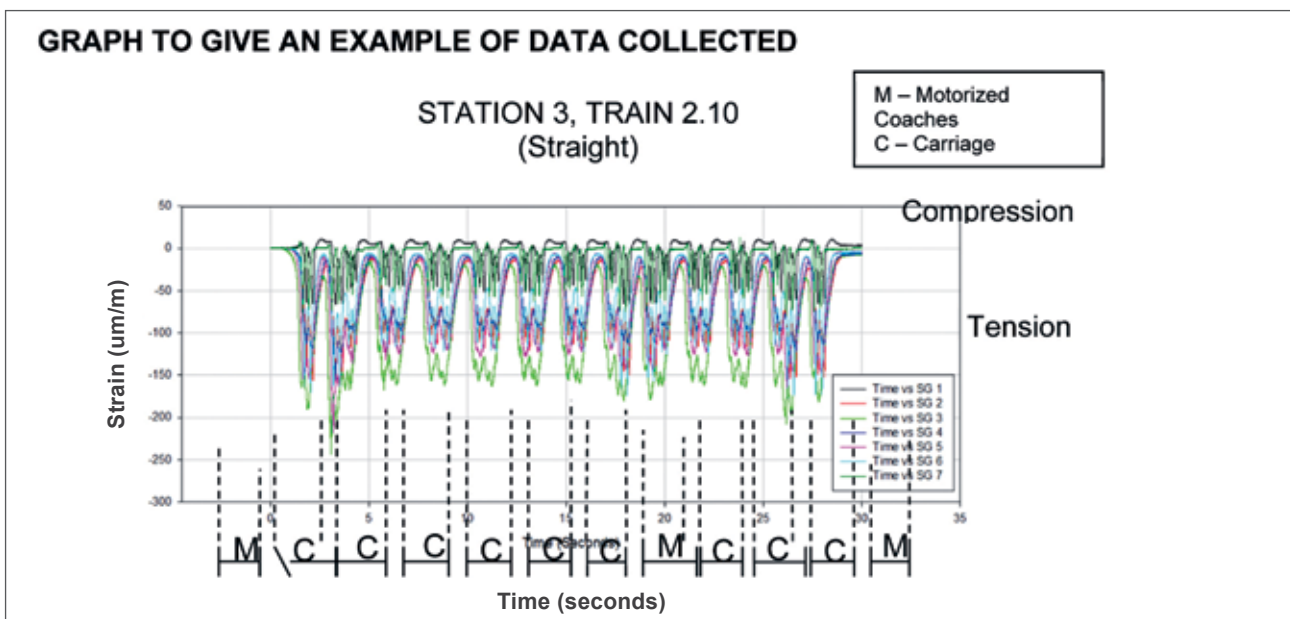
The largest stresses were found to be generated in the transitional curve, but some exceptions were measured where the maximum was located in the circular curve as a result of the relative lateral movement of the train as it travelled through the curve.

Different strain measurements were obtained along the top of the gauge bar, but the highest stresses were measured next to the weld that connected the gauge beam and the shoulder plate. The high peak stresses were believed to be a result of the welding, as well as the change in stiffness between the combined action of the gauge beam and the shoulder plate in comparison with the gauge beam only.

As illustrated, gauge bars can be subjected to tension, as well as compression forces. The top of the gauge bar, between the two rails, experienced tension, regardless of its position on the track. In the transition



→ Figure 4: Placement of the strain gauges on the gauge bar



→ Figure 5: An example of the data collected

zone, the outside of the gauge bar was in pure tension and in the circular curve in pure compression. However, on the straight portion of the track, the outside of the gauge bar experienced compression first as the train wheel neared the gauge bar, then tension as the wheel reached the gauge bar, and finally compression as the wheel of the train moved away.

The two main factors to influence the stresses in the gauge bar were identified as the weight and the speed of the train. As the researchers expected, the heavier the train, the higher the stresses that were measured. On the other hand, it was observed that higher speeds resulted in lower gauge bar stresses.

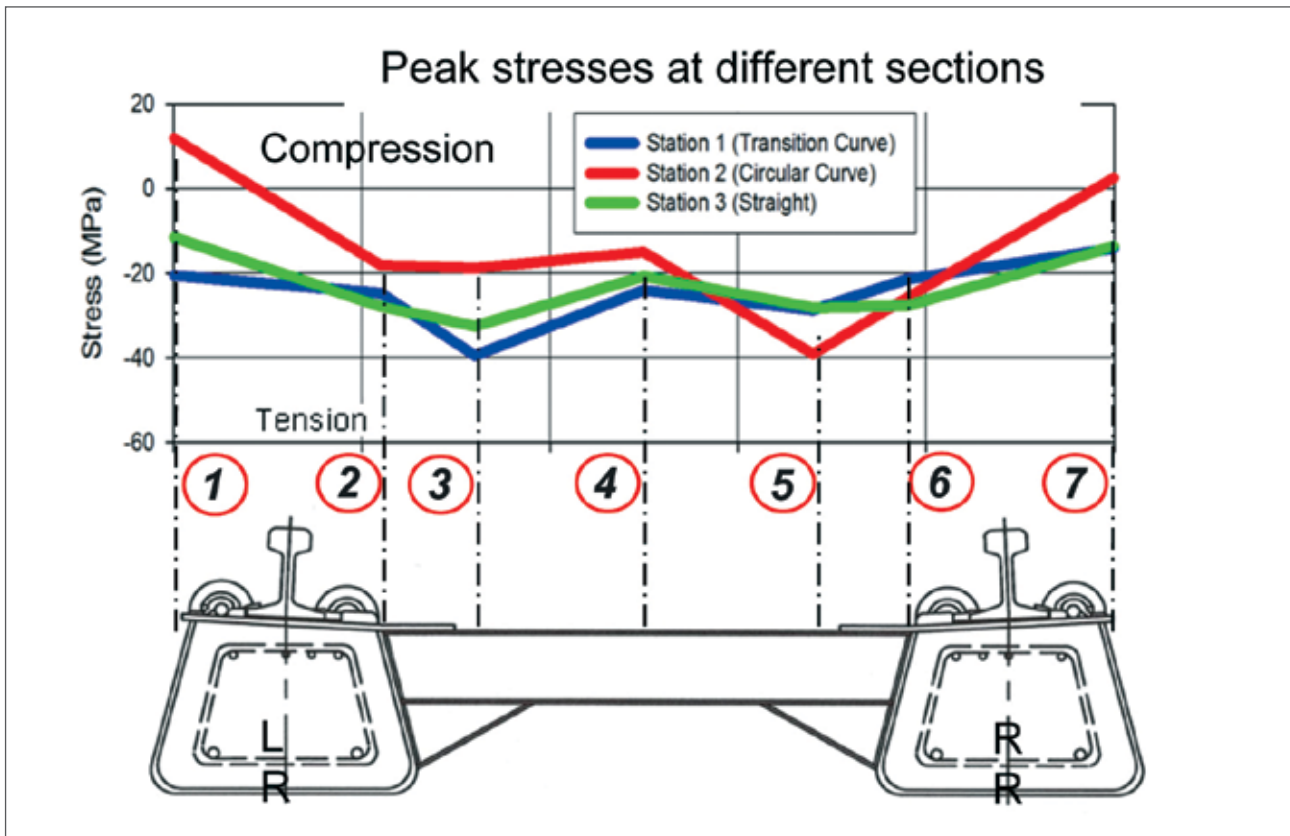
This can be explained in terms of the balancing speed of this specific curve. Due to the close proximity of the site to the station, most trains travelled at lower speeds than that for which the curve was designed. This excess in superelevation at low speed is responsible for the unbalance in lateral forces and the resultant higher gauge bar stresses.

The researchers concluded that when designing gauge bars for Tubular Modular Track, designers should consider that the gauge bar can experience tension and compression forces, as well as compression stresses, depending on the position of the gauge bar on the track section. 📍

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→ Figure 6: Stresses along the top of the gauge bar

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**Prof Hannes Gräbe** is the incumbent of the Chair in Railway Engineering in the Department of Civil Engineering, Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria.

## The Chair in Railway Engineering at the University of Pretoria

The Chair in Railway Engineering in the Department of Civil Engineering at the University of Pretoria was established in 1992 when Spoornet (now Transnet Freight Rail) initiated a partnership between industry and the University. This partnership revolves around three major aspects: graduate training, continuing education courses for industry, and railway research. The chairholder is Prof Hannes Gräbe, a civil engineer with 16 years' experience in track technology, track geotechnology, advanced laboratory testing, field investigations, maintenance models and numerical analysis of track structures. He lectures undergraduate and postgraduate courses in railway engineering, and is responsible for railway research, as well as continued professional education in the form of short courses presented to industry.

After completing his undergraduate studies at the University of Pretoria in 1994, Prof Gräbe joined Transnet Freight Rail's Track Technology Centre, Johannesburg. He studied abroad from 1999 to 2002 and obtained a PhD in Geotechnical Engineering from the University of Southampton (UK). This research was focused on the design life prediction of railway foundations under heavy axle loading.

He is a registered professional engineer, Fellow of the South African Institution of Civil Engineering (SAICE) and chairperson of the SAICE Railway and Harbour Division.

# Science in South Africa: The dawn of a renaissance?<sup>1</sup>

Prof Anastassios Pouris

During the last ten years, science in South Africa has been the subject of a multitude of changes. Not least of these is the change to the rating of scientists by the National Research Foundation (NRF). Provided that the plan of the Minister of Science and Technology to increase the research and development expenditure in the country materialises, South Africa may be on the verge of a scientific renaissance.

In a scientometric analysis of South Africa's research performance during 2000–2010, it was found that a multitude of government initiatives had been introduced, the effects of which were evident in the country's research outputs. In contrast with earlier investigations, it was found that South Africa's world share of publications is on the verge of reaching the highest contribution ever. South Africa improved its international ranking by two positions during this period, and was ranked 33rd in the world during 2010.

## Background

In 2001, social scientists joined their peers in the natural sciences and engineering to participate in the evaluation and rating system of the NRF, which is based solely on previous performance and research outputs. In 2007, the Department of Science and Technology (DST) introduced the Ten-year Innovation Plan, and established the Technology Innovation Agency and the South African National Space Agency during 2008. The Intellectual Property Rights from Publicly Financed Research and Development Act (Act 51 of 2008), was also promulgated in 2008.

The Ten-year Innovation Plan sets high objectives for the innovation system in the country, and has the following vision:

- Be one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity.
- Deploy satellites that provide a range of scientific, security and specialised services for the government, the public and the private sector.
- Achieve a diversified, supply-secured sustainable energy sector.

- Achieve a 25% share of the global hydrogen and fuel cell catalysts market with novel platinum group metal catalysts.
- Be a world leader in climate science and the response to climate change.
- Meet the 2014 Millennium Development Goal to halve poverty.

Similarly, the Department of Education (as it was then known) introduced the New Funding Formula (NFF) for higher education institutions in 2003.

According to this formula, higher education institutions are supported financially on the basis of their research outputs (number of publications and number of postgraduate students produced).

The pinnacle of all initiatives was probably the DST's Strategic Plan for 2011–2016, which was accompanied by a statement by the Minister of Science and Technology that "South Africa will be able to spend R45 billion on research and development by 2014 and reach its target for gross expenditure on research and development of 1.5% of GDP".

The DST indicated that during 2008/09, the country spent R21 billion (or 0.92% of GDP) on research and development.

These initiatives should be seen in the context of past assessments, which had invariably identified a decline in the country's science outputs.

## South Africa's research performance

The research conducted to identify South Africa's science performance up to 2010 focused on how South African science has fared during the last decade, how South Africa's share of

1. This article is based on a paper published in the *South African Journal of Science*, 108(7/8): 1018, by Prof Anastassios Pouris of the Institute for Technological Innovation at the University of Pretoria.

world publications has changed during the past decade, and which major scientific disciplines were emphasised by the country's research system in terms of activity and impact.

For bibliometric analysis (the research methodology used), an appropriate database is required. The ISI-Thomson Reuters databases (Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index) were identified as the most appropriate for this study, as they cover the most prestigious journals in the world in all fields and constitute a unique information platform.

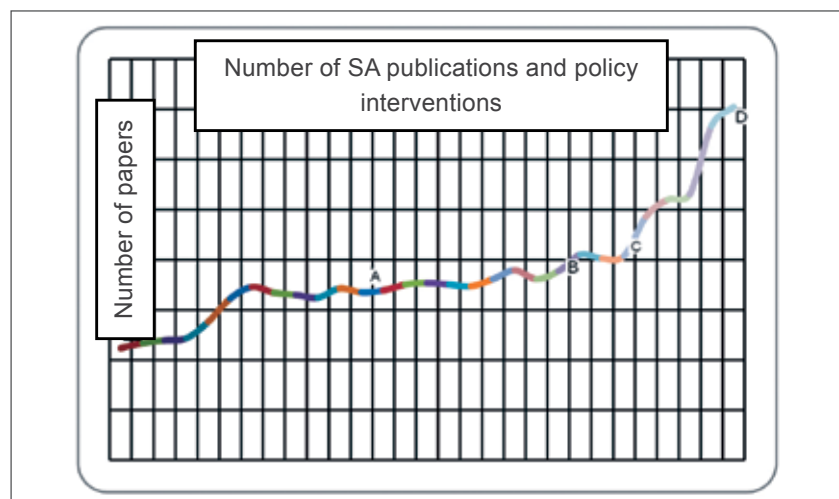
For South Africa, the ISI Thomson Reuters databases are particularly appropriate, as the educational authorities and universities direct researchers to publish mainly in the journals covered by these databases. The indicators of research activity are the country's contribution in terms of the number of publications in the international literature, the country's share in the world literature, the activity index and the relative citation index. The activity index is the ratio of the country's share of the world publication output in a given field to the country's share of the world publication output in all science fields. An activity index of 1 indicates that the country's research output in the given field corresponds to the world average. A relative citation index above 1 indicates that the country's publications in the particular field attract more than average citations, while an index of less than 1 indicates that it attracts fewer citations.

### South Africa's research performance

An analysis of South African publications for the period 1980–2010 (see Figure 1), shows that after a long period of consolidating around 3 500 publications per year, the number rose steeply between 2004 and 2010. In 2010, the database contained 7 468 articles with at least one South African address. A similar analysis of the country's share of the world's publications for the same period (see Figure 2) indicates a peak during 1987 (0.65%) and then a decline, with the lowest point in 2003 (0.47%). Since then, the share gradually increased to 0.65% in 2010.

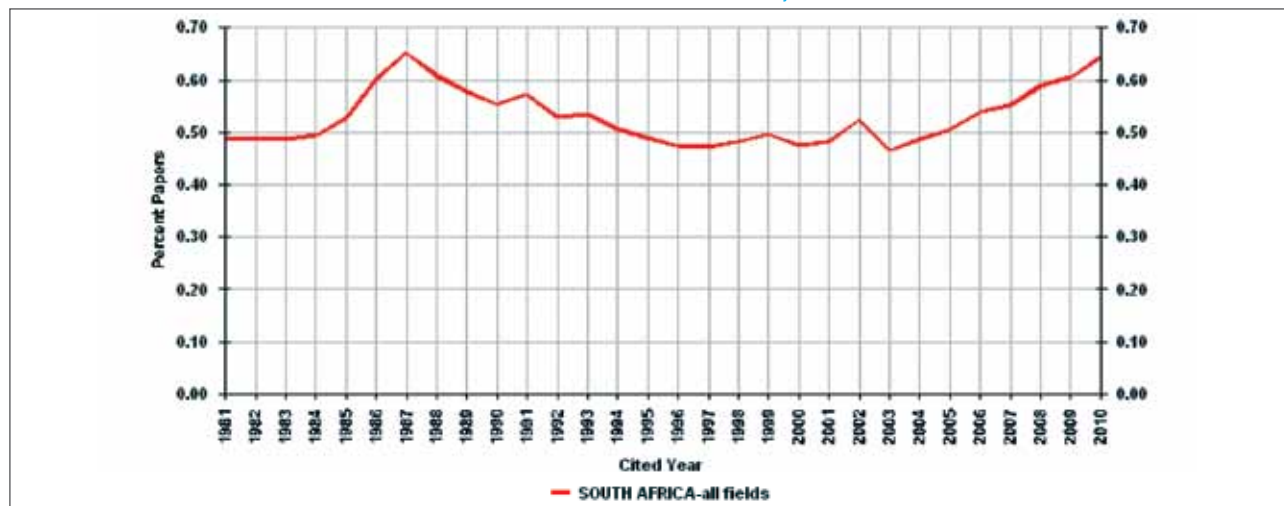
These figures should be examined in context. Even though South Africa had improved its ranking since 2000 by

only two positions in 2010, it more than doubled its number of publications. During that period, South Africa also overtook Argentina, New Zealand, the Ukraine and Hungary. However, Portugal and Iran overtook South Africa. It is interesting that Brazil, Russia, India and China (the BRIC countries) are all scientifically stronger than South Africa in terms of research. In 2010, China produced 124 822 publications, India 40 711, Brazil 31 274 and Russia 26 374. South Africa produced only 7 468 (see Table 1). The performance of the country's main scientific disciplines was also investigated. In an analysis of the world share and activity indices of 22 scientific disciplines for the two periods 2000–2004 and 2006–2010, only geosciences, molecular biology and multidisciplinary research exhibited a decline.



→ Figure 1: Trend in South African publications (1981–2010) amid policy interventions

A: Sanctions were lifted. B: Social sciences were incorporated in the NRF. C: Introduction of the NRF. D: ISI increases the number of South African journals indexed.



→ Figure 2: South Africa's share of world publications in all fields (1981–2010)

→ Table 1: Country ranking according to number of publications in 2000 and 2010

Ranking	Country	Publications 2000	Ranking	Publications 2010
1	USA	255 099	1	330 339
2	Japan	72 029	5	72 607
3	UK	71 775	3	90 004
4	Germany	67 272	4	86 978
5	France	48 065	6	62 324
6	Canada	33 649	7	53 519
7	Italy	31 157	8	50 691
8	Russia	28 629	15	26 374
9	China Mainland	24 566	2	124 822
10	Spain	22 230	9	43 693
11	Australia	21 386	12	38 753
12	The Netherlands	19 169	14	30 532
13	India	16 538	10	40 711
14	Sweden	15 055	19	19 770
15	Switzerland	14 185	17	21 960
16	South Korea	13 448	11	39 397
17	Brazil	10 465	13	31 274
18	Belgium	9 977	21	16 535
19	Poland	9 751	20	19 192
20	Israel	9 678	24	11 574
21	Taiwan	9 652	16	23 715
22	Denmark	7 900	23	11 702
23	Finland	7 494	27	9 777
24	Austria	7 105	25	11 284
25	Turkey	5 303	18	21 846
26	Norway	4 896	28	9 227
27	Greece	4 876	26	10 105
28	Mexico	4 862	29	9 170
29	New Zealand	4 465	34	7 172
30	Argentina	4 402	35	7 123
31	Czech Republic	4 322	32	8 684
32	Ukraine	4 306	43	4 422
33	Hungary	4 105	41	5 061
34	Singapore	3 634	31	8 811
35	South Africa	3 617	33	7 468
36	Portugal	3 141	30	8 975
37	Ireland	2 697	36	6 492
38	Egypt	2 290	39	5 386
39	Romania	1 955	37	6 356
40	Chile	1 906	42	4 623
41	Slovenia	1 616	45	3 193
42	Iran	1 291	22	16 391
43	Thailand	1 232	40	5 155
44	Malaysia	859	38	5 664
45	Pakistan	620	44	4 232

Plant and animal sciences remained static, contributing to 1.57% of the world literature. The activity indices for 2006–2010 show that space science, immunology and social sciences have moved into the fields of revealed priorities that are overemphasised in the country (activity index above 1).

However, a number of important disciplines like materials science, molecular biology and engineering are underemphasised. Social sciences appear to be the discipline with the highest growth (growing from a world share of 0.52% during 1990–1994 to 1.22% during 2006–2010).

In an analysis of the relative citation index (an indicator of research quality) of the various disciplines for the periods 2000–2004 and 2006–2010, only three disciplines appear to have dropped in ranking during the period: computer science, molecular biology and psychiatry/psychology. The country's relative citation index moved from 0.69% during 2000–2004 to 0.88% during 2006–2010.

An analysis of South Africa's scientific performance during 2000–2010 shows that research publications in South Africa are on an ascending path, and the country's world share of publications is on the verge of reaching the highest contribution in history.

### Forces that contributed to the growth of science in South Africa

In an article on some trends and implications of a bibliometric analysis of South Africa's scientific outputs, Michael Kahn (published in the *South African Journal of Science* in 2011) suggested that the growth in the country's publications for the periods 1990–1994 and 2004–2008 was the result of a number of factors. "There are greater rewards for publishing; there is a shift towards health science fields with high publication rates, there are more South African journals indexed by the Web of Science... there may be more PhD students available to assist with research and the system is more open [to] co-publication with foreign parties."

Changes that may have affected the country's publication performance include the introduction of social sciences into the NRF's responsibilities, more publications being covered by the ISI Thomson Reuters databases and the provision of incentives by the Department of Education.

In a scientometric impact assessment of the NRF rating system, Dr Roula Inglesi-Lotz and Prof Anastassios Pouris of the University of Pretoria's Institute for Technological Innovation used the before/after control impact (BACI) method to identify the impact of the NRF rating system on social sciences publications in the country.

→ Table 2: South Africa's world share and activity indices by discipline

Discipline	2000–2004	Activity index	2006–2010	Activity index
Agriculture science	0.58	1.18	0.70	1.19
Biology and biochemistry	0.35	0.71	0.54	0.92
Chemistry	0.31	0.63	0.39	0.66
Clinical medicine	0.40	0.82	0.45	0.76
Computer science	0.22	0.45	0.28	0.47
Economic and business sciences	0.46	0.94	0.86	1.46
Engineering	0.32	0.65	0.38	0.64
Environmental/ecology	1.26	2.57	1.39	2.36
Geosciences	1.19	2.43	1.09	1.85
Immunology	0.49	1.00	1.09	1.85
Materials science	0.25	0.51	0.28	0.47
Mathematics	0.46	0.94	0.58	0.98
Microbiology	0.57	1.16	0.78	1.32
Molecular biology	0.25	0.51	0.24	0.41
Multidisciplinary	2.93	5.98	1.60	2.71
Neuroscience and behaviour	0.17	0.35	0.22	0.37
Pharmacology and toxicology	0.39	0.80	0.42	0.71
Physics	0.24	0.49	0.28	0.47
Plant and animal science	1.57	3.20	1.57	2.66
Psychiatry/psychology	0.45	0.92	0.69	1.17
Social sciences, general	0.76	1.55	1.22	2.07
Space science	0.89	1.82	1.05	1.78
Overall country	0.49		0.59	

→ Table 3: Relative impact of South Africa's publications during 2000–2004 and 2006–2010

Discipline	Relative impact 2000–2004	Relative impact 2006–2010
Agriculture science	0.74	0.82
Biology and biochemistry	0.56	0.81
Chemistry	0.65	0.70
Clinical medicine	0.86	1.15
Computer science	1.10	0.90
Economic and business sciences	0.38	0.40
Engineering	0.81	0.85
Environmental/ecology	0.83	0.95
Geosciences	0.79	0.89
Immunology	0.71	1.09
Materials science	0.76	0.77
Mathematics	0.82	1.12
Microbiology	1.00	1.27
Molecular biology	0.79	0.76
Multidisciplinary	0.36	0.41
Neuroscience and behaviour	0.63	0.71
Pharmacology and toxicology	0.58	0.70
Physics	0.71	0.93
Plant and animal science	0.72	0.93
Psychiatry/psychology	0.67	0.61
Social sciences, general	0.81	0.86
Space science	0.77	1.35
Overall country	0.69	0.88

They found that the number of social sciences publications in South Africa had increased by 24.7% after 2001 because of their inclusion in the NRF's evaluation and rating system. However, the discipline contributed only 10.6% to the country's publications in 2008.

The NFF for higher education institutions appears to have played an important role in the increase of the number of publications in South Africa. According to this funding formula of the Department of Higher Education and Training, higher education institutions in South Africa receive financial support according to their research outputs (number of publications and number of postgraduates). Universities, in turn, provide incentives to staff to improve their publication profiles. 📌

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## About the author



**Prof Anastassios Pouris** is Director of the Institute for Technological Innovation at the University of Pretoria. His

research is focused on science, technology and innovation policy studies, including assessments and international benchmarking. He has been a member of the editorial boards of the *International Journal: Scientometrics* and of the *South African Journal of Science*. He is also a member of the *Institute of Management Development (IMD) World Competitiveness Report*.



# Health care service science: The innovation frontier

Dr Richard Weeks

Health care facilities function in an environment that is characterised by complex interacting multidisciplinary systems, which tend to produce unexpected circumstances. It is these circumstances and their impact on communities that place health care at the innovation frontier. This is where traditional paradigms are no longer effective in dealing with the complex situations that arise when unexpected events occur.

The circumstances change frequently and it is necessary for stakeholders in the health care industry to re-evaluate their systems and practices. There are trends that could play an important role in shaping the life world of communities and health care institutions. In his book, *The wisdom of crowds* (2005), James Surowiecki states that navigating uncertainty requires “the wisdom of crowds”, as no single person has the answers that are necessary to deal with the uncertainty that unforeseen events create. This truth forms an important part of navigating health care facilities through difficulty.

According to Surowiecki, groups of people are more intelligent under some circumstances than individuals are. Often this wisdom of crowds manifests by a group of people with different experiential backgrounds and insights coming together.

## A health care service delivery framework

Figure 1 illustrates the diverse systems that play a role in providing solutions for health care service delivery issues. It is the collective human intelligence that develops from these diverse streams that is crucial to finding the appropriate solutions to problems.

The importance of enabling a collective intelligence to find solutions cannot be overemphasised. In general, individuals have less information, limited foresight and are less capable of finding insightful solutions. Despite these limitations, their collective judgments often produce excellent solutions. Consequently, the collective wisdom of stakeholders in health care service delivery should be used to find innovative solutions to national health care service delivery issues.

These stakeholders include medical practitioners, technologists and economists. The current and

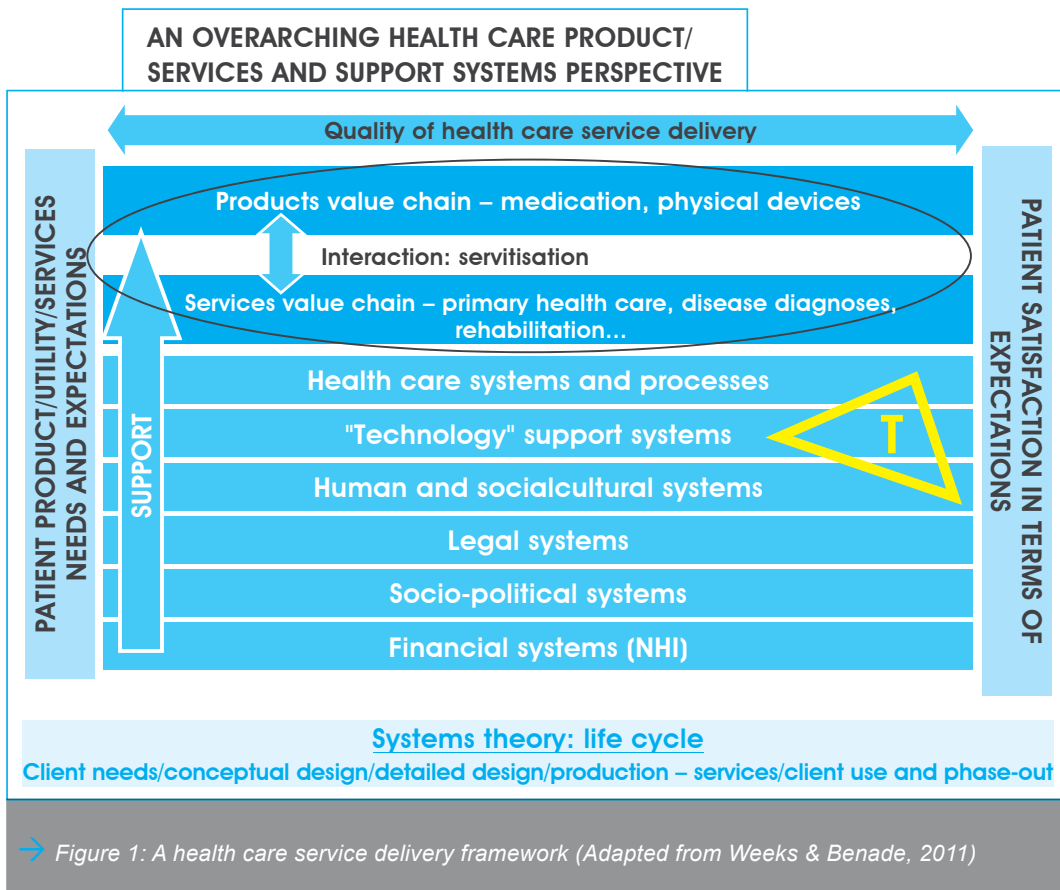
developing frontiers that need to be crossed are defined by the collective thinking of all these stakeholders. The ethical commitment to enhancing health care service delivery to South Africans, as envisaged in the National Health Insurance (NHI) initiative, is also important.

Traditional health care tends to assume a curative orientation, while the contemporary trend of social innovation is directed at adopting preventive primary health care (PHC). The latter assumes a multidisciplinary approach, with technology playing an enabling role and the community becoming part of the health care service delivery infrastructure.

With community health care workers using mobile health technology systems, the emphasis is on economical preventative care. It is a multidisciplinary approach, as social workers, psychologists, health care practitioners, nurses and similar community-based knowledge resources can be used. Students from local academic institutions (medical students in particular) are frequently involved at clinics and community centres and bring an increased capacity into the PHC innovation frontier.

There is a shortage of health care professionals and resources, and an innovative, preventive stance within such a setting can play a significant role. The tailoring of services and technologies that enable health care workers to provide specific services to patient groups, such as diabetics, also establishes preventive care to communities. It is the PHC services and the wisdom of the collective service providers that bring innovation to the forefront in facilitating health care service delivery.

Building health care infrastructure in rural South Africa is difficult. Telemedicine solutions are constantly



in the new NHI dispensation, and establishing a culture of learning will be a challenge.

Wolfgang Grulke and Gus Silber, in their book *Lessons in radical innovation: South Africans leading the world* (2010), confirm the fractal nature of extensive innovation because the outcomes are unpredictable. There are sudden divergence points and even small changes that can have unforeseen consequences. The convergence of e-health technologies, applied in a significantly

being researched, tested and implemented. However, South Africa has major connectivity and bandwidth challenges. Technological innovations in the delivery of health care services will require a new or extended infrastructure.

Currently, mobile technology research is making a broad spectrum of new PHC devices and services available to communities. Unfortunately, network connectivity and bandwidth availability has not kept up with new technologies, and this remains a constraint in the application of these technologies. Skills and knowledge transfer is also problematic. Advances made in one sphere enable advances in another sphere. This process allows stakeholders to effectively cross the innovative frontier of health care service delivery.

### A new business model

The business model of health care service provision has undergone an improvement-driven transformation that will be motivated by the introduction of the government's NHI initiative. A transformation of health care service

delivery, an overhaul of the health care system and a change of administration will form the foundation of the new business model.

The provision of a comprehensive care package underpinned by re-engineered PHC, as envisaged in the NHI policy document issued by the Department of Health in 2011, is also an integral part of this business model. The current, curative-orientated business model will no longer be effective within this transformed health care dispensation. Instead, the focus will be on preventive PHC. Most of the health care-related support systems contained in Figure 1, as well as the PHC value chain itself, will be scrutinised in the development of this business model.

An important feature of the transformation of the health care business model will be the realignment of skills and knowledge. It is argued that a culture of learning should form the foundation of the new health care business model and it should be determined if such a culture exists within the prevailing health care dispensation. Engendering different mindsets, values, beliefs and methods

transformed NHI dispensation, will hardly follow a well-planned linear path. It will rather reflect points of divergence. These can either create opportunities or negative consequences that should be managed on a complex, adaptive systems basis.

According to Grulke and Silber, bold and visionary individuals are at the heart of radical innovation strategies. These individuals do not like to be constrained by corporate cultures and perceptions of effective health care service delivery. Technological innovation and its application within the health care services sector are hardly going to wait for South Africa to move into a new health care dispensation. As stated in *Lessons in radical innovation: South Africans leading the world*, the future is no longer tethered to the past. As new technologies converge to open possibilities in PHC and the treatment of chronic diseases, they will need to be explored and integrated into the new health services delivery framework.

As reflected in Figure 1, e-health technology assumes both a technology systems convergence and a human element. In some instances, innovative

mobile health technologies are already being successfully implemented at some health care institutions. The envisaged system undoubtedly embodies a number of human factors that need to be considered. These include the training of health care workers in the use of mobile devices, the capturing of patient information and technology support.

There are concerns at the back-end of the system. These include the securing of patient confidentiality and information security. Patient trust in the system and information confidentiality is important, as even a minor breach can disrupt the system. There are also the issues of technology, knowledge transfer, socio-legal and ethical considerations, PHC processes and other systemic issues that converge within the context of electronic health care records. These factors are vital for effective patient-centred health care service delivery. Consider the number of clinics, wards and health care workers involved, and the challenges associated with a national e-health infrastructure to support PHC becomes a radical frontier to transcend.

Innovative technology is the world of networks, databases, servers, main frames and cloud computing. Some health care practitioners may not understand this jargon, but the health care jargon is equally confusing to information and communication technology (ICT) professionals. Add to this the jargon associated with management, law and politics, and it becomes complex.

The stakeholders have different perspectives of innovative health care service delivery, and it is difficult to consolidate all their ideas. From the preceding discussion, it is clear that finding innovative health care solutions for a future South African health care dispensation requires a new mindset and a multidisciplinary skills base. It could be argued that such a skills base is only possible once a culture of learning has been established.

### The transition to a new health care dispensation

As stated above, the different disciplines should effectively interact

with each other in order to deal with the complex challenges in health care institutions. The profile of people required to bring about a new health care dispensation is in essence reflected in *Succeeding through service innovation: A service perspective for education, research, business and government* (2008), published by the Institute for Manufacturing (IfM) of the University of Cambridge, together with International Business Machines Corporation (IBM).

This publication describes T-shaped professionals as being people “who are deep problem-solvers in their home discipline, but also capable of interacting with and understanding specialists from a wide range of disciplines and functional areas”. Perhaps the changing South African health care landscape requires professionals with varied strategic skills and experience in mastering multifaceted challenges. This is exactly what T-shaped people possess.

In an online article, “Strategy by design” (<http://www.fastcompany.com/52795/strategy-design>), Tim Brown states: “We look for people who are so inquisitive about the world that they’re willing to try to do what you do. We call them ‘T-shaped people’. They have a principal skill that describes the vertical leg of the T... But they are so empathetic that they can branch out into other skills... They are able to explore insights... and recognize patterns of behavior that point to a universal human need. That’s what you’re after at this point – patterns that yield ideas.”

Notably, the vertical leg of the “T” would apply equally to health care practitioners and other professionals in the health care industry. The transition to a new health care dispensation that can ensure a healthy life for South Africans will not only require planned strategies and policies. It will demand a change in traditional thinking, a culture of learning, people from diverse disciplines cooperating, and people with a “T-shaped” skills profile. The focus will be on managing unexpected events and the challenges that can occur in a new dispensation.

Undoubtedly, traditional top-down hierarchical management practices will need to make way for multidisciplinary involvement at a grass-roots level. In a volatile transformation, making sense of the situation is complex and traditional management approaches no longer appear effective. Accessing the “wisdom of crowds” is becoming more pertinent. Management structures should be resilient or they will fail when unexpected circumstances occur. This will have an immense impact on the future dispensation. 📍

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### About the author



**Dr Richard Weeks** established the *Engineering Services Management* domain at the Graduate School of *Technology Management* and has of late been extensively involved with students researching health care services delivery from a *National Health Insurance* perspective.

# Assisting California to lower transportation-related costs

Prof Wynand Steyn

Research conducted in the University of Pretoria's Department of Civil Engineering is assisting California to lower transportation-related costs. A pilot study used vehicle-pavement interaction (V-PI) principles and other tools to measure the peak loads and vertical acceleration of trucks and freight on different pavement surface profiles. This study was limited to the State Highway System (SHS) and a district of the California Department of Transportation (Caltrans).

The purpose of the study was to gather information from simulations and measurements, track truck logistics (and costs, if available), and provide input for an economic evaluation based on V-PI principles and a freight logistics investigation. The findings of the research will be used to improve Caltrans's decision-making and help manage the pavement network more effectively. The decisions taken (in other words, whether to resurface and improve riding quality or delays) will have an economic effect.

The researchers also examined links to available information, pavement construction specifications and roadway maintenance, in order to make an economic evaluation of the effects of delayed road maintenance, which could lead to deteriorated riding quality and subsequent increases in vehicle operating costs, as well as vehicle and freight damage. The information provided would support Caltrans's freight programme and legislation.

Challenges, operational concerns and strategies were also identified, as well as costs to the economy and the transportation network (delay, packaging and the environment).

The results of the study could lead to improved pavement policies and practices, such as strategic recommendations that link pavement surface profiles, design, construction and preservation with V-PI principles.

The study included a road inventory and a vehicle inventory. The purpose of the road inventory was to determine the condition of each of the routes in each district that has the necessary data available. Certain routes in California were identified and a database containing road profiles and riding quality data was developed.

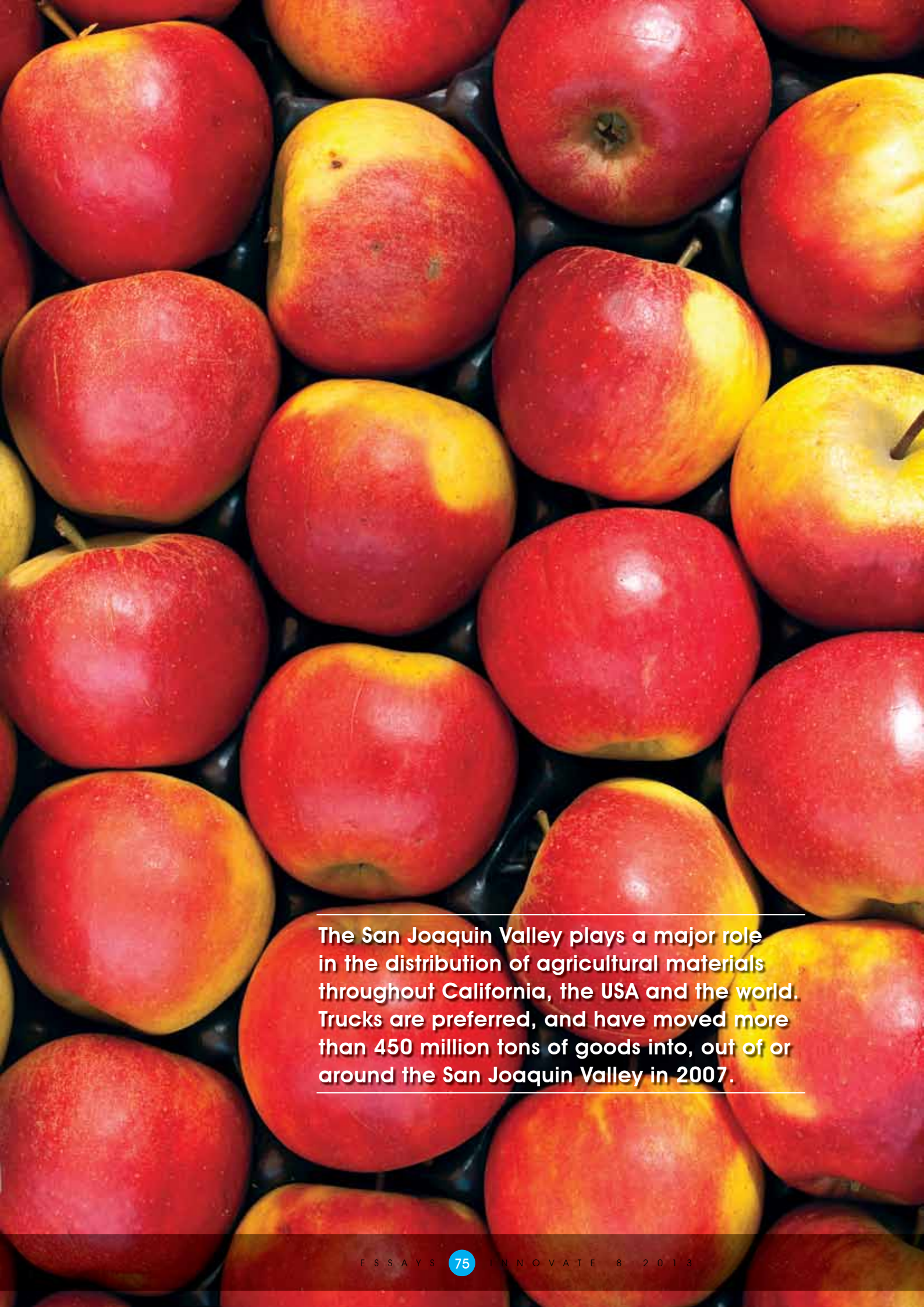
The purpose of the vehicle inventory was to provide a summary of the current vehicle population per standard Federal Highway Administration

(FHWA) vehicle classification by Caltrans. Based on the FHWA truck classifications, commodity flow analysis and weigh-in-motion (WIM) data, the following was determined:

- The most common truck types used were FHWA Class 9 and 12 (up to 48% of the trucks on selected routes), followed by Class 5.
- High truck flows were observed in District 6 in the San Joaquin Valley.
- Axle load spectra were heavier at night than during the day.
- Axle load spectra and truck type distribution showed very little seasonal variation.
- Axle load spectra were much higher in the Central Valley than in the Bay Area and Southern California, particularly for tandem axles.
- More than 90% of truck traffic travelled in the outside (two-lane highways) or two outside (three-lane highways) lanes.
- Truck speeds ranged between 80 and 120 km/h.
- Steering axles and trailer axles mainly used leaf suspension, while drive axles used air suspension.

The study produced a detailed report on the available data sources and required analyses for the project, which included indications of the potential links between the outputs of this project and the inputs for various economic and planning models.

A commodity flow survey provided data that indicated that the highest percentage of commodities (in terms of value, tons and ton-miles) transported by truck for the whole of California consisted of manufacturing goods, wholesale trade and non-durable goods. Truck transportation is the most frequent mode of freight transportation in California, and trucks are used to transport 82% of the freight shipped from California. Information on the



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The San Joaquin Valley plays a major role in the distribution of agricultural materials throughout California, the USA and the world. Trucks are preferred, and have moved more than 450 million tons of goods into, out of or around the San Joaquin Valley in 2007.

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→ Trucks are used to transport 82% of the freight shipped from California.

San Joaquin Valley revealed that this region of California comprises eight counties and 62 cities. It has a diverse economy and plays a major role in the distribution of agricultural materials throughout California, the USA and the world. Trucks are preferred, with more than 450 million tons of goods having been moved into, out of or around San Joaquin Valley in 2007. This is more than 85% of all tonnage associated with transportation of this type in the San Joaquin Valley. Trucks in this region rely on a combination of all levels of highways and roads. Key regional highways include the primary north-south corridors and the east-west corridors.

There are over 2 700 lane miles of truck routes in the San Joaquin Valley, with over 80% designated Surface Transportation Assistance Act (STAA) national truck routes. Mainly farm products (comprising 33% of the total outbound movements) are carried from the San Joaquin Valley. Stone and aggregates account for 18%, food and tobacco products around 10%, waste 6% and mixed freight 4% of the

total tonnage. The region contributes over 8% of the total GDP for the state of California and accounts for higher output in sectors such as agriculture (nearly 50%) and mining (25%).

The California Life Cycle Benefit/Cost Analysis Model (Cal-B/C) is used by Caltrans to conduct investment analyses of proposed projects for the interregional portion of the State Transportation Improvement Programme (STIP), the State Highway Operations and Protection Programme (SHOPP), and other analyses that require cost-benefit analysis. The following are potentially affected by the work conducted in this pilot study: roadway type, the number of general traffic lanes, the number of high-occupancy vehicle (HOV) lanes, HOV restriction, highway free-flow speed, current and forecast average daily traffic (ADT), hourly HOV and high-occupancy toll (HOT) volumes, truck speed and pavement condition.

The potential involvement of industry includes the following:

- GPS tracking and acceleration measurements on selected trucks travelling on designated state highway segments
- Truck trailer information, as entered into computer simulations of vehicles travelling over a range of pavements

The Models for Rolling Resistance in Road Infrastructure Asset Management Systems (MIRIAM) project aims to research sustainable and environmentally friendly road infrastructure by reducing vehicle rolling resistance and subsequently lowering CO<sub>2</sub> emissions and increasing energy efficiency. Links between the MIRIAM project and the pilot study lie in the potential use of selected rolling resistance models originating from MIRIAM in the evaluation of the effects of pavement roughness on vehicle energy use, emissions and rolling resistance. Initial MIRIAM studies indicated the following:

- Rolling resistance is a property of tyres and the pavement surface.

- A tentative source model for the pavement influence on rolling resistance contains the mean profile depth (MPD), pavement roughness (IRI) and pavement stiffness as significant pavement parameters.
- For light vehicles, the pavement roughness effect on rolling resistance is a third of the effect of the MPD, and it appears to be higher for heavy vehicles.

An origin-and-destination truck study for the primary north-south corridors indicated the following:

- Traffic volumes were mostly consistent for autumn and spring. Overall truck percentages were mostly higher in spring than in autumn.
- Little variance was observed in truck travel patterns between autumn and spring.
- The majority of trucks (83.8%) were of the five-axle double-unit type.
- About 70% of trucks were based in California and 47% of the California-based trucks were based in the San Joaquin Valley. Another 34% were based in Southern California.
- The top five commodities are food products (21%), empty trucks (18%), farm products (14%), miscellaneous freight (12%) and transportation equipment (4%).

The state of logistics in South Africa revealed that, for many years, the riding quality of a road has been used as the primary indication of the road quality. Studies on the effect of riding quality in terms of vibrations and responses in vehicles have shown that a decrease in the quality of a road is a major cause of increased vibrations and subsequent structural damage to vehicles.

These vibrations and structural damage to vehicles can have a negative effect on the transportation costs and economy of a country. Most transportation companies are affected by the increase in logistics costs due to inadequate road conditions. As these costs increase, the costs of products in the global marketplace increase, which affects the country's global



→ Damaged freight results in direct and indirect losses in revenue.

competitiveness. The potential savings in vehicle operating costs is significant when roads are in a good condition, compared to the estimated annual road maintenance costs per kilometre. The vertical acceleration when travelling over rough road surfaces may damage vehicles and cargo.

The economic impact of damaged agricultural cargo is absorbed differently by large-scale and small-scale farming companies.

Freight logistics revealed that damaged freight results in both direct and indirect losses in revenue. These operational repercussions depend on the type of freight, as well as the standard operating procedures of the shipper and receiver. These repercussions include the following:

- The product is sent back to the shipper for replacement, repair or repackaging, placing a burden on the reverse supply chain.
- The product is “written off” and the receiver disposes of it.
- The product must be reclassified as “damaged” before being sold.

Implications for the freight logistics aspect is the link to the Cal-B/C model. To perform a cost-benefit analysis of upgrading a stretch of road, potential freight damage savings accrued by the upgrade must be included in the Cal-B/C model. This requires cost calculations, which include calculations related to the type of goods, type

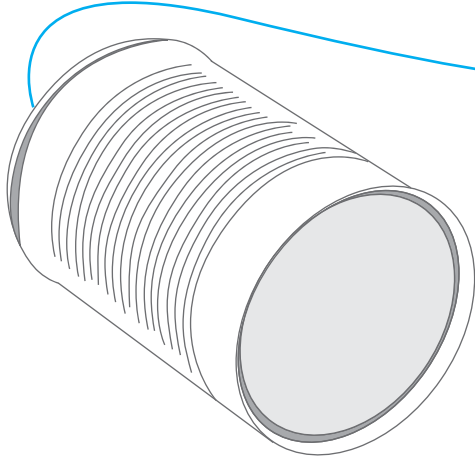
and attributes of the truck or trailer, and attributes of the roadway. The expected freight damage cost incurred by a particular type of shipment must first be quantified. The individual shipment costs are then calculated to provide higher-level cost estimates.

Based on the information obtained in this study, a good understanding was obtained of the SHS pavement conditions in California. This included riding quality and the major truck types, as well as the operational conditions on these pavements. 📍

#### About the author



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# The future of two-way radio in South Africa

Derrick Mogale and Dr Louwrence Erasmus

In general, the world has been moving from analogue to digital systems for quite a while now. This migration is also taking place in the area of two-way radio communication, but the digital uptake in South Africa is reasonably slow. Derrick Mogale, a radio frequency engineer, and Dr Louwrence Erasmus of the University of Pretoria conducted a survey to determine how stakeholders in the two-way radio industry see its future.

This study was the first one since the introduction of digital technology. It paves the way for the improvement of certain aspects of the research, as well as for taking research in the industry further. This study is designed to make the industry aware of the obstacles of digital technology adoption and the lack of knowledge on the new technology. Furthermore, the information collected could be used to evaluate the Technology Adoption Model (TAM) developed at the beginning of the study.

The survey took the form of an online questionnaire. Participants were divided into end-users and radio dealers to place all the role-players in the two-way radio (TWR) industry in South Africa in perspective. The questions were tailored in a specific way to test the TAM.

Of the 400 organisations invited to partake in the study, 161 responded. Interviews were held with three technology suppliers. Respondents were questioned on their opinions of the following external factors to the adoption of digital TWR technology:

- Affordability and cost
- Technology-readiness and availability

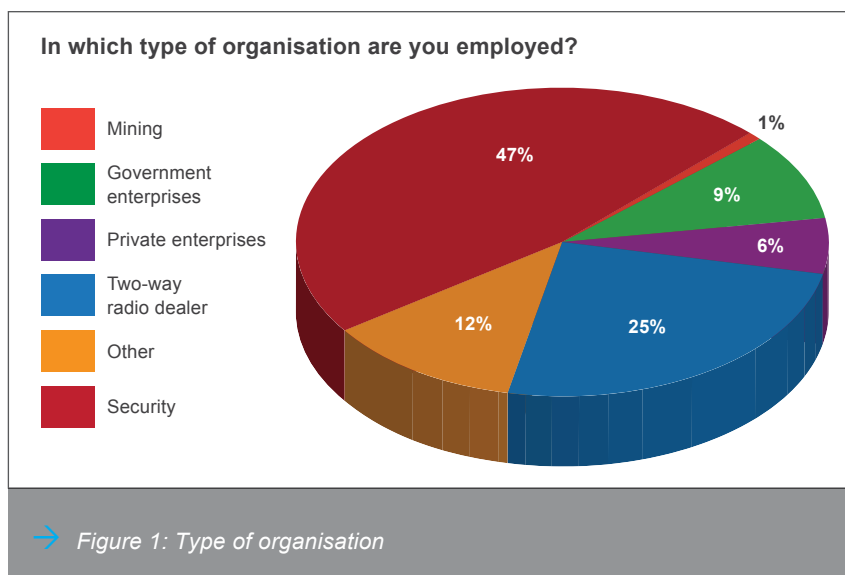
- Long-term benefits and added features of digital technology
- The standard regulator's influence on the adoption of technology
- The influence of industrial push and technology suppliers
- The influence of technology drag

## The results

General information on the industry stakeholders was first collected. Figure 1 represents the composition of the type of organisations that participated in the survey. Security companies constituted the majority of the respondents, followed by radio dealers. Mining organisations had the fewest respondents.

The study was aimed at technology managers, and the results show that 62.1% of those who responded were indeed in management positions. Approximately 20.5% of respondents fulfilled technical roles, 6.8% fulfilled sales roles, 2.5% fulfilled strategic roles and 8.1% fulfilled other roles in the organisation (total 100%).

In order to determine how far the migration process has progressed in South Africa, respondents had to indicate whether they used analogue or digital technology.





The results (see Figure 2) show that almost 85% of organisations still use analogue technology and about 9% have already adopted digital technology, including some departments of the South African Police Service.

These results validate the need for the study, since such a large percentage of organisations still use analogue systems. Approximately 6% of respondents indicated that they used other technology, such as cellular technology. Some also used both analogue and digital systems. The technology suppliers confirmed that there are devices that cater for both technologies.

### Affordability and cost

The affordability and cost of digital technology were investigated next, as these are vital factors influencing the migration from analogue to digital systems, especially in the current global economic climate. Affordability and cost were thus surveyed as viewed by the industry in relation to perceived usefulness, perceived ease of use, attitude towards use, behavioural intention to use and actual usage of digital technology. Most organisations (80%) believe that cost is a crucial factor in the adoption of digital technology.

The researchers tried to eliminate cost as an external factor to gauge the perceived ease of use of digital technology. The intention was to establish whether companies would have adopted digital technology if

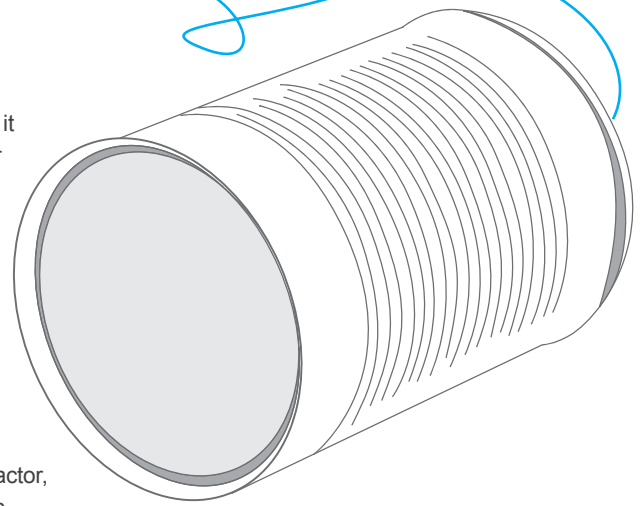
there was no cost barrier. From the results of the questionnaire, it was clear that the majority (over 85%) would adopt the digital technology, which proves that they viewed the technology as viable in the absence of cost as an external factor.

The behavioural intention of respondents to use digital technology, gauged against cost and affordability as an external factor, was also determined. The results indicated that the industry did not have a clear positive intention to adopt the new technology. Almost 39% of the respondents were undecided and 23% did not show any behavioural intention to adopt digital TWR. Although almost 38% of respondents indicated a positive behavioural intention towards adopting the new technology, the industry had doubts about the new technology.

The survey also attempted to determine actual use of the technology. The majority of companies (83%) believed that if the external factors were removed, they would actually be willing to adopt digital technology.

### Technology-readiness and availability

Another factor that was tested was the technology-readiness and availability of digital technology in South Africa. Respondents strongly agreed that digital technology would replace analogue technology in South Africa. The results showed that companies believed that the digital technology was ready and available to be adopted.

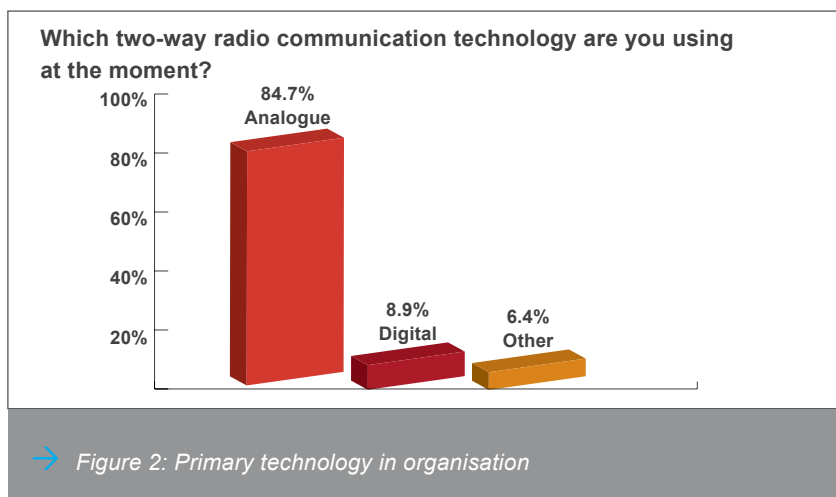


Less than 15% of respondents did not think that the technology was ready. A positive response of 66% indicated that digital technology was perceived as being easy to use. This is an indication of willingness to adopt the technology. Perceived usefulness was tested in relation to technology-readiness and availability, and 80% of respondents indicated that they thought digital technology was better than the technology they were using. The results also showed that respondents perceived the technology as being useful, which was an indication that companies would adopt the technology. In terms of respondents' actual use of digital technology, the survey results indicated that there was agreement by 61% of the respondents that the technology was ready and available to be adopted. This indicates that companies believed they would adopt and use digital TWR technology in the future.

### Long-term benefits and added features

The third factor that plays a role in the adoption of digital TWR technology is its long-term benefits and added features. Most respondents (88%) believed that digital systems have more features than analogue systems. This question was used to test respondents' attitudes towards the use of digital technology. The positive attitude towards the features of digital technology could lead to the adoption of the technology.

Respondents were also questioned about their perception of the long-term benefits and added features of digital technology.



The usefulness of digital TWR technology is related to the value the technology can add to companies' communication systems. The majority of respondents (85%) agreed that digital technology could indeed add value. The results clearly indicated that there was a strong belief that digital technology was perceived to be useful if adopted by companies.

If organisations intend to adopt the digital TWR technology, it can be seen as an indication of its long-term benefits in relation to the behavioural intention to use the technology. The results showed that there was consistency among respondents in their long-term adoption plans.

The actual use of digital TWR against the factor of long-term benefits and added features was also tested. Although the benefits and added value of digital technology were clear, almost 15% of respondents did not believe that their companies would adopt digital technology in the next three to five years, while 28% were undecided.

Respondents were also asked to rank the following features of digital technology in order of importance: enhanced security, spectral effectiveness, clear and enhanced voice quality, voice and data support, and other features (see Figure 3).

It is clear that respondents felt that all these features were more or less equally important. GPS and software

advantages were mentioned under "other".

### Standard regulator's influence

Next, the perceived influence of the standard regulator – the Independent Communications Authority of South Africa (ICASA) – on the migration of analogue to digital technology was ascertained. Almost 30% of respondents were not sure if the standard regulator influenced the adoption rate. A question was used to test the standard regulator as an external factor to the behavioural intention to use digital technology by organisations in South Africa. The results indicated that 52% of respondents thought that the government could determine and had an influence on digital technology adoption. There was also a 25% disagreement on the involvement of the regulator when it comes to adoption.

The actual use of technology influenced by ICASA as an external factor was also tested. Respondents felt that the government and the regulator could influence the actual use of digital technology in the country. On the question of how respondents felt about the regulator possibly forcing one standard of digital technology down on the industry, the responses were almost evened out. Although almost 38% agreed that they would adopt the selected standard, 33% were undecided and 29% disagreed.

### Influence of industrial push

The next aspect researchers investigated, was the influence of industrial push and technology suppliers on digital technology adoption. The majority of respondents agreed (84%) that the technology supplier played a vital role in digital technology adoption.

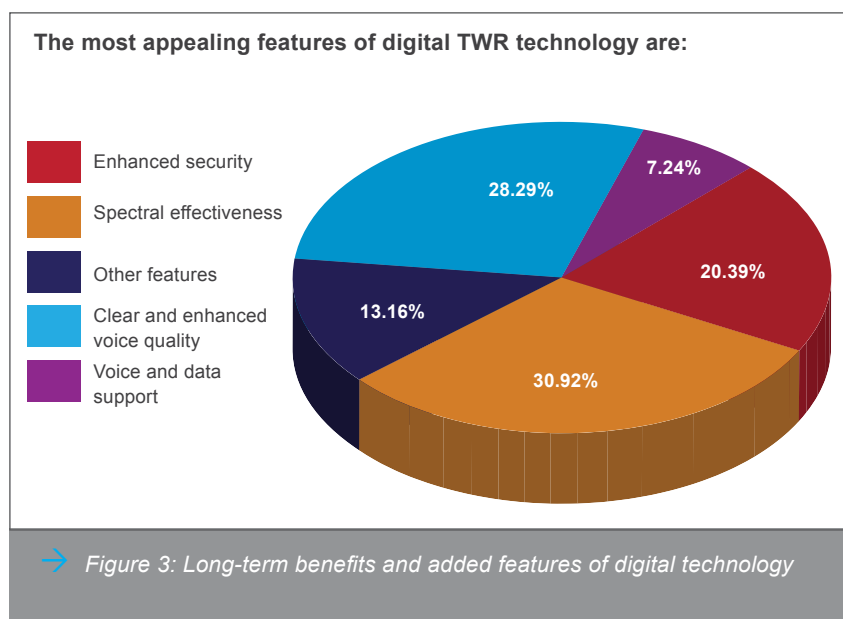
If the level of adoption is influenced strongly by technology suppliers, it follows that the actual use by the organisation is highly influenced by technology suppliers. The results indicated that there was a significant relationship between suppliers and the actual use of digital technology.

The survey also attempted to establish whether respondents were of the opinion that their companies would adopt digital technology if the suppliers ceased to support the old (analogue) technology. Some 58% of respondents agreed that they would adopt digital technology and about 24% of respondents reacted negatively to the adoption of the technology. The results also showed that an industrial push in the form of technology suppliers could influence the adoption of digital technology.

### Influence of technology drag

Finally, the influence of technology drag on the adoption of digital technology was tested. Most organisations agreed on the fact that investment in analogue technology was a factor to the adoption process of digital technology. The results found that 62% of respondents thought that technology drag was, in fact, the limiting factor. They were more worried about their investment in analogue technology and the loss they might incur if they switched to digital technology.

Respondents' view of perceived ease of use relating to technology drag was limited to the fact that organisations would lose their current investment, which caused them to delay the adoption process. The minority (15%) of respondents thought that such an investment had no influence on the adoption of new technology. When questioned about the influence of the maturity of older (analogue) technology



on new (digital) technology, approximately 58% of respondents agreed that it had an influence on the migration process, as people tend to feel comfortable with technology they know and are reluctant to use new technology.

The last two questions in the survey asked respondents to indicate whether they were of the opinion that digital technology would be the future, and to identify the most important external factor they felt restricted organisations from migrating to digital technology.

Most respondents (86%) were of the opinion that digital technology was the future. This was an indication that organisations would adopt digital technology once they felt that the risks associated with external factors had been reduced. The most restrictive external factor to the adoption rate of digital technology was identified as affordability and cost – by almost 76% of respondents.

### The road ahead

In conclusion, it is believed that if the industry looks closely at the external factors mentioned in these results, they will be able to unlock the migration process of digital TWR.

Cost and affordability appeared to be the most important limiting external factor to migration. However, technology-readiness and availability also have a big influence, which is largely positive.

The long-term benefits and added features of digital technology are also seen as positive, but only slightly more than half of the respondents were of the opinion that their companies would migrate in the next three to five years.

Respondents were of the opinion that industrial push and technology suppliers influenced the adoption of digital technology, especially if they ceased to support analogue technology. It is worth mentioning that technology suppliers have stopped developing analogue technology and their focus is on new digital

technology. The interviews with Global Communications-Kenwood, Alcom Matomo-Motorola and Multisource-Icom revealed that these technology suppliers would keep on supporting the existing analogue technology, but their focus was on digital technology.

Although respondents felt that ICASA could influence the adoption of digital TWR technology, the regulator has no guidelines in this regard. The researchers repeatedly tried to obtain the view of the regulator without success.

Most companies still use analogue technology, but they believe that digital technology is the future. Analysing the results according to the Rogers' bell curve, it can be assumed that the technology has not yet reached the early adopters (13.5% of adopters).

Digital TWR migration will only have a full impact on the industry if it reaches 34% of adopters, which means reaching an early majority of organisations in South Africa.

More work needs to be done to investigate organisations' future plans in terms of their communication systems. Some companies think that digital technology is almost the same as cellular technology, so they might as well move to cellular communications. This can still be investigated in future studies. ➔

### About the authors



**Derrick Mogale** is a radio frequency engineer and a technical manager at Webb Industries-Jasco ICT, Johannesburg. He is a specialist in the field of RF filters and system combining. He received his MSc in Technology Management from the University of Pretoria in 2011.



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# Interactive learning through gaming simulation in an integrated land use-transportation planning course

Prof Christo Venter and Dr Johnny Coetzee

Apart from changing the way the entire world lives and works, computers and technology have changed lecture rooms and teaching styles. In line with (unusual, but effective) trends at other universities, final-year civil engineering students at the University of Pretoria now play a simulation game, UPTown, much like SimCity, as part of the integrated land use-transportation planning module. UPTown was developed by the University.

The simulation game promotes active and social learning – the preferred style of learning of students these days – and allows them to explore and experience the problems they will encounter in the world of work. Assessment of student performance showed that the game significantly enhanced the achievement of learning outcomes.

The simulation game addressed an additional need – to integrate the practice of land use development and transportation planning in order to achieve more sustainable, livable and inclusive communities. This need has been investigated by many scholars (Levinson & Krizek, 2008; Handy et al., 2002). Civil engineering curriculums increasingly reflect this integration by including modules on land use and urban and regional planning (Lyles 1987; Khisty, 1987; Krizek & Levinson, 2005) in order to “contribute to the development of analytical, synthetic, and creative abilities of engineers” (Khisty, 1987:58).

There still seems to be some confusion on what the nature and content of a typical integrated planning module should be, in what is regarded as an already overloaded engineering curriculum. The integration of urban and regional planning with the engineering curriculum is hindered by epistemological differences between the disciplines: various authors have argued that civil engineers and planners are fundamentally different in terms of their preferred approach to knowledge, their personality traits, and even their values (Lyles, 1987).

Planning modules in the civil engineering curriculum thus need to be appropriately structured to elucidate the conceptual linkages between the engineering and planning disciplines and should be delivered using appropriate and innovative teaching methods that help bridge the

epistemological gap between “social” planning and “technical” engineering.

Computer-based simulation is a promising tool to enhance classroom instruction (Zhu et al., 2011). The UPTown simulation game is designed to help students explore the links between infrastructure investment, land development, city efficiency and equity outcomes, by guiding the development of a hypothetical city over time. Its innovation lies in the way it asks students to simulate the decisions of both public sector planners and profit-seeking developers, and the interactions between them. This allows them to discover the value of collaboration and integration not only across professional disciplines, but also between the public and private sectors.

## The need for new teaching methods

The changing abilities and preferences among students require teachers to adapt their teaching methods. Brown and Adler (2008) describe contemporary students as social learners, based on the premise that their “understanding of content is socially constructed through conversations about that content and through grounded interactions, especially with others, around problems or actions. The focus is not on what we are learning but on how we are learning” (Brown & Adler, 2008:3).

A number of teaching approaches have emerged in response to the changing needs of students. Among the most prominent is active learning – a generic approach seeking to engage students more actively in the classroom through activities such as reading, writing, discussion or problem-solving (Bonwell & Eison, 1991). Studies have shown that active learning approaches are generally preferred by students

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A key characteristic of the game is its orientation towards discovery. No outcomes are spelled out in advance.

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(Nirmalakhandan et al., 2007; Carpenter, 2006), and tend to lead to improved student learning and achievement (Nirmalakhandan et al., 2007; Light, n.d.). The simulation game described here has cooperative elements, as it organises students into groups simulating agents with different objectives that – as students discover while playing the game – are best met when aligned with those of other groups in a collaborative rather than a competitive fashion.

### Gaming simulation as a learning tool

The land use-transportation simulation game, UPTown, has some features in common with the SimCity approach. The most notable is its objective of making a game out of a complex social system. The game simulates the evolution of spatial and economic systems, population dynamics, and transport and travel demand. It also allows players to influence (but not entirely control) the trajectory of the game through simulated interventions and makes use of attractive graphics and visuals for displaying output.

### Embedding gaming simulation within an integrated land use-transportation planning curriculum

The game is designed to help students engage with the practical implications of many of the topics discussed in class. It is intended to train students to do the following:

- Understand the nature of the relationships between land development, travel demand and transport system performance.
- Critically examine the implications of various land use-transportation strategies (such as compact city, sprawl, or corridor development strategies) on city performance and quality-of-life criteria.
- Explain, based on own experience, the role of different role-players (private and public)

in the spatial development process, and the nature of the relationships between them.

- Communicate effectively with other role-players via formal planning documents and informal discussion.

A key characteristic of the game is its orientation towards discovery. None of the outcomes listed above are spelled out in advance. Students are merely given the overall objective of the game – to facilitate the spatial and economic growth of a town over time within the constraints of the “action space” at their disposal (as public or private sector actors). They are then left to explore various strategies and relationships on their own. Feedback is provided to help students identify the positive and negative outcomes of their actions in order to develop their own understanding of these matters.

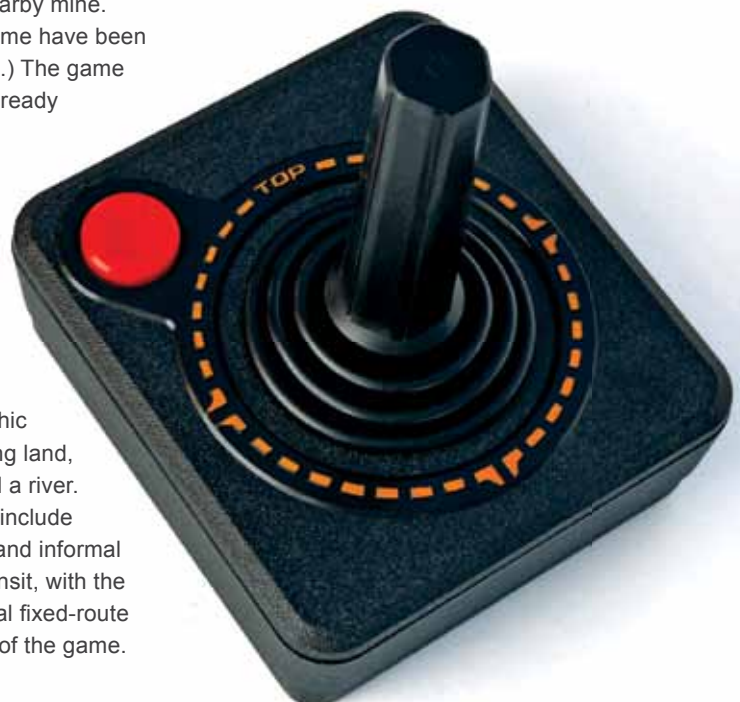
### The UPTown game

The hypothetical setting chosen for the game is one typical of the South African development landscape, namely that of a mining town faced with high population growth due to the expansion of a nearby mine. (Variations on this theme have been added in recent years.) The game starts with the town already housing 60 000 people, with a rudimentary street network, and a large rural hinterland where future expansion may occur. Growth is constrained here and there by geographic barriers such as mining land, a mountain range and a river. Travel modes initially include walking, automobile, and informal (minibus-taxi) paratransit, with the option of adding formal fixed-route transit in later stages of the game.

Both walking and taxi modes are used extensively, typical of travel patterns in developing countries. Each game is structured as an encounter between public sector planners, exercising control over both land use management and investment in the transportation network, and private sector real estate developers. Planners and developers both pursue the ultimate aim of accommodating as much growth as possible (in terms of population and employment, but not necessarily spatial footprint), as high growth levels are directly linked to the town’s success as a vibrant and attractive community.

Planners and developers have different objectives and different means of pursuing them. For planners, success is measured by a number of objectives reflecting the general health of the city, such as the following:

- Sufficient land being available to accommodate housing and business growth
- Improving low-income workers’ access to jobs (to reflect progressive social goals)
- Facilitating the efficient movement of people by finding a balance between sufficient investment in transport capacity (by highway and/or transit modes) and cost-effectiveness (thus avoiding over-investment) of the transport network



- Reducing the cost of living and vehicle emissions by containing growth in average trip distances

The game proceeds in three rounds, each representing a 10-year period, and each building on the previous round. Planners are thus forced to consider land use development and transport demand together. They are encouraged to start the game by developing a spatial development strategy for managing the growth of the town for the coming decade, to ensure the coordination of zoning and investment decisions.

Developers have the ultimate objective of maximising the profits derived from developing and selling or renting out building stock. The program simulates land values and construction costs based on the size, type and location of new development, and then calculates the developers' profits based on the amount of floor space that is actually occupied. Developers have to find a balance between developing sufficient floor space to accommodate all

### Cooperation and competition

It is this link between public sector planning and private sector investment decisions that gives the game its cooperative nature. Neither planners nor developers can control each other's actions. The actions of a third group of role-players – private households and businesses – are not controlled directly by either group, but simulated externally. A key feature of the game is that it takes the performance of both planners and developers into account when determining the overall performance score for the town. Each group thus benefits from the other group reaching its objectives. Objectives are structured so as not to be perfectly aligned – for instance, excessively sprawling development might reduce development costs (favouring developers), but decrease cost-effectiveness of road investments (penalising planners). This creates an incentive for groups to compromise and to coordinate their actions around a common vision for the area. Each game is played by six students

Jobs are simulated as either basic (including manufacturing and mining industries) or retail (including commercial, office and public services).

Students do not have access to the simulator when making decisions, and only receive feedback on the success of their actions at the end of every round. The fact that the game is not as interactive as, for instance, SimCity, is intentional. The focus of the course is to allow students to explore and understand the substantive relationships underlying spatial and transport development, and not to run modelling software.

At the end of each round, participants in each game receive feedback in the form of a city scorecard, on which the performance of the city is scored against the objectives for each group. Typical scorecard indicators include the sufficiency of land and buildings made available for accommodating growth, profitability of development, cost-effectiveness of the road and transit networks, the reduction in congestion levels, containing growth in average trip distances and job accessibility for low-income residents. Scorecard scores contribute about 10% of student marks for the course.

A key feature of the game is that it takes the performance of both planners and developers into account when determining overall performance.

potential growth in households and businesses (so as not to constrain overall growth by a shortage of building stock), and keeping vacancies low (as vacant buildings reduce profits). There is no explicit budget constraint, but the last point acts as a penalty for over-development.

The actions of planners and developers affect each other in current and subsequent rounds of the game. The amount of floor space of any given type that developers can construct in a zone is constrained by zoning and maximum density specifications chosen by planners. The location decisions of developers affect the distribution and density of travel demand, and the need for planners to expand transport capacity in subsequent periods.

divided into two groups: two students work together as developers and four as planners. The experience is competitive to the extent that students compete against one another in different games in order to emerge with the highest cumulative growth over three rounds of the game.

### Simulation engine

The behaviour of private role-players – households and businesses – and their impact on land use and travel are simulated off-line through a two-step simulation package developed specifically for this purpose.

Households are simulated in three income categories, each demanding different amounts of residential floor space.

### Attainment of subject matter competence

Since the integrated course was a new one that incorporated the simulation game from the start, the opportunity was not available to test the impact of the simulation game objectively against a no-game control case. Two measures were considered to assess the effectiveness of the game to help students attain subject matter competence, namely scorecard scores and subjective ratings.

As a subjective measure of the effectiveness of the game as a teaching tool, students were asked to rate the extent to which the game contributed to their understanding of the integrated land use-transportation planning subject matter. Students' answers (summarised in Table 1) were generally positive, with an average score of 6.1 out of 9.

→ Table 1: Student assessment of simulation game (n=94)

Question	Number (percentage) of responses per category		
To what extent did the UPTown game contribute to your understanding of the infrastructure/development planning process? (Scale: 1=no help, to 9=significant)	Poor contribution (rating = 1–3)	Average contribution (rating = 4–6)	Good contribution (rating = 7–9)
	2 (3%) 0 (-)	27 (45%) 22 (67%)	31 (52%) 11 (33%)
How would you rate the contributions provided by various members of your group?	Everybody contributed equally	Unequal: some did less than others or nothing	One person did all the work
	55 (59%)	38 (41%)	0 (-)

In general, students performed better, and developed a better grasp of the material when faced with more complex analytical tasks and more “degrees of freedom” in terms of the set of actions they can take to reach their objectives.

### Outcomes

The UPTown game is structured to allow students to explore aspects of the land use-transportation relationship in a hypothetical setting, while practising to work on complex problems in a collaborative teamwork environment.

Self-assessments of student performance showed that the game contributed to their ability to master the course matter. Students who faced more complex tasks (planners, as opposed to private sector developers) performed better, and reached higher levels of competence earlier on in the game. Grappling with complexity and a larger action space seems to lead to a better grasp of the material, and better achievement of the learning outcomes.

The game’s key innovation over existing urban simulation software is particularly useful as a learning strategy, as it allows students to experience the benefit of collaboration. In the process, they learn syncretic thinking, clear communication and compromise. Some improvements can be made to the game to enhance its usefulness as a learning experience.

The first is to rotate students to be both planners and developers. This will give all students the opportunity to grapple with the issues faced by public and private sector agents. This would probably help equalise the achievement of competence across the class. Some students expressed a need for greater guidance and more extensive feedback. Some students lacked the skill to identify causal relationships between their own decisions and actions (as planners or developers) and the subsequent performance of their town.

While it is important to preserve the self-guided exploratory character of the game, it might be useful to spend more time modelling critical analysis and problem-solving skills for such students early on in the game. Lastly, the simulation engine needs to be migrated to an open-source platform to make it directly available to educators at other institutions. ➔

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# Water conservation strategies at Gauteng municipalities

Obby Masia and Dr Louwrence Erasmus

Water conservation is becoming an increasingly urgent practice as the earth's water resources are depleting and so much of it is wasted. A study was done on the water management strategies and practices of the municipalities in Gauteng to determine how effective these are.

The water situation is so dire that government should not only focus on water conservation, but also on water demand management.

## The status quo

The provision of water services is the responsibility of a water services authority (WSA), which comprises local, district and metropolitan municipalities. The Water Services Act (Act 108 of 1997) defines a water services provider (WSP) as an institution that is responsible for the operation of the water works that supplies water services to the end consumers (South Africa, 1999).

Mogale City and Emfuleni are the two local municipalities in Gauteng that consume the most water. Among the metropolitan municipalities, the City of Johannesburg (CoJ), Ekurhuleni Metropolitan Municipality (EMM), and the City of Tshwane (CoT) consume about 85% of the municipal water supplied by Rand Water from the Vaal River System (Table 1). They have each developed a water conservation or demand management (WC/WDM) strategy in order to reduce demand by 15%, as set by national government.

Water loss or non-revenue water (NRW) is between 30% and 40% for the Gauteng metropolitan authorities and in South Africa as a whole.

The non-revenue water – the free basic water (FBW) municipalities supply to households and the water supplied to indigents – for Ekurhuleni was 39.9% (EMM Water Balance, 2011) or 128 848 350 kℓ/annum for the 2009/10 financial year. The total bulk water purchased from Rand Water was 322 821 747 kℓ/annum. The NRW for CoJ was 37.7% (CoJ Water Balance, 2012). The national average NRW for all South African municipalities is 37%, and 36% for Gauteng municipalities.

## Smart metering technology

Smart metering technology can be broadly categorised according to the level of sophistication as follows:

- Automated meter reading (AMR)
- Automated meter management (AMM)
- Interval metering with automated meter management (AMM-IM)
- Prepayment meters (PPM)
- Advanced metering infrastructure (AMI)

→ Table 1: Rand Water bulk supply to municipalities with potential savings

Rand water area of supply	2008/09 annual demand (mm <sup>3</sup> /annum)	2008/09 non-revenue water (mm <sup>3</sup> /annum)	2005/06 target savings (mm <sup>3</sup> /annum)
Johannesburg	503	161	110.2
Ekurhuleni	327	124	28.3
Tshwane	214	62	20.4
Emfuleni	77	32	26.1
Rustenburg	28	9.8	3.1
Mogale City	26	7.1	1.7
Govan Mbeki	20	5.9	1.5
Matjhabeng	19	6.6	4.3
Randfontein	9	2.6	0.4
<b>TOTAL</b>	<b>1 223</b>	<b>411</b>	<b>196</b>

(Source: EMM WC/WDM, 2010)

## Conceptual model

The ISO 50001 follows the Plan-Do-Check-Act process for the continual improvement of the water management system. This process can be explained as follows:

- Plan: conduct the water review and establish the baseline
- Do: implement the water management plans
- Check: monitor and measure processes and key characteristics of operations that determine the water performance against the water policy and objectives and report the results
- Act: take action to continually improve the water management systems

Water conservation and water demand management are ongoing processes that need to be planned properly, implemented and checked. Corrective actions should be taken to improve performance. The ISO 50001 follows other ISO standards, such as ISO 9000 and ISO 14000. The ISO 50001 principles were used as basis for testing this hypothesis.

## The survey

In the study, it was established whether these municipalities' water conservation or water demand management strategies are being implemented successfully or result in the reduction of non-revenue water. The intention was also to determine whether smart meter technology is used in the implementation of WC/WDM strategies. Structured questionnaires were used to elicit the required information from managers and engineers at the relevant municipalities.

The majority of participants were from the Capital Expenditure sections in the municipalities – they are involved in the planning and implementation of water projects – while 32% were employees involved in operations and the maintenance of water infrastructure.

Respondents were asked to rank the biggest challenges facing the water industry. The biggest challenge was water scarcity, followed by demand management and conservation issues.

The cities of Johannesburg, Ekurhuleni and Tshwane have each developed a WC/WDM strategy. A percentage of 88% of the participants in the survey indicated that their municipality had a WC/WDM strategy based on legislation like the Water Services Act.

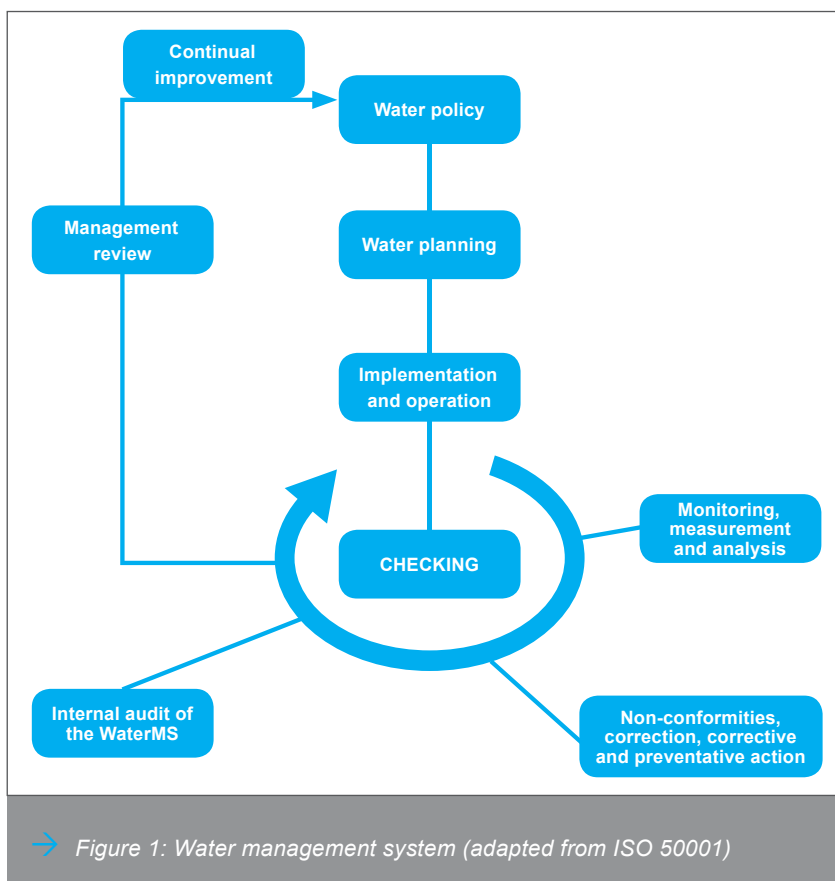
Furthermore, 86% of respondents indicated that their municipality had a section dedicated to WC/WDM, although only 71% indicated that the action plans of the WC/WDMs were being implemented. Only 73% said that a budget had been allocated for implementation.

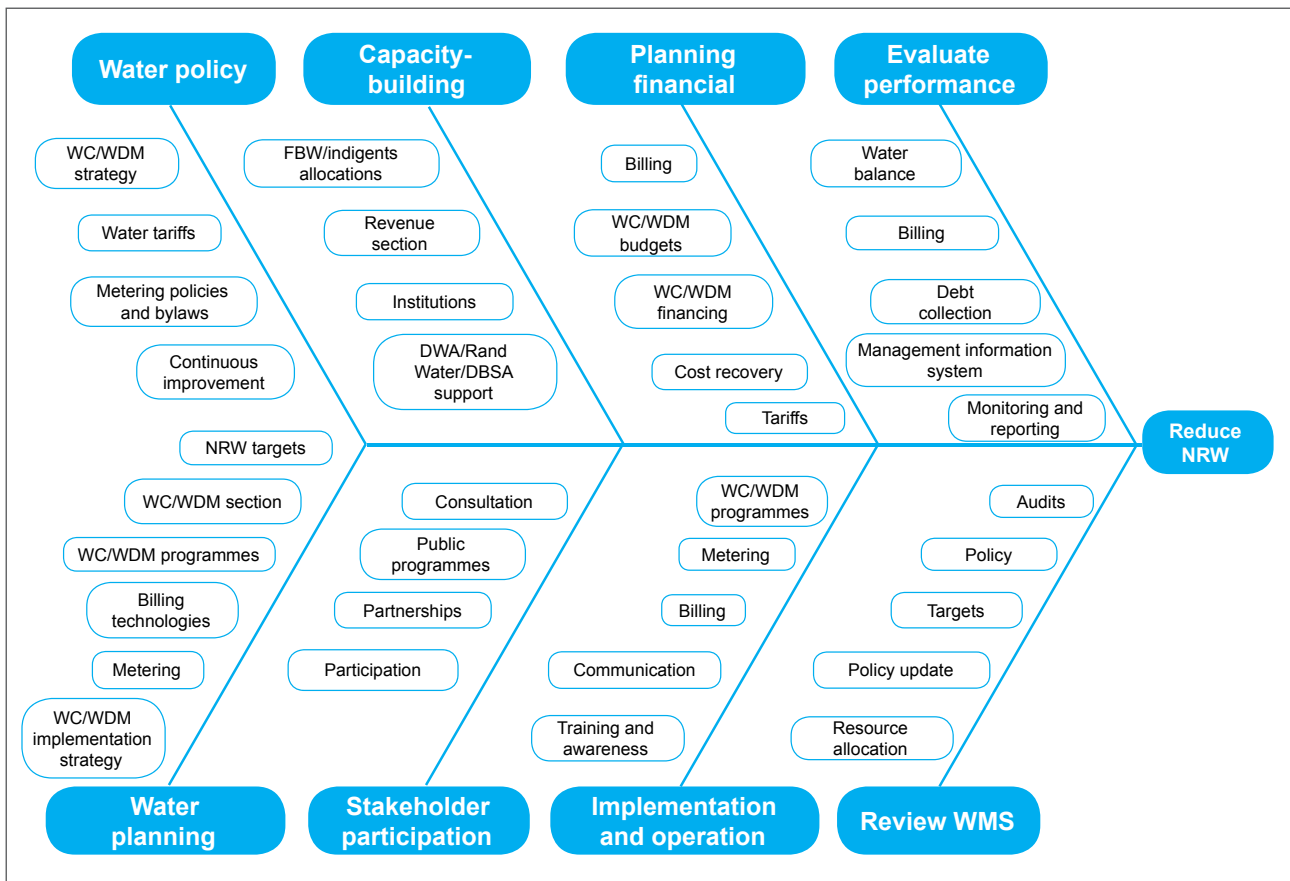
The majority of participants indicated that their municipality actively promoted water conservation. With regard to finances, less than half of respondents indicated that there was an adequate budget for operations and the maintenance of the WC/WDM infrastructure.

Some 68% of participants said provision was made for training – the implication of this is that the municipalities will be able to deal with the implementation of new metering technologies.

Meter reading and billing is the core function of a water utility, and only 46% of respondents indicated that meters were read on a monthly basis. This raises concern, as NRW cannot be reduced, due to a lack of information. It was further disconcerting that approximately half of the participants said they did not have detailed information on water leaks in households. Furthermore, only 41% indicated that they were able to manage the allocation and consumption of free water.

However, 66% of respondents said they were running educational programmes in schools to try and limit NRW, and 73% indicated that they had water-wise or similar programmes in communities. Some 78% of respondents indicated that advertising or media campaigns were used to reach the community at large and encourage them to conserve water.





→ Figure 2: Cause-and-effect diagram for the water management system

With regard to maintenance, only 66% of participants had leak detection programmes. Although 83% indicated that they performed pressure management, the amount of water lost due to leaks does not confirm this. Because the water infrastructure is 50 to 100 years old, water mains replacement programmes are vital. The majority of respondents indicated that these programmes were in place.

Residential users constitute the majority of customers for the municipalities and have to be metered in order to recover revenue. Some 66% of participants indicated that there were adequate meters for residential customers. Furthermore, 71% said there were adequate meters for industrial customers. Only 54% of respondents indicated that there were enough meters for municipal buildings and it was indicated that only 25% of municipal irrigation was metered.

The types of meters used are an important aspect. A total of 34% of respondents indicated that automatic

meter reading was used, 59% said prepaid meters were used and 22% indicated using smart meters. There is little information on customer interest in smart meters, as well as on customers using smart meters.

Respondents were asked about their primary motivation for implementing smart meters. Most indicated that it was for efficient billing, followed by assisting households to be more aware of the quantity of water they use, and alleviating pressure on a limited resource.

Municipalities' major concerns regarding smart meters are the reliability of the technology, capital costs, operating costs, security, customer engagement and compatibility between the new and existing systems. The major benefits of smart meters were seen as enabling early leak detection, supplying customers with tools to reduce and monitor water use, and providing more accurate rates.

## Findings

This study dealt with water conservation/water demand management at large, with the emphasis on smart metering technology. The non-revenue water at Gauteng municipalities remains at 36% to 40%, which is unsustainable.

According to the survey results, the municipalities have WC/WDM strategies in place, but it seems that they are not being implemented or only on a small scale. There are no dedicated sections responsible for WC/WDM at most of the municipalities, and separate budgets to implement WC/WDM have not been allocated. The dedicated WC/WDM sections can be used to coordinate all the activities that are currently being performed by different sections.

Although participants indicated that their municipalities actively promoted water conservation, it can be assumed to be ineffective, as the NRW remains high.

Households consume most of the water supplied by municipalities, and consumer education campaigns should be intensified. The top industrial customers need to be prioritised, as they can easily buy into water-saving programmes. Leak detection, pressure management and mains replacement are major activities that should form part of the daily operations of municipalities. Consumer metering should also be intensified to determine reliable water balance calculations. Tariff structures and billing procedures are in place at most municipalities, but their implementation might be a problem due to it being done by finance departments, which are run separately from the water departments. Prepaid metering is currently in use in Johannesburg, and the other municipalities need to follow suit to manage water consumption by households.

Prepaid metering, automatic meter reading (AMR) and some smart metering technologies are already in use in Gauteng. This indicates some potential for growth in the use of smart metering technology. The billing of water use is crucial to ensure a reduced demand for water. If customers are not billed correctly for water use, they will continue to abuse the scarce resource and lose trust in the municipalities. Smart metering technology and metering technology in general can be used to reduce apparent or commercial losses.

### The way forward

Rand Water, municipalities and the Department of Water Affairs (DWA) need to conduct further research on the use of appropriate WC/WDM strategies for the Gauteng water supply. A standard approach should be introduced to all the municipal Vaal River System users. Municipalities and their customers should start taking WC/WDM seriously and work together in order to reduce the NRW. The DWA should put policies and strategies in place that will support municipalities in water loss programmes. Special attention should be given to research on the water demand and supply in Gauteng

because of its huge economic activities. The municipalities need to invest in updated billing technology and advanced metering in order to reduce NRW.

A common approach towards implementing WC/WDM is needed for all the municipalities and it should become compulsory. The stakeholders need to share resources and knowledge on WC/WDM planning and implementation. The DWA needs to consolidate the overall implementation of water demand reduction strategies, so that correct measurements can be taken on the entire system. Currently, each municipality is conducting its own operations and these do not necessarily focus on reducing NRW. It is the responsibility of government to provide its citizens with sufficient and efficient water resources.

The municipalities do not seem to have technology acquisition and management strategies for metering technology. The role of consulting engineers in the acquisition and management of metering technology in South African municipalities should be researched. Furthermore, research should be conducted on the use of system engineering in WC/WDM management programmes due to a lack of operations and maintenance of water infrastructure. The adoption and implementation of billing systems in municipalities also require further research.

Prepaid metering should be more widely adopted by municipalities and smart metering technology developments should be monitored by government for future consideration. Government needs to consider the standardisation of smart metering communication technologies the same way it was done in Europe. This will assist smart metering technology developers, producers and utilities to have a common direction towards the implementation of smart metering technologies in South Africa. A huge amount of research is currently being done on advanced metering infrastructure across the world, and the local industry needs to monitor these developments closely. ➔

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# Investigating an organisational culture conducive to project management

Lorium Mashiane

Organisations doing business in highly competitive markets where products and services are rapidly changing are under immense pressure to perform better. These organisations are frustrated by the results of their efforts to establish project management processes. Organisations with stronger hierarchical structures find it hard to put project management into practice to achieve the desired level of performance.

A study conducted in the Graduate School of Technology Management adopted the definition of culture characterised by the functional and sociological approach. It aspired to assess the perceived culture as an attribute of the organisation.

A project can be successful, but that does not mean that the project management was a success or implemented efficiently (Morrison, 2005). People are the driving force behind the accomplishment of project deliverables, and the efficient management of time, resources and costs during the course of a project. Organisational culture drives the behaviour of people in an organisation and consequently has a great influence on the project management culture.

The purpose of the study was to assess both organisational culture and project management culture in a division of Telkom called Cybernest.

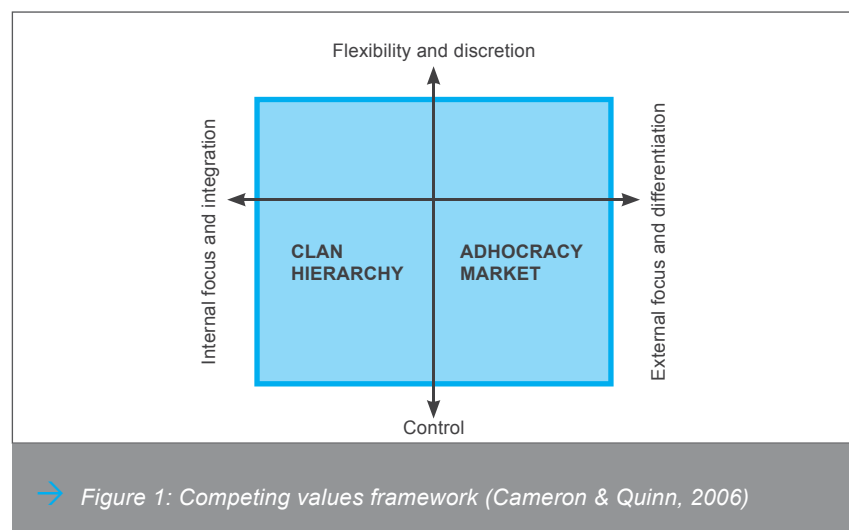
## Organisational culture

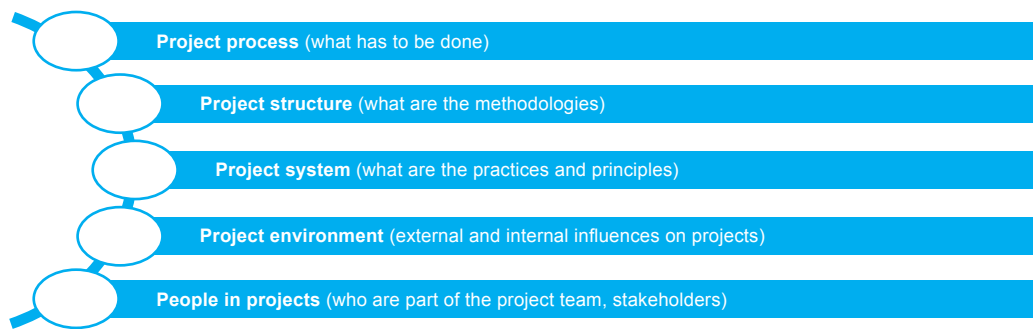
Individuals come into contact with formal procedures, norms and informal behaviour that are understood by insiders alone. Individuals who are in the

organisation for a longer period, develop assumptions about how the organisation performs tasks to meet its objectives. In essence, organisational culture is “the way we do things around here” (Du Plessis, 2003).

Figure 1 illustrates the competing values framework. It builds a theory of how various aspects of the organisation (corporate strategy, culture, leadership, communication and decision-making) function in simultaneous harmony and tension with one another (Cameron & Quinn, 2006).

These competing values are flexibility versus control, and external versus internal. The framework forms an approach for extracting values from leading constituents about how to effectively run an organisation (Morrison, 2005). The first set of competing values differentiates effectiveness criteria that emphasise flexibility, discretion and dynamism from criteria that emphasise stability, order and control. The second set of competing values differentiates effectiveness criteria that emphasise an internal orientation, integration and unity from criteria that emphasise an external orientation, differentiation and rivalry.





→ Figure 2: Dimensions of project management culture by Du Plessis (2003)

Greater flexibility is characterised by “flatter” organisational structures, decentralised decision-making, and minimal specialisation of jobs, whereas greater control is characterised by hierarchical structures, centralised decision-making, and a large number of specialised jobs with a proliferation of job titles.

External forces also shape organisational culture because organisations reflect the national, regional, industrial and occupational cultures within which they function.

### Project management culture

Project management involves clear objectives that describe the project scope, and that are quality-, cost- and time-oriented. Project management also focuses on a management process that is inclusive of planning, organising, implementing and control, and addresses all the strategic goals of the organisation.

Assessing the culture that operates in Cybernest can be beneficial to organisational success.

Du Plessis (2003) developed an instrument to evaluate project management culture in the division by assessing contributing dimensions.

This study follows the competing values framework to assess the organisational culture (illustrated in Figure 1) and the project management culture. It is a theory and framework developed by Du Plessis (2003), which is illustrated in Figure 2.

### The competing values framework

According to Cameron et al. (2006), many organisations note that the competing values framework allows for the valuable diagnosis and implementation of a culture change, the setting up of a competitive strategy, the administering of a quality process, as well as the development of prospective leaders.

When the division has an external focus, it focuses on external opportunities. These opportunities include acquisitions, the identification of future trends, persuasion of innovative ideas, and market share competition and growth. These can exist in the adhocracy and market quadrants. An internally focused company focuses on its internal capability. This includes systems, culture, cost reduction, continuous quality improvement and human development.

Ajmal and Koskinen (2011) believe that a competing values approach to organisational culture is made up of four core cultures. A control culture ensures certainty, predictability, safety, accuracy and dependability. A competence culture is concerned with achievement and gaining distinction through having the highest quality and unique products or services (Cameron et al., 2006). Leaders in this culture are directive, competitive, take up challenges and stretch goals. Their power and success are judged on the basis of results. A collaboration culture is concerned with affiliation and synergy in a culture of unity

and close connections (Ajmal & Koskinen, 2011). Leaders take on parent figures, and are mentors and facilitators, and they use team-building (Cameron et al., 2006). A cultivation culture deals with meaningfulness, self-actualisation and enrichment.

Leaders see compensation, nurturing employee engagement and loyalty as a key to long-term company success.

Du Plessis (2003) indicates that project management culture can be based on five highly interdependent dimensions, as illustrated in Figure 2. It is important to develop a shared set of project management values in order to build a stronger project management culture. The instrument measures the culture and aligns it with the dimensions.

Cameron et al. (2006) argue that competing values can also become complementary values. The value-enhancing activities located in quadrants diagonally across from each other appear to be diametrically opposed.

A person who performs primarily in the “compete” quadrant will typically view many activities in the “collaborate” quadrant as less meaningful (Cameron et al., 2006). There is a perception that if the organisational members who focus on the “control” quadrant behaved like people who focus on the “create” quadrant, they would be considered failures. This perception creates much friction in organisations (Cameron et al., 2006).

→ Table 1: Management style orientations arranged according to quadrants

Clan quadrant	Adhocracy quadrant
Managing teams Managing interpersonal relationships Development of others	Managing innovation Managing the future Continuous improvement
Hierarchy quadrant	Market quadrant
Managing acculturation Managing the control system Managing coordination	Managing competitiveness Energising employees Managing customer service

Project management is a complex managerial process that ensures an optimal balance between the internal organisational design of a firm and its emerging strategies (Ajmal & Koskinen, 2011).

### Research paradigms on culture

Scholars in the study of culture have different views on culture when conducting research. With regard to cultural research paradigms, Smircich (1983) differentiates between three different paradigms, each pursuing different research interests and purposes. These paradigms are culture as a background factor, an internal organisational variable, and a metaphor. According to Denison (1996), culture and the individual organisational members cannot exist

independently from each other, and various scholars bring to attention the interactive and reciprocal relationship.

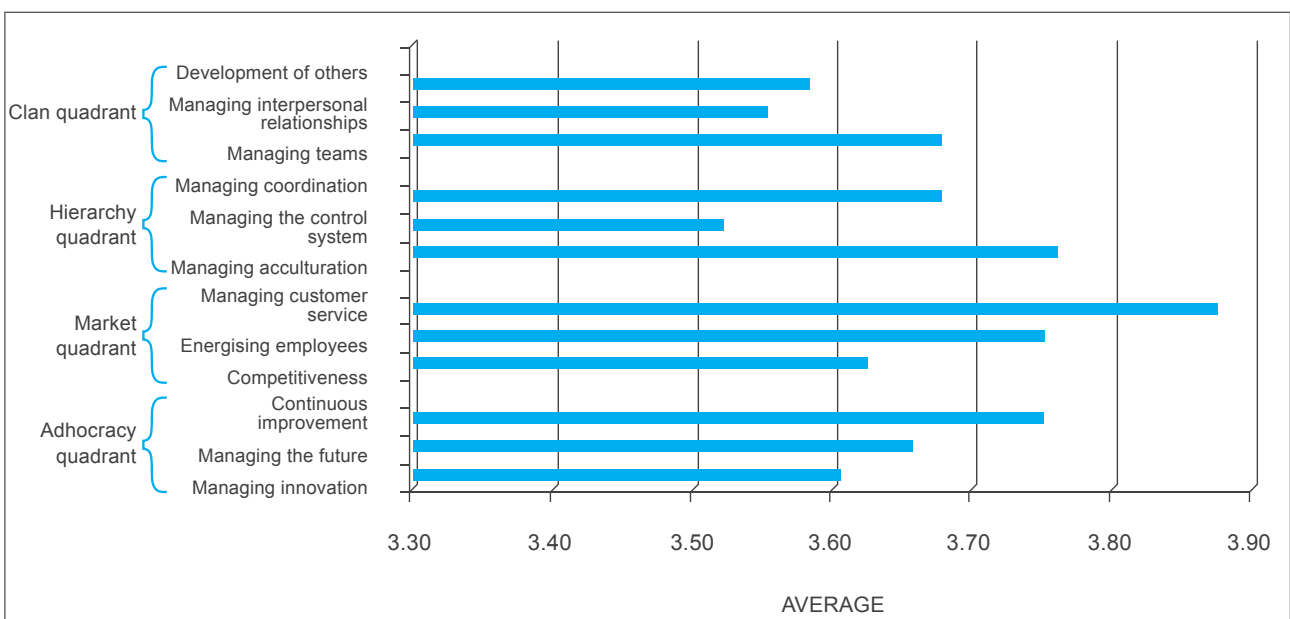
### The study

Questionnaires were used to assess organisational culture and the culture in the project management environment. The questionnaire instruments are the management skills assessment instrument (MSAI), developed by Cameron and Quinn (2006), and the project management culture assessment tool (PMCAT), developed by Du Plessis (2003), which is used to distinguish whether an organisation has or does not have project management culture. The study focuses on the division Data Centre Operations (DCO), branded as Cybernest.

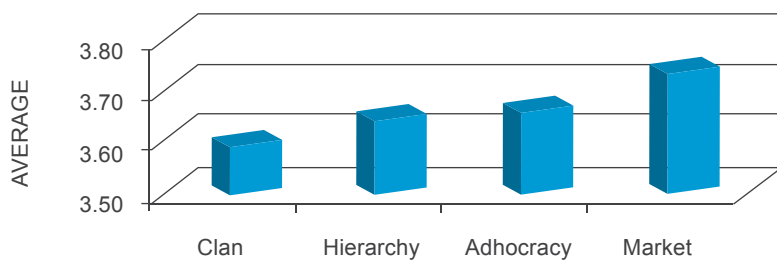
The 110 respondents from this division were divided into 15 teams, which included project managers who participate in the whole project management life cycle and implement solutions for external clients.

The MSAI assesses individual orientations towards a range of stylistic options, including the management style orientations of clan, hierarchy, market and adhocracy (Cameron & Quinn, 2006).

The outcome will guide management on critical competencies that will require more attention in order to develop into a high-performing organisation. Table 1 illustrates the components that make up the quadrants.



→ Figure 3: MSAI dimensions



→ Figure 4: Average group MSAI culture profile

The PMCAT is used to evaluate and diagnose a project management culture as the operational culture of an organisation involved in project work. This instrument measures the culture-descriptive elements of the project management culture.

Data gathered from the MSAI facilitates the investigation of culture, based on the competing values framework approach. Although it has not been adapted to focus on a particular leader in an organisation, it evaluates general leadership. The profile that results from the findings resembles the same framework as the profile for the organisational culture. The results will identify the skills and competencies required to develop some alignment with the project management culture.

Figure 3 illustrates the 12 competencies of the MSAI, which represent the four quadrants of the competing values framework. The average of the competencies is calculated to provide a mean value per quadrant. The mean values of the four quadrants are presented in Figure 4. This figure shows that the market culture is dominant, while the clan quadrant has the weakest competency.

The objective of using the management skills assessment is to measure dimensions that match the competing values framework and to determine whether the predicted relationships between the quadrants exist.

The diagonal quadrants have competing values. For example, if an organisation performs high in one quadrant, it will automatically perform lower in the diagonal quadrant.

The challenge is to eliminate the influence of bias so that the behaviour of the manager can be found.

### Conclusions

The two profiles drawn from the two instruments were developed to address the research question, which sought to establish if the culture of the organisation under investigation promoted a conducive environment for project management. Culture type is important, since organisational success depends on the extent to which culture matches the demands of the industry. Figure 4 shows the MSAI culture profile of the organisation and indicates that the market quadrant is the dominant culture.

The dominant market-oriented culture in the organisation is not surprising, as it provides infrastructure hosting solutions and technical support to external clients. The strategy of the organisation and, by extension, the culture of the organisation focuses on the market or clients.

Success is defined in terms of client satisfaction and retention. In this quadrant, the competencies include managing customer service and competitiveness. The clan culture is on the opposite quadrant to the market quadrant, and is weaker. The clan culture involves managing teams, developing others and managing interpersonal relationships, as opposed to the values that predominate the market culture.

Culture strength is determined by the points awarded to a culture. The dominant quadrant is the market culture and this depends on the

competition. The organisation is in the information and communication technology (ICT) industry, which depends on innovation, flexibility, creativity and entrepreneurship, which is the adhocracy quadrant.

However, the benefits of a market culture are still very relevant to the ICT business environment. The results of the PMCAT illustrate that project systems and project processes are weighed as the most competent in the organisation of the five dimensions of project management culture.

Little attention is given to project structure and people in projects. These two dimensions need to be prioritised. The strongest dimension is project systems. Depending on the competitive environment, there is no valid reason to support the objectives of the organisation or the ones that do not achieve competitive gain over the competition. 📌

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# Requirements for wireless sensor networks in order to achieve digital forensic readiness

Francois Mouton and Prof Hein Venter

Man's pursuit of a better lifestyle has led to a vast improvement in technology. Wireless sensor networks (WSNs) have been developed to improve our ability to accomplish daily tasks. The implementation of security protocols on WSNs has not received much attention to date and very little consideration has been given to digital forensics in a WSN environment.

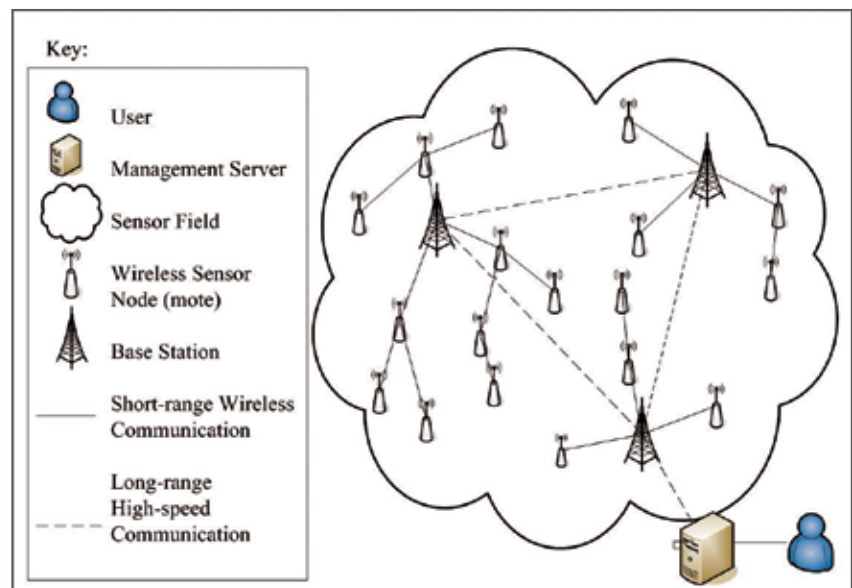
There is currently no formal set of requirements for achieving digital forensic readiness in a WSN.

## Wireless sensor networks

WSNs belong to the general family of sensor networks that use multiple distributed sensors to retrieve data

from various environments.

A WSN is defined as an ad hoc wireless network that consists of tiny and resilient computing nodes known as motes or sensors. These motes are extremely efficient in terms of power consumption and collaborate effectively with other motes in their vicinity.



→ Figure 1: A graphical representation of a WSN (Mouton & Venter, 2009)

→ Table 1: A graphical representation of a WSN (Mouton & Venter, 2009)

WSN component	Functions of each component
User	The user can interact with the WSN through the management server.
Management server	The management server serves as an interface console for the WSN.
Sensor field	The sensor field denotes the physical boundaries of the WSN.
Wireless sensor node (mote)	Each mote contains a small subset of the various sensors. Motes in the network can also act as repeaters for packets that need to reach the base station.
Base station	A base station serves as a gateway node through which the information of the motes has to travel to reach the management server.
Short-range wireless communication	Short-range wireless communication links are established between neighbouring motes and the neighbouring base stations.
Long-range high-speed communication	Long-range high-speed communication links are established between further-ranged base stations and the management server.

WSNs can be used in many environments. Their motes may consist of many different types of sensors, such as thermal, visual, infrared, radar or acoustic. These motes can monitor a variety of ambient conditions, including humidity, pressure, sound, noise levels, temperature, lighting conditions and objects moving through a designated area (Elson & Estrin, 2001; Kahn et al., 1999).

### Digital forensic readiness

Tan (2001) identifies two objectives that have to be balanced carefully: maximising the ability to collect credible digital evidence, and minimising the cost of performing a digital forensic investigation. Even though these objectives provide a good definition of digital forensic readiness, it is important to refine them to make them more specific to a WSN environment.

For the purpose of this article, digital forensic readiness is defined as performing a digital forensic investigation in the shortest time with the lowest cost, without disrupting the original network that has to perform mission-critical tasks.

### Differences between WSNs and WLANs

Wireless sensory networks have special needs and have more specialised requirements than wireless local area networks (WLANs). There are many factors that distinguish a WSN from a WLAN, including the following:

- Communication protocol
- Proof of authenticity and integrity
- Time stamping
- Modification of the network after deployment
- Protocol data packets

While examining each of these factors, the authors assume that no modification to the original WSN (oWSN) is allowed and a secondary independent forensic WSN (fWSN) would be used for the digital forensic readiness implementation of the oWSN.

### Communication protocol

All communication within a WSN occurs in a broadcast fashion and a mote never really knows which of its neighbouring motes actually receives the packet (Akyildiz et al., 2002; Tseng et al., 2003). The default functioning of a mote in the sensor field is to listen for all packets. Upon receipt of a packet, it has to analyse if the packet was meant for it or not. This analysis requires some processing that drains the battery of the mote.

The broadcasting technique used in WSNs is very different from the communication techniques used in IEEE 802.11x wireless networks. In the WLAN environment, one can always determine if a packet has arrived at its destination by monitoring the network (Xylomenos & Polyzos, 1999; Xylomenos et al., 2001). This is not the case in a WSN environment.

Due to the broadcasting fashion in which WSNs communicate, the mote that broadcasts packets will never be completely sure whether the packet was received by the correct mote. This uncertainty could be overcome by a communication protocol that allows the receiving mote to reply with a receipt acknowledgement packet. If a flooding attack is launched against the oWSN, it would compel the oWSN to reply to each flooding attempt with receipt acknowledgement messages.

### Proof of authenticity and integrity

Considering that it can have a severe impact on a WSN environment, it is impractical to use a protocol founded on receipt acknowledgement packets. In the case of the fWSN, this problem could be avoided by implementing a protocol that uses receipt acknowledgement packets, because it is in the nature of a forensic network to always be sure that the information received at either point of the communication line contains some degree of authenticity and integrity. In order to achieve sound digital forensic readiness, it is crucial to prove the authenticity and integrity of the data packets that have been received. In the context of this article, authenticity is the certainty that the origin and

intentions of the data packet are kept intact throughout its lifetime. Integrity is defined as the certainty that the correctness of the data in the data packet is kept intact throughout the lifetime of the data packet.

Firewalls and wireless routers are examples of equipment that could be found in an IEEE 802.11x wireless network. Most of these devices can generate a log or some other way of showing which data packets have passed through the network. This log file can also be backed up by looking at all the other devices through which this single packet has travelled.

In a WSN environment, very little or no logging is done on the motes in the sensor field. WSN equipment, by default, only does logging at the base station. Because WSNs differ so significantly from WLANs, a form of logging that is based on the Casey Certainty Scale (Casey, 2002) is proposed.

Fortunately, in a WSN environment, multiple motes tend to be able to capture the same data packet simply because they are all in range of a particular broadcasted packet. This is a feature of WSNs, which is not the case in IEEE 802.11x networks. Most devices in WLANs will ignore packets that are not meant for them and do not even attempt to log these packets. The opposite is true for WSNs, where motes attempt to capture every data packet within range. This feature of WSNs can be exploited in an attempt to prove the authenticity and integrity of packets in the WSN. All the packets captured by each independent fWSN mote could be forwarded to the base station, as a central point of analysis, in an effort to prove the authenticity and integrity of the data packet.

According to Casey (2002), the integrity and authenticity of information is more certain if it was recorded by different independent sources. Each mote can be seen as an independent source and the authenticity and integrity of each packet can be determined, based on the number of motes in the network that have received the same broadcasted packet.

This article assumes that a packet that has been seen by a larger number of motes has far greater authenticity and integrity than a packet that has only been seen by a few forensic motes in the network.

### Time stamping

Time stamping in a WLAN environment is a fairly easy task, since all the devices in a WLAN would, under normal conditions, either have access to a time server or have been set to the correct time. Thus, time stamping in the logs for a WLAN would, under most conditions, be correct, provided that the device has not been tampered with or is not faulty. In the case of a WSN, however, only the management server (which is connected to the base station) has a sense of time. The only measurement the motes in a WSN environment can use is their own sense of time, which is the time that has elapsed since they were switched on (Sundararaman et al., 2005; Su & Akyildiz, 2005; Sun et al., 2006). This uptime is a poor indication of time, because all motes in the entire network have to be switched on simultaneously.

It was noted that it takes at most one second to capture any data packet and transmit it to the fWSN base station. This introduces a time delay between capturing a packet and receiving it at the base station. The time delay also differed according to the distance of the fWSN mote from the base station in terms of hops and physical distance. The time stamps at the base station are not an accurate reflection of when the packet was initially captured, as the base station is the only device that can assign an accurate time stamp if it is connected to the management server. It is also important to note that each fWSN mote captures packets sequentially, which means that even if the time stamps are altered, the sequence would still be intact.

The sequence of the data packets is not altered, and this (rather than the time stamps) could be used to verify the authenticity and integrity of the data packets. More information can be gathered by looking at the sequence of the data packets than by looking at their time of transmission.

It is therefore sufficient to capture the data packets and merely provide a time stamp for them as soon as they arrive at the fWSN base station. In the event that this is done, one would create a time stamp error (a constant error for each oWSN mote respectively), as it would reflect the time the data packet was first transmitted together with the added time it took for this data packet to reach the fWSN base station.

The time stamp error stays constant for all the packets received from a specific mote in the sensor field, so it is still possible to guarantee the authenticity and integrity of a packet. This constant error could be measured, if needed, by comparing the time stamps at the oWSN base station and the fWSN base station. The time stamp, combined with the sequence of the data packets, would then be used in a forensic investigation.

→ Table 2: Requirements for achieving digital forensic readiness

Requirements for achieving digital forensic readiness in an IEEE 802.15.4 WSN environment	
Communication protocol	<ol style="list-style-type: none"> <li>1. The fWSN should use a receipt acknowledgement packet protocol to ensure that all data packets captured by the motes in the field reach the base station.</li> <li>2. The broadcasted communication from the oWSN should be intercepted in a manner that ensures that the data packets are not altered in any fashion.</li> <li>3. The fWSN should be able to capture all possible types of communication that can be sent from the oWSN.</li> </ol>
Proof of authenticity and integrity	<ol style="list-style-type: none"> <li>4. The authenticity and integrity of all the data packets should remain intact while being captured on the fWSN.</li> <li>5. The data packets that are captured on the fWSN should be stored in such a way that their authenticity and integrity are not compromised.</li> <li>6. It should be possible to verify the authenticity and integrity of all the data packets in case a digital investigation takes place.</li> </ol>
Time stamping	<ol style="list-style-type: none"> <li>7. The data packets should have a time stamp that does not violate their authenticity and integrity.</li> <li>8. The sequence of the packets captured should reflect the true sequence in which they were transmitted from the original network.</li> </ol>
Modification of the network after deployment	<ol style="list-style-type: none"> <li>9. It should be possible to implement the fWSN without any modification of the oWSN.</li> </ol>
Protocol data packets	<ol style="list-style-type: none"> <li>10. The fWSN should be designed in such a manner that the network topology or the routing protocol used by the oWSN does not influence the fWSN's operation.</li> </ol>
Radio frequencies	<ol style="list-style-type: none"> <li>11. The fWSN should be able to communicate on the same radio frequencies that are available to the oWSN.</li> <li>12. All communication within the fWSN should occur on a frequency not utilised by the oWSN.</li> <li>13. If an intruder WSN is in the area and communicates on a frequency that influences the oWSN, then the fWSN should be able to forensically capture these data packets.</li> </ol>
Power constraints	<ol style="list-style-type: none"> <li>14. The fWSN should not increase power consumption in the oWSN and the fWSN should have at least the same or a longer network lifetime than the oWSN in terms of battery power.</li> </ol>
Network overhead	<ol style="list-style-type: none"> <li>15. While intercepting communication, there should be no extra network overhead on the oWSN.</li> </ol>
Data integrity	<ol style="list-style-type: none"> <li>16. The fWSN should by no means be able to influence the oWSN or influence any sensory data transmitted within the oWSN.</li> </ol>

## Modifying the network after deployment

The ability to modify the network after deployment is the only factor that is fairly similar between WLANs and WSNs, as it is always possible to modify the code on a device by retracting it from the field, re-developing it and then redeploying it.

However, the practicality of altering oWSN devices after deployment must be considered. It is important to remember that oWSN motes are usually scattered in an area and to alter them, one would have to collect the entire network and redeploy it.

The difficulty and impracticality of modifying the oWSN led the authors to believe that this should also be seen as a specific requirement when attempting to provide forensic readiness to a WSN environment.

Considering that one cannot easily alter the oWSN, one must ensure that the fWSN is able to handle any type of protocol headers and footers that could originate from the oWSN.

## Protocol data packets

The oWSN can have different types of communication protocols in its normal operation. The data packets can include packets to determine the routing protocol, sensory packets, encrypted packets or even malformed packets. To ensure that all the possible protocols used in WSNs are encapsulated in this approach, it is assumed that the oWSN uses an address-free protocol, which generates the largest amount of network overhead in WSNs, as it would cause data to be sent from a source mote in the network to every other mote in the network on each data transmission.

The most common address-free protocols are data dissemination protocols, where neither the sender mote nor any of the other motes in the network know the address of the receiving mote. If the fWSN is able to successfully log this communication of an address-free protocol in a way that ensures authenticity and integrity, one could assume that the name-based

WSN protocols would effortlessly be accounted for, as they have much less network overhead (Dunkels et al., 2007).

As is also the case in WLANs, the motes in the fWSN should listen in promiscuous mode and should be able to handle any type of packet that is transmitted or received by the oWSN. Promiscuous mode is a configuration of the WSN mote in which all traffic within the WSN mote's frequency range and wireless range will be received by the WSN mote. If an attacker uses a foreign mote to inject data into the oWSN, the fWSN should also be able to listen in on this data.

The fWSN should be using a name-based WSN protocol for communication between other fWSN motes, as it is more effective than address-free protocols in terms of network overhead. In name-based protocols, the source mote knows the address of the receiving mote and the motes between the sender and receiver know the path to the receiving mote (Dunkels et al., 2007).

## Forensic readiness requirements for WSNs

A list of requirements is thus proposed that need to be taken into consideration when implementing digital forensic readiness for an IEEE 802.15.4 wireless sensor network. Table 2 summarises the important requirements that need to be taken into account in order to achieve digital forensic

readiness in an IEEE 802.15.4 WSN environment. 📌

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# Optimal Metering Plan of Measurement and Verification for Energy-efficient Lighting Projects

Prof Xiaohua Xia, Xianming Ye and Prof Jiangfeng Zhang



The Centre for New Energy Systems in the Department of Electrical, Electronic and Computer Engineering devised two models to minimise the metering costs of the measurement and verification of energy-efficient lighting projects. Both models proved to be useful, reliable and flexible. They imply the potential to minimise metering costs, while maintaining expected accuracy in the measurement and verification of other energy-efficiency projects.

In order to evaluate the impact of an energy-efficient (EE) project, the reduction in energy consumption must be determined. Measurement and verification (M&V) is the process of measuring and verifying energy and cost savings due to the implementation of energy conservation measures.

Independent M&V inspection bodies are appointed to evaluate the impact of EE projects. The key objective of the M&V teams is to provide unbiased and reliable information on energy and cost savings to a certain degree of accuracy for the EE projects. The accuracy requirements are typically expressed in terms of precision and confidence, where precision is an assessment of the error margin of the final estimate, and confidence is the likelihood that the sampling results in an estimate within a certain range of the true value. In most M&V projects, the degree of accuracy is regarded as a good way to achieve a minimum requirement of 90% confidence within 10% precision (known as the 90/10 criterion).

There are many M&V guidelines that provide metering and sampling methodologies to achieve the 90/10 criterion. According to these general metering and sampling methodologies, M&V professionals can design specific metering plans for any project. There are usually two components in the metering plan. Firstly, an initial sample size is decided on in order to ensure the measurements can be made in stochastically representative ways, and secondly, specific metering

devices and measuring points are recommended and the metering costs are evaluated accordingly.

Cost is an important issue to consider in any M&V metering plan. The average annual M&V costs should be less than 10% of the verified average annual cost savings. It is thus of great interest that the desired accuracy with the lowest metering costs is achieved. Research conducted in this regard proposed a metering cost minimisation model for M&V lighting projects. For a typical M&V lighting project, the entire lighting population was subdivided into different groups according to the uncertainties of the daily energy consumption of the bulbs. By using a proposed optimisation model, the overall accuracy of the project could be maintained by sacrificing the confidence/precision criteria of the groups with high uncertainty, while improving the accuracy in the groups with low uncertainty. The metering costs were then minimised by optimising the sample size of each group. The optimal sample sizes were calculated by the specific confidence and precision levels in each group. The optimal solutions showed that the proposed model largely reduced the metering costs of the sampling, while still maintaining the accuracy requirements of the project.

Lighting characteristics and classification

## Lighting characteristics

According to Mills (2002), lighting consumes more than 2000 TWh

of electricity globally, which corresponds to about 1 800 million metric tons of carbon emissions per year. Lighting harbours a great potential for energy savings and carbon emission reductions. Energy-efficient lighting can be implemented by either reducing the input wattage or the burning time of the bulb. The wattage and burning hours of the bulbs should therefore be identified, or the energy consumed by the bulbs directly measured. The required metering efforts can be determined by the uncertainties of the metering targets.

### Lighting classification

In order to quantify the power and energy savings, measurements are required to characterise the daily energy consumption of the bulbs involved. In practice, the budget for metering is usually limited. Therefore, to achieve the required accuracy with the minimal metering costs, it is wise to perform different metering efforts for different uncertainties of the metering targets. Uncertainties can be quantified by the coefficients of variance (CV), which are defined as the standard deviation of the metering records divided by the mean. The CV value is between zero and one. If the CV is close to zero, it indicates that the uncertainty of measurement is small. If the CV is close to one, the monitored parameter has a large uncertainty. A higher CV indicates more metering efforts, given a certain accuracy requirement.

The bulb population involved in an M&V project can be classified into groups in terms of CV values. According to the sample size calculation formula, when a CV is assigned to each group, the sample size is determined by the desired precision and the confidence level.

Evidently, more metering efforts are required to achieve a high accuracy level for the group with a high CV value than for the group with a low CV value. If the confidence/precision requirements are sacrificed in the group with a high CV and the accuracy requirements are improved in the group with a small CV value,

→ Table 1: Details of the EE lighting Project 1

Existing lighting system		Proposed technologies		Operating schedule	Quantity
Type	Wattage	Type	Wattage		
Halogen downlighters	60 W	LED	8 W	0:00–24:00	15 000
Incan-descent	100 W	CFL	20 W	Based on occupancy	5 000
Sampling target	Average daily energy consumption per bulb after the implementation				
Accuracy requirement	90/10 criterion				

→ Table 2: Initial values of the EE lighting Project 1

Parameters	Group I	Group II
Meter installation costs (R)	$a_1=500$	$a_2=1\ 000$
Maintenance costs (R)	$b_1=500$	$b_2=1\ 000$
Unit price of meter (R)	$c_1=500$	$c_2=5\ 000$
CV values	$cv_1=0.15$	$cv_2=0.5$
Estimated mean	$E_1=0.19$	$E_2=0.12$
Population size	$N_1=15\ 000$	$N_2=5\ 000$

then the accuracy requirements of the overall project may still be maintained and the metering costs can be minimised accordingly.

### The metering cost minimisation model

In order to calculate the specified confidence and precision levels for each group, a metering cost optimisation model was built.

The proposed optimal metering cost model was adopted to design the metering plan for the first year for two specific M&V energy-efficient lighting projects. Results showed that the model could be used for EE lighting projects with different groups.

### Metering cost minimisation for the lighting project with two groups

A number of 20 000 energy-efficient bulbs were installed at a Pretoria hospital. The project aimed to reduce the lighting load in the hospital. An energy audit was conducted to gather the detailed information to help design the metering plan.

Details of the project are provided in Table 1.

In order to obtain reliable results of the claimed power and energy savings for this project, the sampling results of the key parameters of the project had to satisfy the 90/10 criterion.

In addition, the hospital expected minimal metering costs for the savings quantification of the overall project. The bulbs could be classified into two groups according to their different operating schedules. It can be assumed that the CV of the sampling target in Group I was under 0.15, since both the rated power and the operating schedule were known. The CV in Group II was assumed to be 0.5.

To calculate the metering costs, the initial values are listed in Table 2, where  $N_i$  is the lighting population in the  $i$ -th group, and  $E_i$  is the estimated sample mean, which is the estimated daily energy consumption at post-implementation stage in the  $i$ -th group. After the retrofitting, the

8 W light-emitting diodes (LEDs) were burning 24 hours per day. Based on the known power and burning hours, the estimation of  $E_1=0.19$  kWh with a low CV value as 0.15 could be obtained. However, for the 20 W compact fluorescent lamps (CFLs), the daily burning hours are unknown. An estimation of  $E_2=0.12$  can be made on the assumption that the CFLs were burning six hours per day with a high CV value of 0.5.

Before solving the optimisation problem, the metering costs for the desired sampling accuracy without optimisation were calculated as a benchmark for comparison purposes. Without this optimisation idea, the 90/10 criterion is usually applied to each group.

Table 3 shows that the overall confidence and precision levels are 95.09% and 9.45%, respectively, given that both groups achieve the 90/10 criterion. For the sampling, if all the bulbs are classified into only one group, a worst possible CV value of 0.5 can be used for the sample size calculation. The obtained sample size is 67, with a metering cost of R469 000, given that the more expensive meters have to be used when the CV is high. For one of the groups' solutions, the 90/10 criterion is achieved without spending unnecessary money on metering to achieve an overall accuracy level that is better than the 90/10 criterion. The results provided in Table 3 indicate that to achieve the 90/10 criterion, it may not be necessary for each group to satisfy the 90/10 criterion. Therefore, different confidence and precision levels can be assigned to individual groups, while the combination of the

→ Table 3: Metering costs without optimisation of Project 1

Parameters	Group I	Group II	Overall
Confidence	90%	90%	95.09%
Precision	10%	10%	9.45%
Meter number	7	67	74
Metering costs (R)	14 000	469 000	483 000

→ Table 4: Optimal metering cost for Project 1

Parameters	Group I	Group II	Overall
Confidence	89.20%	56.50%	90.23%
Precision	7.77%	20.55%	9.69%
Meter number	10	4	14
Metering costs (R)	20 000	28 000	48 000

confidence and precision levels in the entire project still maintains the 90/10 criterion.

The optimal results are provided in Table 4. Compared to the metering costs in Table 3, it shows that although the metering costs for Group I increase, the metering costs for Group II decrease sharply. Furthermore, significant metering cost savings are achieved and the 90/10 criterion is met.

#### Metering cost minimisation for the lighting project with four groups

A number of 24 000 energy-efficient bulbs were installed at a Pretoria office. The project aimed to reduce the lighting load in the office through the new lighting luminaries. An energy audit was conducted to gather the detailed information to help design the sampling plan. Details of the project are provided in Table 5.

The bulbs without control devices had fixed operating schedules. Others were controlled by EE devices, such as daylight dim and motion sensors. Therefore, the bulbs could be classified into four groups on the different levels of uncertainties of the wattage and operating schedules. For instance, for the bulbs with fixed wattage and operating schedules, a small CV of 0.05 for the daily energy consumption of the bulbs could be assigned. For the bulbs with daylight dim control and a fixed operating schedule, only the wattage variation contributed to the uncertainty of the daily energy consumption.

Since working power only has two states, it can be expected that a CV value of 0.15 is relevant for the daily energy consumption for these lamps. For the bulbs with motion sensor control, the uncertainty of the daily energy consumption of the bulbs came from the unknown operating schedules. A CV of 0.35 could be assigned to these bulbs.

For the bulbs with two control strategies, a default CV value of 0.5 will apply, given that both the power and operating schedules are unknown. In Table 6, initial values such as the installation costs, maintenance costs, meter unit price, CV values, and estimated sample mean for the sampling target and the population sizes in each group are provided.



An energy audit was conducted to determine whether the introduction of new lighting luminaries would reduce the lighting load at a city hospital.



→ Table 5: Details of the energy-efficient lighting Project 2

Existing lighting system		Proposed technologies		Operating schedule	Quantity
Type	Wattage	Type	Wattage		
Halogen down-lighters	60 W	LED	8 W	8:00–16:00	10 000
Incandescent	100 W	CFL	20 W	Daylight dim control (two states: half power and full power), 8:00–16:00	3 000
Incandescent	60 W	CFL	23 W	Motion sensor control	6 000
Incandescent	60 W	CFL	18 W	Daylight dim control and motion sensor control	5 000
Sampling target	Average daily energy consumption per bulb after the implementation				
Accuracy requirement	90/10 criterion				

→ Table 6: Initial values for Project 2

Parameters	Group I	Group II	Group III	Group IV
Meter installation costs (R)	$a_1=500$	$a_2=500$	$a_3=1000$	$a_4=1000$
Maintenance costs (R)	$b_1=200$	$b_2=300$	$b_3=500$	$b_4=1000$
Unit price of meter (R)	$c_1=300$	$c_2=500$	$c_3=1000$	$c_4=5000$
CV values	$cv_1=0.05$	$cv_2=0.15$	$cv_3=0.35$	$cv_4=0.50$
Estimated mean	$E_1=0.19$	$E_2=0.12$	$E_3=0.14$	$E_4=0.11$
Population size	$N_1=10\ 000$	$N_2=3\ 000$	$N_3=6\ 000$	$N_4=5\ 000$

→ Table 7: Metering costs without optimisation for Project 2

Parameters	Group I	Group II	Group III	Group IV	Overall
Confidence	90%	90%	90%	90%	99.59%
Precision	10%	10%	10%	10%	9.02%
Meter number	1	7	33	67	108
Metering costs (R)	1 000	9 100	82 500	469 000	561 600

→ Table 8: Optimal metering costs for Project 2

Parameters	Group I	Group II	Group III	Group IV	Overall
Confidence	96.45%	52.83%	52.00%	52.00%	89.43%
Precision	6.51%	9.47%	10.95%	20.92%	9.31%
Meter number	3	2	6	3	14
Metering costs (R)	3 000	2 600	15 000	21 000	41 600

→ Table 9: Metering costs without optimisation over two years

Parameters	Year 1	Year 2	Overall
Confidence	90%	90%	97.61%
Precision	10%	10%	10%
Meter number	68	67	68
Metering costs (R)	102 000	13 900	115 900

→ Table 10: Optimal metering costs 1

Parameters	Year 1	Year 2	Overall
Confidence	80.02%	69.80%	90%
Precision	9.94%	10.04%	9.91%
Meter number	42	27	42
Metering costs (R)	63 000	12 900	75 900

In tables 7 and 8, metering costs and sample sizes with or without optimisation are also given. By comparing tables 7 and 8, it is clear that by applying the metering cost minimisation model, overall metering costs are minimised and the overall accuracy requirements are maintained.

#### Long-term optimal metering plan

In order to capture the sustainability of the achieved savings, a long-term performance assessment is conducted for the lighting M&V project to continuously report the savings in five or up to ten years after the implementation. When considering the long-term metering plan, the proposed metering cost minimisation model can be generalised to achieve minimal metering costs for a project over a certain number of years.

The preliminary results of an optimal metering plan over two years for one group are provided as an example to illustrate the ideas of designing the optimal metering plan.

Suppose the project window is 10 years and the required reporting interval is two years. This means that during the reporting years, the 90/10 criterion must be upheld. For the first reporting interval (after two years), an accuracy requirement for an M&V EE lighting project is to satisfy the 90/10 criterion over two years of the achieved savings.

#### Metering cost minimisation over two years

The metering cost minimisation model is generalised and applied to the optimal metering plan design over two years. Assume that there are 10 000 CFLs installed in the first year and only 6 000 bulbs survive in the second year. The CV and the estimated sample mean do not change over the two years.

Table 9 shows the metering costs without the optimisation. The number of required meters in the first year is 68, and 67 for the second year because of the decrease in the lighting population. In addition, all these meters are purchased in the

→ Table 11: Optimal metering costs 2

Parameters	Year 1	Year 2	Overall
Confidence	74.89%	83.78%	90%
Precision	10.01%	9.91%	9.95%
Meter number	33	50	50
Metering costs (R)	49 500	32 100	81 600

→ Table 12: Optimal metering costs 3

Parameters	Year 1	Year 2	Overall
Confidence	57.91%	93.65%	90%
Precision	6.70%	15.43%	9.99%
Meter number	36	36	36
Metering costs (R)	54 000	7 200	61 200

first year, and only maintenance costs are required in the second year. If the 90/10 criterion is achieved in each year, the overall accuracy is very high and a large amount of money is spent without awareness.

In Table 10, 42 meters are installed in the first year and a higher accuracy is achieved. To guarantee the 90/10 criterion over the two years, only 27 meters are required in the second year. Compared to the results shown in Table 9, additional meter removal costs are spent although metering costs are less.

Table 11 indicates that to maintain the 90/10 criterion over the two years, 33 meters are required for the first year and 50 for the second year. However, since more meters are installed in the second year to achieve a higher accuracy, the 90/10 criterion over the two years is still maintained.

In Table 12, the number of meters remains unchanged over the two

years, while the overall 90/10 criterion over the two years is maintained. Minimal metering costs are also incurred, compared to the results in tables 10 and 11.

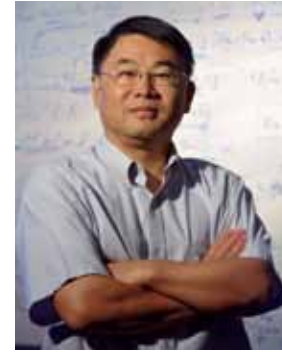
### Application

Both the models developed imply the potential to minimise metering costs while maintaining expected accuracy in other M&V energy-efficient lighting projects. These models can also help with the metering plan for a project with different numbers of groups. In addition, when long-term metering plans are designed by the proposed model, the project developer will be able to make the optimal arrangement of the budget more easily. The proposed optimisation models can also be applied to projects with accuracy requirements other than the 90/10 criterion. ➔

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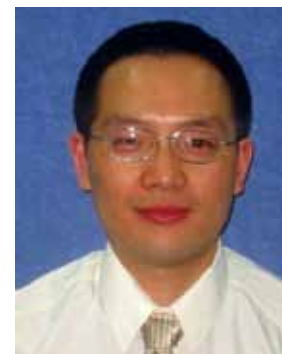
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The University of Pretoria houses the South African National Energy Research Institute (SANERI) National Hub for Energy Efficiency and Demand-side Management.

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# Competing in a globalising world: International ranking of South African universities

Prof Anastassios Pouris and Ms Anthipi Pouris

The rankings of higher education institutions are important to students, research administrations, industries and academics. A university's performance is indicative of postgraduate employment. National research administrations are interested to know the performance of the institutions they support, and individual academic institutions are interested to know their performance, so that they can adjust their policies and strategies appropriately. South Africa, like most of the developing countries, does not produce rankings similar to those in the developed world.

Seven South African universities (out of the 22 in the country) are included in the top 1% of the world's institutions cited in international scientific literature. These institutions are the universities of Cape Town (UCT), Pretoria (UP), the Free State (UFS), the Witwatersrand (Wits), KwaZulu-Natal (UKZN), Stellenbosch (SU) and Rhodes.

A number of national and international rankings of higher education institutions exist. These rankings include those by the *Times Higher Education Supplement* (THES, 2008), the US News and World Report (US News, 2009) and the Shanghai Jiao Tong University (2009). In a globalising world, students, staff and funders prefer to associate themselves with high-ranked institutions rather than with low-ranked ones.

The rankings are also so criticised (Bowden, 2000; Dill et al., 2005, Taylor et al., 2007). One criticism is that complex multi-indicator rankings are not able to assist in the development of policy/strategy guidelines. For example, in the Shanghai Jiao Tong ranking, 30% of the weighting is allocated for alumni and staff of the institution who have won Nobel prizes and Fields medals. While single indicator rankings may not reflect all desirable characteristics of universities, they are amenable to manipulation through appropriate management instruments.

For this investigation, the Essential Science Indicators (ESI) database of the Institute for Scientific Information (ISI) Thomson Reuters is used. In its ESI database, ISI Thomson Reuters provides information of the most cited institutions worldwide during the last ten years. The database identifies 22 scientific fields. To compensate for varying citation rates across scientific fields, different thresholds are applied to each field.

The thresholds are set to select the top 1% of entities from each scientific field. Hence, institutions appear in the dataset only if they receive citations over the threshold. The thresholds of the different scientific disciplines for two different ten-year periods (ending April 2005 and April 2009) appear in Table 1.

Table 1 shows that different disciplines have substantial different thresholds and that for most disciplines, the thresholds are increasing over time.

The ESI database was investigated in order to identify the South African institutions that were included.

Tables 2 and 3 show the number of citations received by the various universities in the different disciplines and the number of publications authored by those institutions respectively.

The identified institutions, together with their rankings, appear in Table 4. The table also shows the number of institutions in each discipline in the database. The different universities have a varied presence in different disciplines. For example, the University of Cape Town has a presence in nine scientific disciplines, with the best ranking in environment/ecology (114<sup>th</sup> in the world). On the other hand, Rhodes University and the University of the Free State have a presence only in one discipline – plant and animal sciences.

In comparison with Table 1, Table 4 can also identify disciplines that are underemphasised by the universities in the country. For example, computer sciences and material sciences are absent from the list, indicating that no university in the country reached the relevant thresholds for these fields.

Comparisons of the individual rankings with the total number of

→ Table 1: Scientific field citation threshold for institutions

Scientific field	Threshold (April 2005)	Threshold (April 2009)
Agricultural sciences	550	769
Biology and biochemistry	3 759	3 774
Chemistry	2 540	2 918
Clinical medicine	1 121	1 496
Computer science	496	845
Economics and business sciences	1 015	1 597
Engineering	525	765
Environment/ecology	1 181	1 585
Geosciences	1 812	2 295
Immunology	3 670	3 708
Materials science	757	1 204
Mathematics	1 102	1 584
Microbiology	2 972	2 969
Molecular biology and genetics	6 597	6 413
Multidisciplinary	516	496
Neuroscience and behaviour	3 679	3 946
Pharmacology and toxicology	1 771	1 995
Physics	3 633	4 397
Plant and animal sciences	959	1 223
Psychiatry/psychology	1 312	2 070
Social sciences, general	335	507
Space science	6 754	10 089

institutions in the database provide an indication of the extent to which the institution runs the risk of being dropped from the database.

The ESI database is commercially available and contains data for 4 050 institutions from around the world.

Inclusion in the database means that the particular institution meets the minimum citation threshold and that the institution is part of the top 1% of institutions in the world in the particular discipline. University administrations most likely want to have a presence in as many disciplines as possible and the highest ranking possible.

The advantage of the developed ranking is that it can provide a picture of the particular institutions over time. Table 5 shows, for example, the South African institutions' rankings during 2005. In comparison, tables 4 and 5 can have a valuable inter-temporal

→ Table 2: Number of citations of South African institutions in ESI database (1 January 1999 to 30 April 2009)

Discipline	UCT	UP	UFS	Wits	UKZN	US	Rhodes
Biology and biochemistry	6 788						
Chemistry	3 864			4 661		3 845	
Clinical medicine	21 346	4 496		14 808	5 968	11 405	
Engineering	875	1 533		1 121			
Environment/ecology	8 312	3 823			2 858	4 120	
Geosciences	5 665			4 816			
Plant and animal sciences	7 755	9 546	1 362	2 473	3 465	4 388	2 925
Social sciences, general	2 748	637		2 653	729	564	
Agricultural sciences		1 001				1 182	
Immunology	5 822						
Microbiology						3 329	
Psychiatry/psychology						2 303	

→ Table 3: Number of publications of South African institutions in ESI database (1 January 1999 to 30 April 2009)

Discipline	UCT	UP	UFS	Wits	UKZN	SU	Rhodes
Biology and biochemistry	470						
Chemistry	483			537		3 845	
Clinical medicine	2 079	555		1 509	555	11 405	
Engineering	250	533		361			
Environment/ecology	636	492		217	195	4 120	
Geosciences	617			682			
Plant and animal sciences	1 077	1 914	340	405	403	4 388	586
Social sciences, general	627	319		656	142	564	
Agricultural sciences		202				1 182	
Immunology	266						
Microbiology						3 329	
Psychiatry/psychology						2 303	

→ Table 4: International rankings (1 January 1999 to 30 April 2009)

Discipline	UCT	UP	UFS	Wits	UKZN	SU	Rhodes	Total institutions
Biology and biochemistry	448							687
Chemistry	771			684		774		907
Clinical medicine	456	1 335		593	1 124	726		2 904
Engineering	955	637		802				1 039
Environment/ecology	114	286		353	353	259		515
Geosciences	202			245				429
Plant and animal sciences	166	122	771	509	389	307	443	835
Social sciences, general	197	541		204	499	594		640
Agricultural sciences		326				278		413
Immunology	192							294
Microbiology						288		313
Psychiatry/Psychology						352		367

→ Table 5: International ranking (1 January 1995 to 30 April 2005)

Scientific discipline	UCT	UP	UFS	Wits	UKZN	SU
Biology and biochemistry	444					
Chemistry				604		
Clinical medicine	497	1 136	2 511	560	984	764
Engineering		573		778		
Environment/ecology	103	265			366	
Geosciences	207			166		
Materials science				521		
Plant and animal sciences	188	200	489	533	271	427
Social sciences, general	279			244	565	

(Source: Pouris 2007)

assessment. The University of Cape Town had, for example, a presence in six scientific fields. In 2009, its presence increased to nine fields.

### About the authors



**Prof Anastassios Pouris** is Director of the Institute for Technological Innovation at the University of Pretoria. His research is focused on science, technology and innovation policy studies, including assessments and international benchmarking.

UCT was ranked number 497 in clinical medicine. In 2009, the university was ranked number 456 in the same discipline. 📍



**Ms Anthipi Pouris** is associated with the National Research Foundation and the University of Pretoria. She has been involved in scientometrics research in South Africa since 1987.

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# Diversity in townhouse complexes in South Africa

Dr Karina Landman

In reaction to the continuous challenges posed by social and spatial segregation in contemporary cities, there has been an increasing call for greater socio-spatial integration in housing developments and neighbourhoods in recent years. This is especially the case in South Africa, where fragmentation remains a major challenge in cities.

South African cities have experienced varying degrees of socio-spatial transformation since 1994, which necessitates a reconsideration of the status quo and the levels of diversity and integration – or lack thereof – in urban areas.



→ *Townhouse complexes have contributed to the changing urban landscape.*

It is argued that socially and spatially mixed developments and neighbourhoods can support place diversity and contribute to safer and more sustainable human settlements (Jabardeen, 2004; Baily et al., 2006). Place diversity is diversity that exists within the realm of “everyday life” activities and can broadly be described as “the phenomenon of socially diverse people sharing the same neighbourhoods, where diversity is the result of a mix of income levels, races, ethnicities, ages, and family types” (Talen, 2008:4-5).

One of the most significant factors changing the urban landscape in South Africa has been the proliferation of so-called townhouse complexes or sectional title schemes. These complexes range from large to smaller developments, including a variety of housing types ranging from luxury villas in secure complexes to smaller units catering for the lower middle class. Secure or gated townhouse complexes refer to complexes that are fenced or walled and have controlled access through

a gate. In response, the Department of Town and Regional Planning at the University of Pretoria has embarked on a project to investigate the level of diversity in and around townhouse complexes/developments to determine their impact on socio-spatial transformation in South African cities.

While there is disagreement in the international debate on what constitutes a diverse neighbourhood or housing complex, a number of factors keep reappearing. It is clear that diversity refers to both spatial and social diversity, where spatial diversity is mostly accommodated through a mix of unit types and facilities or amenities in these complexes, while social diversity generally relates to the presence of diverse people in a neighbourhood or complex based on a mix of income groups, races, ethnic groups, ages and family types.

In South Africa, the concepts of diversity and integration are often used in a very broad sense, without common agreement of what this

entails in practice. Therefore, it is difficult to define what it means to say that neighbourhoods are diverse, and on what statements are based that there is a lack of integration in housing complexes and neighbourhoods. There is a need to clarify the meaning of diversity in the South African context and to understand how this influences people's perceptions in typical townhouse complexes. This is especially important, as there is a general perception among the public and some built environment professionals that many South Africans remain hesitant to live in more diverse complexes. A number of students<sup>1</sup> from the University of Pretoria started to explore this in 2012.

These studies indicate that people's perceptions of diversity vary between and within the different townhouse complexes. While many associate diversity with different race or cultural groups, there are also some who link the notion of diversity to a mix of language or religious groups and educational backgrounds. Most of the interviewees agree with the factors linked with social and spatial diversity in the international debate. Everyone agrees that the presence of a variety of race or ethnic groups would contribute to greater diversity, while

the majority also links diversity to the inclusion of various income groups. While most people acknowledge the presence of different age groups and family types in their complexes and agree that these factors contribute to social diversity, a few are more sceptical. For them, this is a given, and not something that should be considered as a factor per se. One resident remarked that while it is easy for a large city such as London to be diverse due to the presence of many cultural, racial and religious groups, it is much more difficult for a complex to be diverse. This also raises the issue of the scale and proximity of diversity that would start to influence people's perceptions. In this regard, diverse neighbourhoods may be more feasible than diverse complexes.

Spatial diversity was not considered as that important. A number of residents did, however, raise the issue of aesthetic diversity. The appearance of the units is considered to be more important by some. Yet, others acknowledge that a variety of unit types and sizes would tend to accommodate a wider range of income groups. For many respondents, the presence of communal space inside the complex is very important, as they feel that this contributes to greater spatial diversity.

A number of issues emerged from the initial studies. Although there are some similarities, ideas regarding diversity vary between the different complexes, both in terms of what constitutes diversity, and how diversity influences their decision to live in the complex. The sampled residents tend to welcome diversity. Some of the motivations include that as South Africans, it is important to learn from different cultures and other people's ways of living. Most of the residents highlighted the fact that diversity did not influence their decisions to stay in townhouse complexes. Other issues such as safety and security, affordability, a secure investment, unit size, well-maintained outdoor spaces, and the income groups in the complex are considered as much more important. Income is therefore the only factor of diversity that appears to play some role in their decision-making. However, some residents from one specific complex stated a concern about the social diversity of neighbours in the development. Finally, it also emerged that diversity is somewhat different to levels of integration and actions towards integration. While many of the respondents acknowledge the presence of diversity in their complexes, this does not automatically lead to more

<sup>1</sup> These included a number of master's students enrolled in the coursework master's study programmes offered by the Department of Town and Regional Planning who elected to work on the project for their mini-dissertations. Each student worked in a different townhouse complex, but used the same interview schedule to guide their questions to residents. Townhouse complexes all over Gauteng were included and students interviewed at least 15 households per complex.



→ *The presence of communal space inside townhouse complexes is very important.*



social interaction. Only in a few cases did respondents remark on the interaction and social integration between neighbours, facilitated by the presence of communal facilities. In other cases, people referred to the presence of these facilities, but maintained that they were rarely used by residents.

This article only highlights some of the initial findings. Further studies are needed, including the influence of the design and layout of the complexes on opportunities for greater diversity and integration. It is also important to widen the scope of the study area. The initial studies only included townhouse complexes in Gauteng. Ongoing studies will look further and also include many other provinces in South Africa to obtain a better understanding of the perceptions towards diversity in townhouse complexes in the country. What is evident, is that the initial studies seem to indicate that people, in general, are much more willing to live in diverse complexes than what is generally considered by the public at large and built environment professionals. 📍

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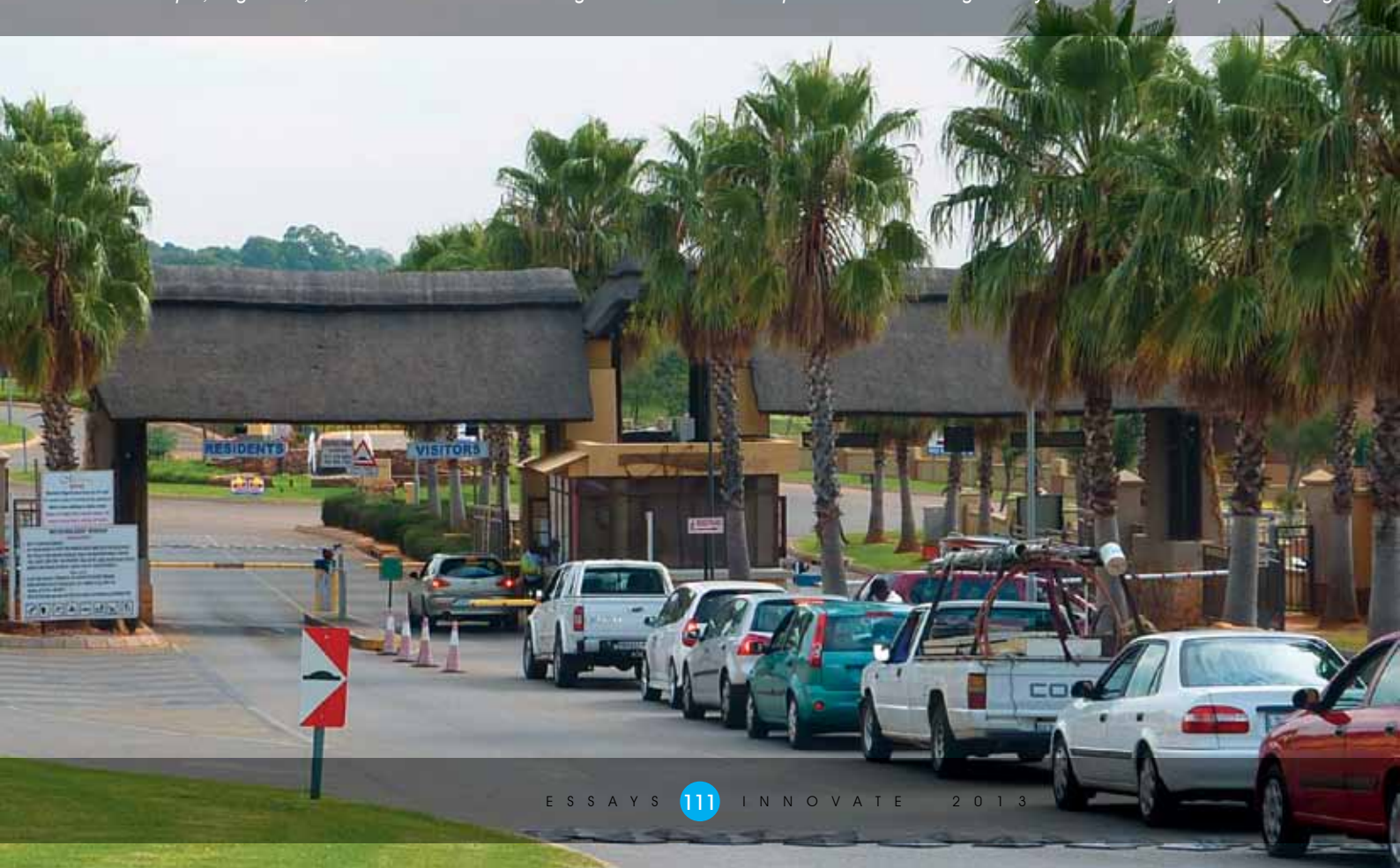
## Acknowledgements

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→ People, in general, seem to be much more willing to live in diverse complexes than what is generally considered by the public at large.



# Tapping untapped renewable energy

Marco van Dijk, Prof Fanie van Vuuren, Jay Bhagwan and Adriaan Kurtz

In water distribution networks in South Africa, water is often fed under gravity from a higher reservoir to another reservoir at a lower level. This provides an opportunity to generate renewable energy by passing the flow through a turbine. The high pressure head at the receiving reservoir is then dissipated through the control valves (altitude valves) or, in some cases, orifice plates. The benefit of this hydropower-generating application is that minimal civil works need to be done, as the control valves are normally inside a control room/valve chamber. No negative environmental or social effects require mitigation and the anticipated lead times should be short.

There are basically four areas where energy generation can occur in the water supply and distribution system as shown in Figure 1:

- Dam releases – conventional hydropower
- At water treatment works (raw water) – the bulk pipeline from the water source can be tapped
- Potable water – at inlets to service reservoirs or in the distribution network itself where excess energy is dissipated, typically with pressure-reducing valves (PRV)
- Treated effluent – cases where the treated effluent has potential energy, based on its elevation above the discharge point

The University of Pretoria, supported by the Water Research Commission (WRC) and collaborating organisations such as the City of Tshwane Metropolitan Municipality, is engaged in a research project to investigate the potential of extracting the available energy from existing and newly installed water supply and distribution systems. The project aims are to enable the owners and administrators of the bulk water supply and distribution systems to install small-scale hydropower systems to generate hydroelectricity for on-site use and in some cases to supply energy to isolated electricity demand clusters or even to the national electricity grid, depending on the location, type and size of installation.

According to the European Small Hydropower Association (ESHA) and the United States Bureau of Reclamation (USBR), hydropower has the following advantages over other forms of energy production in terms of economical, social and environmental impacts:

- It generates clean, renewable and sustainable energy, as it makes use of the energy in water due to flow and available head. It does not emit any atmospheric pollutants

such as carbon dioxide, sulphurous oxides or nitrous oxides, or particulates such as ash.

- Hydropower schemes often have very long lifetimes and high efficiency levels. Operation costs per annum can be as low as 1% of the initial investment costs.
- Hydroelectric energy has no fuel cost and low operating and maintenance costs; thus it is essentially inflation-proof.
- Hydroelectric energy technology is a proven technology that offers high efficiencies as well as reliable and flexible operation.
- Conduit hydropower requires a small capital investment and has a short return on investment period, since existing infrastructure is utilised.

The type of hydropower that will be generated is called “conduit hydropower” (National Hydropower Association, 2011), as shown in Figure 1, at locations 2, 3 and 4.

## What is conduit hydropower?

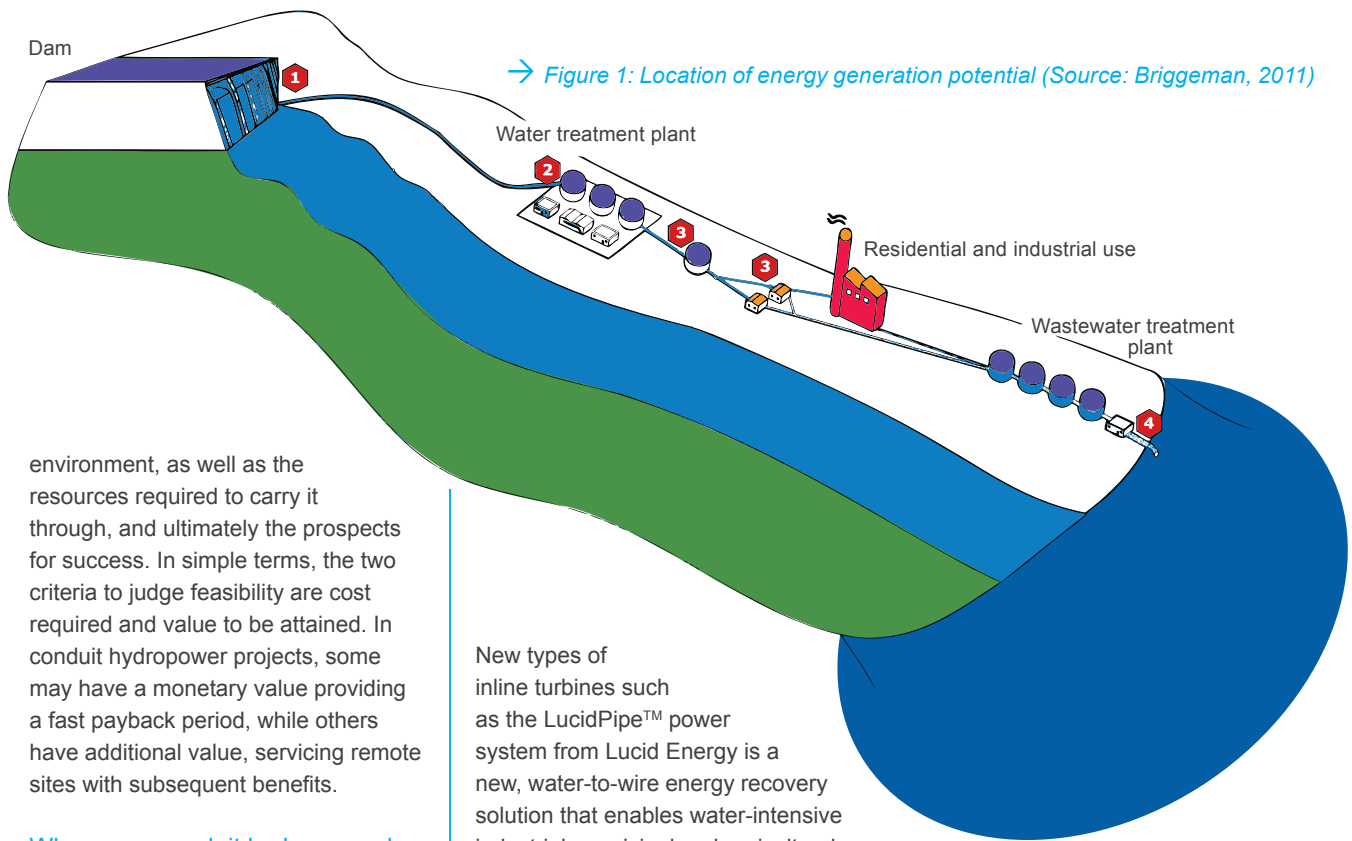
Conduit hydropower is when excess energy available in pressurised conduits (pumping or gravity) is transformed into clean, renewable hydroelectric energy by means of a turbine.

## How does conduit hydropower work?

Due to demand patterns and component size determination, the water entering the reservoir still has excess energy, which is normally dissipated by means of pressure control valves. By installing a parallel system, a turbine, the flow and head is used to generate hydroelectric power.

## When is a site feasible?

Feasibility studies aim to objectively and rationally uncover the strengths, weaknesses, opportunities and threats of the venture as presented by the



→ Figure 1: Location of energy generation potential (Source: Briggeman, 2011)

environment, as well as the resources required to carry it through, and ultimately the prospects for success. In simple terms, the two criteria to judge feasibility are cost required and value to be attained. In conduit hydropower projects, some may have a monetary value providing a fast payback period, while others have additional value, servicing remote sites with subsequent benefits.

### Where can conduit hydropower be installed?

An initial scoping investigation conducted for the Water Research Commission highlighted the potential hydropower generation at the inlets to storage reservoirs. In South Africa, there are 284 municipalities and several water supply utilities that own and operate gravity water supply distribution systems and have some type of pressure-dissipating system at the downstream end of the supply pipe.

New types of inline turbines such as the LucidPipe™ power system from Lucid Energy is a new, water-to-wire energy recovery solution that enables water-intensive industrial, municipal and agricultural facilities to produce clean, reliable, low-cost electricity from their gravity-fed water pipelines (see Figure 2).

### How is the electricity generated by the plant used?

The electricity generated by a plant can be used on site for the lighting, telemetry system, alarm system and electric fence. Larger systems (higher kW output) could be connected to the electrical grid, thus reducing the demand from Eskom.

In some cases electricity can be sold directly to Eskom.

### How are conduit hydropower plants financed?

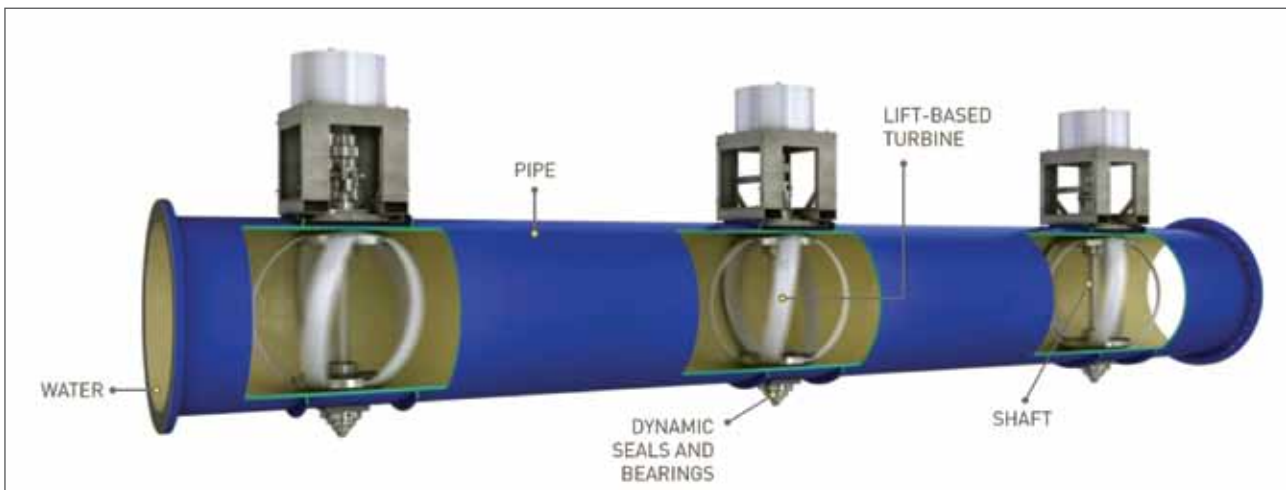
The feasibility studies conducted thus far have indicated that these types of hydropower installations have a relatively short payback period. The reason for this is the minimum amount of civil works required, compared to conventional hydropower projects. Due to the very low profile of small-scale hydropower development in South Africa during the last two decades, there are no defined approaches or methods for financing hydroelectric installations. Currently the municipalities or water boards would utilise their own budgets to finance such projects. Larger types of installation could, however, require other funding mechanisms, such as the Development Bank of South Africa or commercial banks.

### Potential in the City of Tshwane water distribution system

The City of Tshwane Metropolitan Municipality (now including Metsweding) receives bulk water from Rand Water, Magalies Water and its own sources, including boreholes,



→ Example of a Francis turbine installation (Source: Hydrolink, 2011).



→ Figure 2: Inline turbine (LucidPipe™ Power System) (Source: Kanagy, 2011)

water purification plants and fountains. Water is then distributed through a large water system that includes 160 reservoirs, 42 water towers, 10 677 km of pipes and more than 260 pressure-reducing installations (PRVs) that operate at pressures up to 250 m. Geographically speaking, the City of Tshwane has a lower elevation than the bulk service reservoirs of Rand Water, which is the main water supply, resulting in high pressures still available in Tshwane.

In a desktop study, the ten reservoirs with the highest potential in the City of Tshwane were identified. The use of the potential energy stored in the pressurised closed-conduit water systems in Tshwane is, however, not limited to these sites. These 10 sites have the potential to generate 10 000 000 kWh per annum.

#### Case study: Pierre van Ryneveld conduit hydropower plant (PvRCHP)

The first closed-conduit hydropower pilot plant in South Africa was constructed at the Pierre van Ryneveld reservoir, situated in the Country Lane Estate, south of Pretoria. It is a ±15 kW installation that utilises a cross-flow turbine discharging through the roof into the reservoir. A controlled flow is supplied to the turbine from the main supply line into the reservoir.

It is planned to utilise the generated power on site for lighting, as well



→ Pierre van Ryneveld conduit hydropower plant



→ Controlled off-take to turbine

as for alarm and communication systems. The Homeowners' Association of the estate have also indicated that they would like to utilise the power for street lighting. Annually, approximately 131 000 kWh could be generated with this unit, which is enough to supply 10 households. As long as people use water, electricity can be generated.

The pilot plant installation has a favourable payback period and upscaling of the plant would result in an even faster payback period.

### Payback period

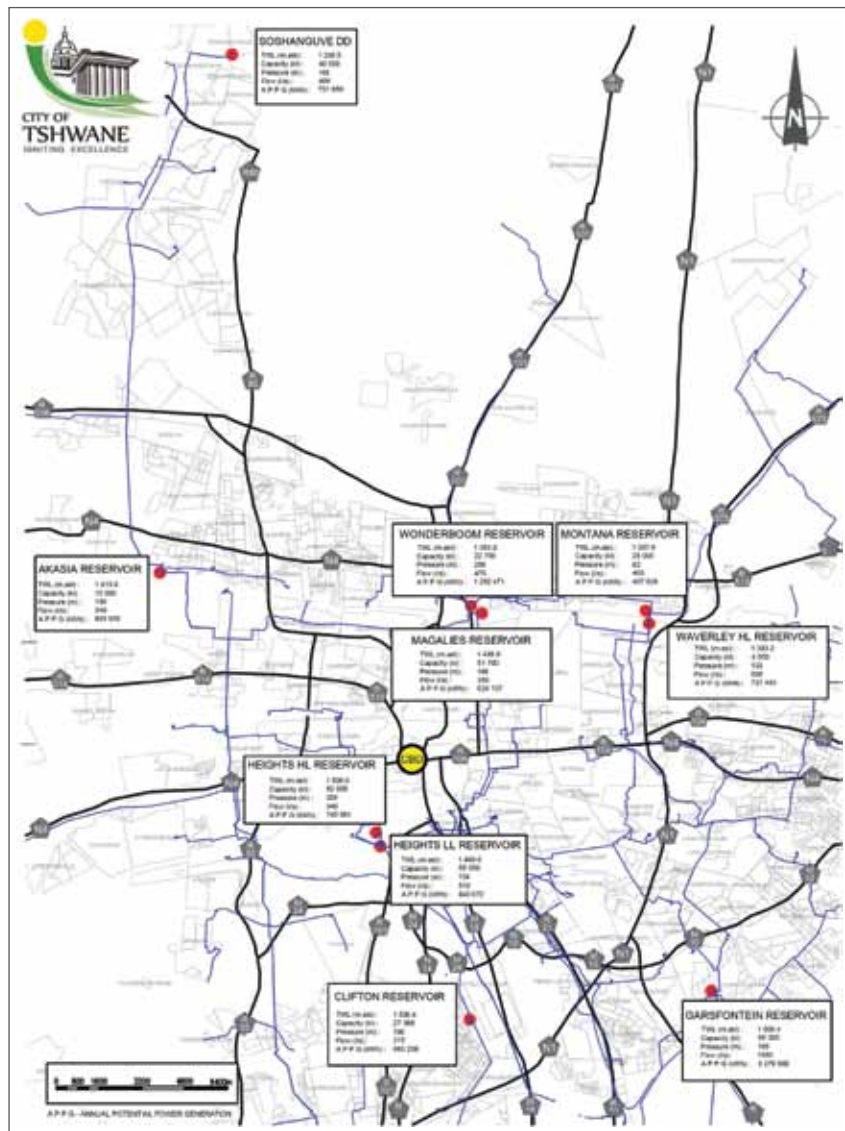
The preliminary cost for the pilot plant totalled R550 000. This was for the turbine and generator, electrical work, pipework, valve chamber, enclosure/ plant housing, monitoring system, data logging and communication system. Annual income would be in the order of R78 000 for electricity generated, based on 60 c per kWh. Assuming a discount rate of 10% and a very optimistic energy escalation rate of only 8%, the payback period can be estimated at approximately nine years. ☺

### Acknowledgements

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→ Hydropower potential in the City of Tshwane (10 reservoirs with highest potential)



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# End user needs for 3G services in rural areas

Louwrence Erasmus and Daniel Smith



With the introduction of mobile technology and mobile telephones in society, information and communication technologies (ICTs) have been strengthened to transform the way in which we live and work.

According to research conducted at the Meraka Institute at the Council for Scientific and Industrial Research (CSIR), the digital divide between urban and rural areas, and the disparities between first- and third-world countries have led to very few people having access to the internet.

Mobility and mobile business can benefit from allowing a subscriber freedom of movement, ubiquity (the utilisation of services independent of location), reachability (ability for subscribers to be reached anytime, anywhere) and convenience.

## Mobile data connectivity

Preliminary findings and investigations suggest that many rural and isolated communities and industries in South Africa do not have adequate and sufficient infrastructure for data connectivity and ICT applications. The data connectivity can either be in the form of fixed-line or mobile connections, but due to the lack of existing fixed-line infrastructure in South Africa (especially in rural South Africa) the only option is via mobile connectivity supplied by mobile network operators (MNOs).

Research conducted in the Graduate School of Technology Management

sought to answer the following questions:

- What are the actual needs and drawbacks for rural and isolated communities and industries when it comes to mobile data connectivity and broadband data connectivity?
- What information and communication technology (ICT) applications and development can arise if mobile broadband is supplied in these locations?
- Is sufficient education provided for the application of ICT development?
- Do people know and understand the choices and freedom of gaining information via applications such as the internet?

The researchers intended to answer these questions by assessing the actual data connectivity issues in the rural areas of South Africa (in particular, Mpumalanga and Limpopo), assessing the actual desires or wants of the communities and individuals with regard to data connectivity, ascertaining the day-to-day business and functionality of ICTs in the areas, and distinguishing the possibilities of improving the quality of mobile broadband.

The researchers conducted two tests with the data that was collected. These included an analysis of the research questions. The results obtained with regard to what the respondents have indicated they own and use, illustrate that the population in the two provinces indeed have the necessary means to communicate effectively. The survey results also illustrated that cellphones are the dominant means of mobile network connectivity and that the majority of respondents are satisfied with the current coverage in the locations.

Although the results indicated that coverage in general was satisfactory, there was still a split between 2G and 3G technology. Many respondents did not know the difference between the two technologies and their attributes. Satisfaction and data speeds were stringent needs for the respondents, especially with the online results, which corresponded to the higher living standard measure (LSM) market, where the need for faster data connectivity was necessary for both work and personal use.

With regard to the availability of sufficient education and knowledge for the application of ICT development, respondents acknowledged the need for education and knowledge-sharing for future provisioning and the access needs of data connectivity.

The results, coupled with the frequency of times the respondents gained access to ICT applications and the internet, and the belief that ICTs and the internet had enhanced the livelihood of the respondents, demonstrated that although subscribers utilised data connectivity on a regular basis, the actual limits to their application and possible data usage could be enhanced.

In 2010, the broadband penetration rate for the entire population of South Africa was 9.76%. With respect to the survey response, a total of 89.2% of respondents indicated that they accessed ICT applications and services via their cellphones, 23.7% of respondents indicated that they had 3G coverage in the area, while 53.8% indicated that both 3G and 2G

→ Table 1: Mid-year population estimates for 2011 for Limpopo and Mpumalanga

Province	Population
Limpopo	5 554 657
Mpumalanga	3 657 181
<b>Total</b>	<b>9 211 838</b>

(Source: Statistics South Africa, 2011)

were available. This indicated that 77.5% of the respondents had mobile broadband infrastructure in the area.

By considering the mid-year population statistics for Mpumalanga and Limpopo for 2011 (see Table 1), the total market can be estimated as the total population of the two provinces (9 211 838 inhabitants) for this period.

The researchers considered the fact that 77.5% of the respondents had access to mobile broadband and accessed the internet from their cellphones. This did not correlate with their calculations of the number of respondents who had adopted mobile broadband (only 13.64%).

### Conclusions and recommendations

Infrastructure is mainly available, and obtaining better coverage from a rural perspective is not necessarily a stumbling block. There is, however, a need for better and more stable broadband services.

The wants and needs of subscribers are becoming more demanding with regard to capacity and the improvement of speed due to the high adoption rates of smartphones and tablet PCs.

The researchers are of the opinion that handset sales and assistance from mobile network operators may aid the adoption rate of data and decrease segmentation between rural and urban locations.

Education is, however, needed for data connectivity adoption in lower LSM markets, which will enhance the day-to-day living conditions of these people. The network analysis indicated that data connectivity and communication is increasing rapidly. ➔

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### About the authors



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# Towards greener pyrotechnics

Prof Walter W Focke, Ollie del Fabbro, Cheryl Kelly, Kolela Illunga, Thilo van der Merwe, Elmar Muller and Maria Atanasova

Green chemistry is an initiative adopted by chemists and chemical engineers striving towards the sustainable manufacture of chemical products. It is a philosophy that encourages the design, development and implementation of chemical products and processes that reduce or eliminate the use and generation of substances that are hazardous to the environment and to human health. Green chemistry for pyrotechnics is currently an intensive global research effort.

AEL Mining Services, a leading developer, producer and supplier of commercial explosives, initiating systems and blasting services for mining, quarrying and construction markets in Modderfontein, is also committed to this ideal. It has made significant progress in developing green chemistry pyrotechnic systems and manufacturing methods. As part of its efforts in this regard, it has partnered with the Institute of Applied Materials (IAM) at the University of Pretoria.

The main focus of this research collaboration over the last 10 years was to find greener alternatives to lead- and other heavy metal-based compounds currently in use in shock tube detonators. This includes lead-based primary explosives, as well as lead-based delay compositions.

The National Research Foundation (NRF) has also supported this research through its Technology for Human Resources in Industry Programme (THRIP). While the research was primarily of an academic nature, it has led to several patents in addition to numerous scientific publications, conference contributions, and master's and bachelor's research dissertations. Many students' studies received generous financial support from AEL Mining Services. Selected students have also excelled by winning innovation awards for their research.

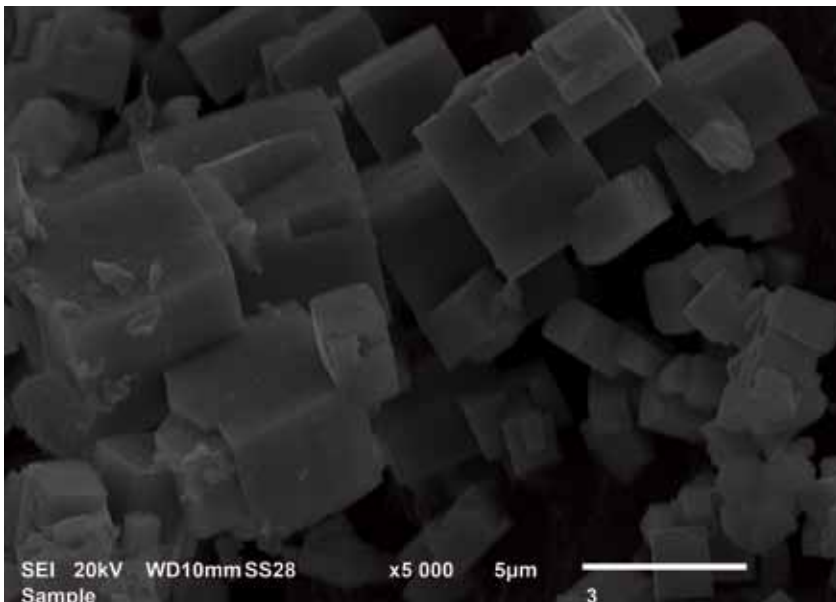
## Pyrotechnics

A conventional pyrotechnic composition is a mixture of a metal fuel and an oxidiser that is capable of a self-sustained exothermic redox reaction. The reaction results in the oxidation of the metal to form a more stable oxide and the reduction of the metallic oxide to the free metal. The thermite reaction between aluminium and iron oxide powders is a popular example. This reaction generates

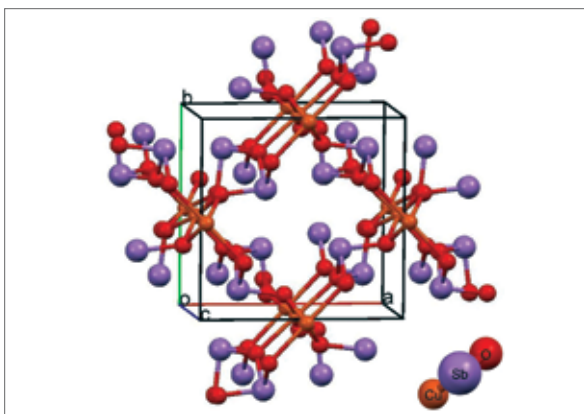
temperatures that exceed 2 000 °C as the aluminium is oxidised to alumina and pure iron metal is formed. Pyrotechnics find widespread use in civilian, military and mining applications, generating sound, light, smoke and high heat. The commercial detonators used in mining and quarrying depend on pyrotechnic compositions for the exact timing of sequential blasting events. This is achieved by the highly reproducible burn rates of the pyrotechnic composition, which is filled into the delay element assemblies.

Ultimately, this detonator subassembly comprises an ignition source, a small-diameter tube containing the compacted pyrotechnic composition and an ignition transfer system. Following ignition, a combustion wave travels down along the tube at a constant velocity. This ensures the transmission of the initiation impulse to the detonator in a precisely adjustable time interval. The delay elements are currently manufactured by pressing the pyrotechnic composition into aluminum tubes. The automated filling and pressing process requires powders with good free-flow behaviour. At present, pyrotechnic time delay formulations are based on silicon as fuel, in combination with red lead oxide (fast-burning for short time delays) or barium sulphate (slow-burning for long time delays).

Ultimately, lead and its compounds in detonator time delays must be phased out owing to environmental and health concerns. The AEL team has found that bismuth oxide ( $\text{Bi}_2\text{O}_3$ ), prepared by thermal decomposition of bismuth subcarbonate, may provide suitable fast-burning compositions with silicon as fuel (155 mm s<sup>-1</sup> with 20% Si). Alternatively, the Si-Sb<sub>6</sub>O<sub>13</sub> system yielded slow-burning compositions that could be slowed down even



→ Figure 1: Scanning electron micrograph of copper antimonite crystal produced by the “green” synthesis process invented by the AEL team



→ Figure 2: The  $\text{CuSb}_2\text{O}_4$  structure represented as a ball-and-sticks model

modelling and Raman spectroscopy. It is evident that this material has a highly unusual crystal structure, as seen in Figure 2. Only half of the crystal positions available for the copper atoms are essentially occupied. This explains the insensitivity of compositions based on this oxidant to accidental ignition by friction and impact.

further by adding fumed silica: a composition obtained by adding 10% fumed silica (add-on basis) to a 10% Si–90%  $\text{Sb}_6\text{O}_{13}$  composition that still burned reliably at a burn rate of  $2.3 \text{ mm s}^{-1}$ .

Early on, a novel oxidant, copper antimonite ( $\text{CuSb}_2\text{O}_4$ ), was identified as a candidate oxidant for use in time delays for mining detonators with desirable properties. The AEL team recently developed a “green” effluent-free process for the synthesis of this compound. The process yields small well-formed crystals, with a cuboid habit as shown in Figure 1. The crystal structure of this material was recently determined via modelling of the powder X-ray diffraction data and confirmed via molecular

Thermite reactions are difficult to start, as they require very high temperatures for ignition. For example, the ignition temperature of the Al–CuO thermite, when comprising micron-sized particles, is ca.  $940 \text{ }^\circ\text{C}$ . The IAM team has discovered that the ignition temperature can be significantly reduced when the binary Si– $\text{Bi}_2\text{O}_3$  system is added as sensitiser. Although even lower ignition temperatures are possible when the reagents are nano-sized powders, the AEL team has found that this system is capable of initiating high explosives even when the particles are only micron-sized.

Thermites are pyrotechnic compositions that undergo reactions that are extremely exothermic and run with self-sustaining oxygen content. The energy density of some stoichiometrically balanced thermites is comparable to that of conventional high explosives. Recently, it was discovered that thermites comprised of nano-sized powders can generate temperature shocks capable of initiating high explosives. Unlike the lead-based primary explosives, they are relatively insensitive to friction, shock and electric spark. Consequently, much effort is expended worldwide to explore the use of thermites as replacements for primary explosives.

Dry mixing of pyrotechnic powders is a hazardous operation. AEL has recently commercialised the much safer slurry spray-drying technology. This innovative method yields free-flowing granules, as it creates almost perfect spherical particle agglomerates. In addition to the acceptable flow properties, this process also yields well-mixed compositions from dispersions containing different powders, and provides control over the particle size distribution of the near-spherical agglomerates. Unfortunately, the silicon powder fuel used in these compositions reacts with water, liberating hydrogen gas that poses a risk for explosion.

The AEL research team developed different ways to suppress this hydrogen generation. These include the addition of a noble ion salt, for example, copper (II) ions, to introduce a competing cathodic reaction, which is controlled air oxidation of the silicon powder before slurring and adding organic corrosion inhibitors. It was found that silane surface modification of silicon is the most effective method for the suppression of hydrogen evolution while maintaining or even improving silicon reactivity in a typical pyrotechnic composition.

Contrary to popular belief, a form of metal rust can react with the neat metal to generate very high temperatures. Manganese dioxide powders, mixed with manganese

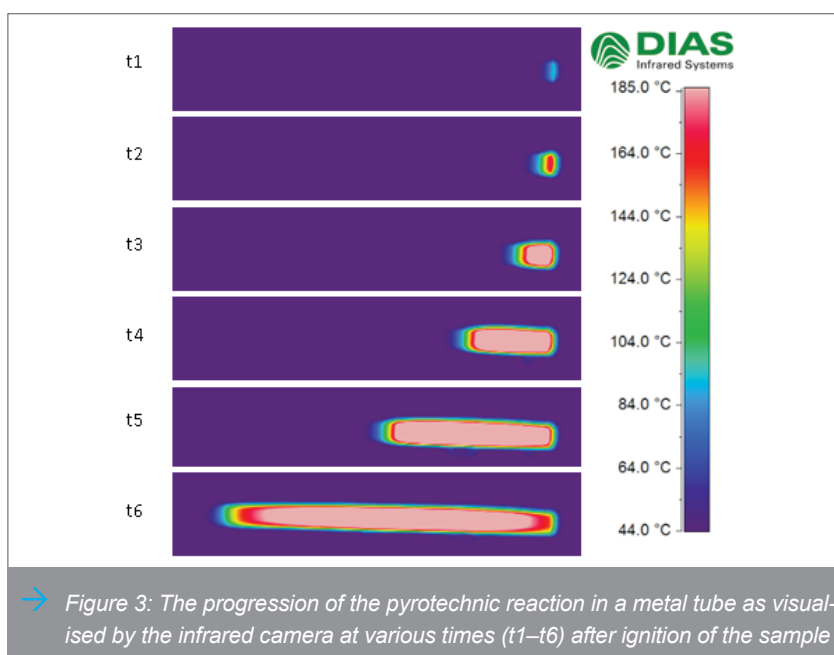
metal powder, showed reliable burning over a wide stoichiometric range. The unusual aspect of this system is that the fuel and the oxidant share a common metal. They combine to form the more stable intermediate oxide (MnO), releasing considerable quantities of heat in the process. Investigations showed that this system is suitable for time delay applications. A major advantage is the fact that hydrogen evolution from the manganese metal in aqueous slurries can be suppressed completely.

The methods currently used for measuring the burn rates of pyrotechnic time delay compositions are destructive in nature and pose some safety risks. The AEL team recently implemented a new method. A high-speed infrared camera is used and allows the real-time recording of surface temperature profiles. In combination with a mathematical model, these can be used to infer the temperature profiles inside the element and to estimate average and instantaneous burn speeds. Figure 3 shows typical images recorded during a burn test of a new formulation in a metal tube.

The example that is described in this article shows that there is potential for further innovations from the AEL team and they look forward to continuing their fruitful collaboration with the University of Pretoria into the future. 📍

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# Planning law within the culture of a new generation of planners

Witness Radebe

Planning law is a very crucial tool with the value and potential to assist South Africa in physically and economically restructuring development and growth. Simply put, it is one of the instruments that helps the country avoid chaos and facilitate order.

In the South African context of planning law, it is ironically not planning and its principles, but the laws employed to implement these that are at times improper. This indicates that although planning has noble goals to improve the social, physical, economic and environmental quality of living for communities, the actual strategies and their implementation have not achieved these goals. This is the result of many factors that are feeding the “artificial order” that South Africa seems to be embracing.

A study conducted by a young black researcher in the Department of Town and Regional Planning on young black planners’ experiences of planning practice revealed interesting insights into the way these planners perceived planning law, as well as the impact of culture on the way they viewed planning.

## The significance of planning

Planners were interviewed to obtain information on their experiences. All the planners interviewed acknowledged the significance of planning and the value it could achieve. They all agreed that national policies and powers were a serious culprit in preventing the positive possibilities of planning.

Respondents indicated that national government sometimes released policies without sufficient consultation with the other spheres of government, although these policies would eventually be implemented by local authorities. In African culture, the “father of the house” is the authority figure of the household and whatever he says goes, whether it is correct or not. This means he has no set reason to consult as extensively as might be needed with the rest of the family before he takes a decision.

The problem with this concept in the three spheres of government is

that the policies released by national government may sometimes not match the need identified by the local authorities. According to a report published by the Centre for Policy Studies of the University of the Witwatersrand, these policies eventually work to misdirect resources from the actual need on the ground, thereby ensuring that South Africa is its own enemy.

A practical example offered by one of the respondents was the Reconstruction and Development Programme (RDP). This programme aimed to provide affordable housing to those who needed it. Affordable housing is a key goal in smart growth approaches, which are tools for implementing planning principles. This planner noted that although the RDP had good intentions, it was not well received in a specific village. The residents of the village wanted more traditional housing. This resulted in a conflict between the residents and the local municipality. Time, funds and natural resources were therefore wasted due to a mismatch between local need and national policy.

Another incident noted by a respondent occurred in Limpopo, where informal traders were given a closed-in building similar to a modern shopping complex, while their need was for a shelter to protect them from the rain and the sun. This also led to a wastage of resources because the informal traders didn’t use the structure for its intended purpose, but rather used the roof overhang outside as the shelter they desired.

In these two instances, national government acted like the African “father of the house” by formulating policies that were correct according to itself and its perspective of community needs. The family, in this case the provincial and local government and the community, had to bear the costs of these policies without successful contest.

## Political influence

Government's "father of the house" mentality has been aggravated by the political agenda, which has missed its original target. Politics is generally about the appropriate governance of a nation. Yet, respondents have indicated that politics is a major setback in facilitating good governance through sustainable planning laws.

Many planners mentioned how they were forced to approve particular development applications, regardless of their professional opinion against it, because of political influences.

This need for self-preservation seems to stem from childhood, and includes the *ubuntu* principle of the African culture, in which all people need each other and are in various ways dependent on each other. It could be one of the reasons why inefficient ways of reconstruction were adopted after 1994. It can be argued that the democratic government could have felt the cultural need to ensure that they take care of their own. Most black South Africans had the expectation that they would be taken care of, even if it meant that a minority would have to be responsible for the majority.

## Socialism feeding neoliberalism

The result of such a policy orientation has been a very dependent yet neoliberal nation, which is proving to work against itself. When the local government was attempting to redistribute resources and wealth, the decisions made seem to have been driven by cultural motives. For instance, the black economic empowerment (BEE) policy can be attributed to the collective nature of African culture.

In a national context, this has manifested through the poor implementation strategies of policies like the RDP, local economic development (LED), BEE and rural development, all in the name of helping your own. It would not have been easy for many black individuals to accept any other kind of solution that did not involve being helped by their own people, yet it could have

been better to have taken different steps. Thus, the new ruling party, as a whole, had a responsibility to the rest of the country, more especially black people, while the members also had a responsibility to their own families.

For the African culture, the choice should be clear – individuals have more of a responsibility to their immediate families than they do to the rest of the country, regardless of their position at work. This dilemma led to the policies that created so much dependency, as seen within the relationship of government and its people in South Africa. Moreover, the need to take care of one's own also worsened the drive to economically improve the self.

## A tarnished ambition

Younger planners indicate that within municipalities there is a serious resistance to change. Some town planning schemes that were formulated under the apartheid laws are still being used, even though there is a need for amendment. For instance, applications for certain land uses within an urban context have the same conditions for approval as those of a rural context.

Even the National Spatial Development Perspective (NSDP) of 2006 indicates that there is a need to deal with these areas a little differently to ensure that the necessary development and growth occurs where possible. These planners actually state that at times, the town planning schemes could allow for the approval of development applications that they, as professionals, view as not being appropriate for approval. In these instances, the older planners tend to tell them that they should follow what the scheme states and not try to do anything differently. As a result, the younger planners get initiated into the culture of the old style of planning and their creativity is tarnished. Where planning school could have tried to instill a new way of thinking, which could have triggered the mindset to think more sustainably, the actual planning practice took them back to the limited thinking that they had already learned through their backgrounds.

## Suitable creativity

This situation shows that too many factors are overwhelming the current planner, almost drowning the younger planners in the older system. However, the deeper issue obviously lies in the counterfeit transformation the government professes, yet fails to enforce. This false transformation is being fed and maintained by the very policies and plans that are supposedly meant to reform South Africa. However, if you use incorrect tools, you probably won't attain the correct results. Therefore, South African planning law is seriously in need of amendment, from the structures of systems to the strategies for implementation. The planner needs more leeway to do what is necessary according to planning principles, rather than being tied by irrelevant, misdirected or incorrect politics.

Moreover, it seems suitable to say that individuals ought to examine the extent to which influences of culture and cultural backgrounds still control the way they think. If this way of thinking persists, it will be to the detriment of the state and the entire country, striking first and mostly those who are already poor. 📍

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# Why do people decide to study engineering?

Jacques Lombard and Anne Crafford

The need for economic reward and competitive advantage is fuelling technological change. A key component to enable this change is engineering. Currently, the work in progress nationally that requires the services of engineers outweighs the engineers available to perform the work. Even though the Engineering Council of South Africa (ECSA) aims to produce 15 000 engineers per year by 2014, it remains a challenge to attract young people to a career in engineering.

Understanding what influences individuals to pursue a career in engineering should help the local industry to create greater interest in engineering, and if constraining factors can be identified, the problem can be addressed more easily. Local engineers roughly service 100 times the amount of people that need to be serviced by engineers in developed countries such as the United Kingdom.

A master's study aimed at determining the factors that influence people to become engineers, has been conducted in the University of Pretoria's Graduate School of Technology Management. The study firstly examined the different factors that influence an individual's career choice and, secondly, discussed the results that were obtained during a survey among engineering students at the University of Pretoria and Stellenbosch University.

Two statistically significant factors emerged, namely career focus and social environment. In addition, demographic differences between age and ethnic groups were explored.

Three social cognitive variables, namely self-efficacy, outcome expectations and personal goals are used to determine how individuals manage their own academic and career behaviour. The more capable people judge themselves to be, the greater the variety of careers they will consider and the better they will prepare themselves to pursue those careers. Self-efficacy refers to people's judgments of their own capabilities to organise and execute courses of action required to attain designated types of performances.

Interests grow out of areas that individuals believe they can perform in effectively, and these interests usually start to develop during high school. An individual's interests will also influence his or her career choice.

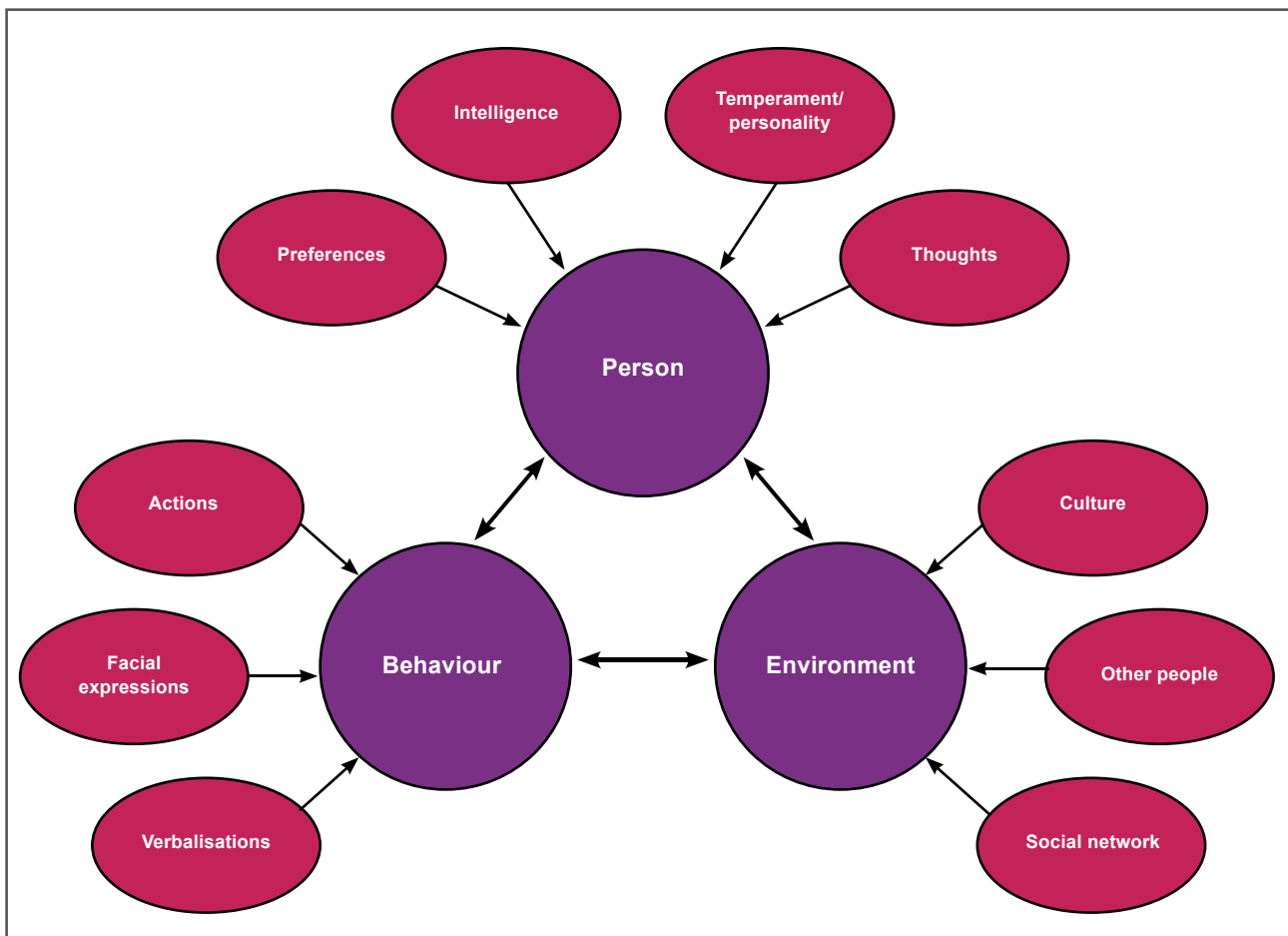
Outcome expectation refers to what an individual anticipates when he or she shows certain behaviour. Some believe that engineers have a high expectancy of obtaining highly valued outcomes such as financial reward and upward movement within the organisation early in their careers. People will develop a lasting interest in a career if they consider that the career will lead to valued outcome expectations and if they have the self-belief in their skills and competency.

Figure 1 illustrates that what people think and feel will influence how they behave, and the outcome of their actions will have an effect on their thought processes and emotions. The section in Figure 1 between "environment" and "person" refers to the interactive relationship between the individual's environment and his or her personal characteristics.

Due to the bidirectionality of influence between behaviour and environmental circumstances, people are both products and producers of their environment. Support from parents for their child's academic and career endeavours, which has been shown to predict a child's career development, positively affects the school engagement of an individual and completion of homework.

Support from friends has shown to improve persistence. Students who experience a supportive environment will most likely consider a wider range of careers, and possibly more challenging ones. Various social barriers have been identified, including pressure from parents to choose a different career, as well as social and economic factors.

In terms of the survey, a significant difference was found between the two groups (18–19 and 20 and older) with regard to social environment, with the older group being less affected by social environment in their career



→ Figure 1: Bidirectional causation (adapted)

choice. This might be because older students are less dependent on their friends and family for support throughout their studies.

There was a significant difference between black and white participants with regard to career focus. Career focus, as part of career decision-making, was more important for black participants than for their white counterparts. This is an interesting finding and counter-intuitive, as differences in social environment would have been expected, given the historical background of our country and the schooling system.

Some institutions, like the University of Pretoria, choose to host a Faculty Day in an attempt to show prospective engineering students what it means to become an engineer. However, less than 40% of the students who participated in the survey indicated that this day had a positive impact on their career choice.

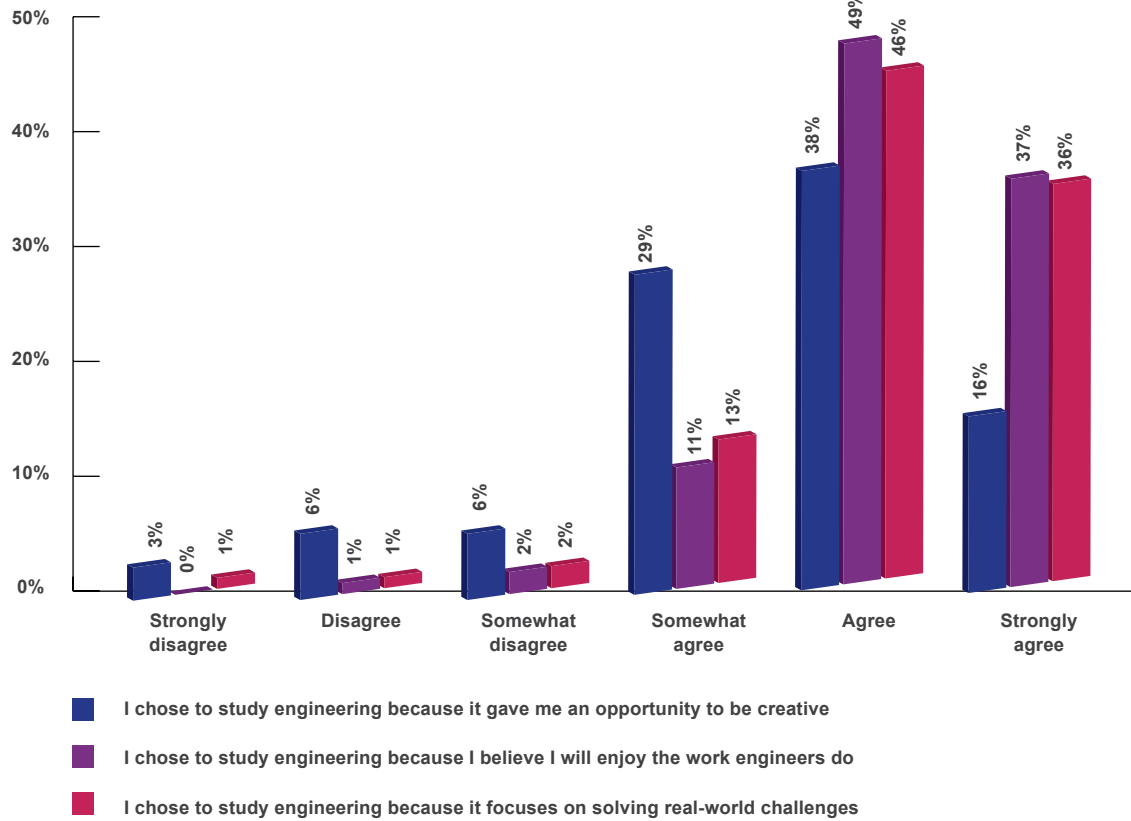
ECSCA's awareness campaign (Enginius) would seemingly be more effective if it involved engineering professionals, as nearly two thirds of the research participants indicated that engineering professionals had a positive impact on their career choice, compared to the positive impact that the campaign had on only 15% of the research population.

The surveyed students felt that enjoying the profession, solving real-world issues and being granted the opportunity to be creative in a profession were factors that contributed to their decisions to become engineers (see Figure 2).

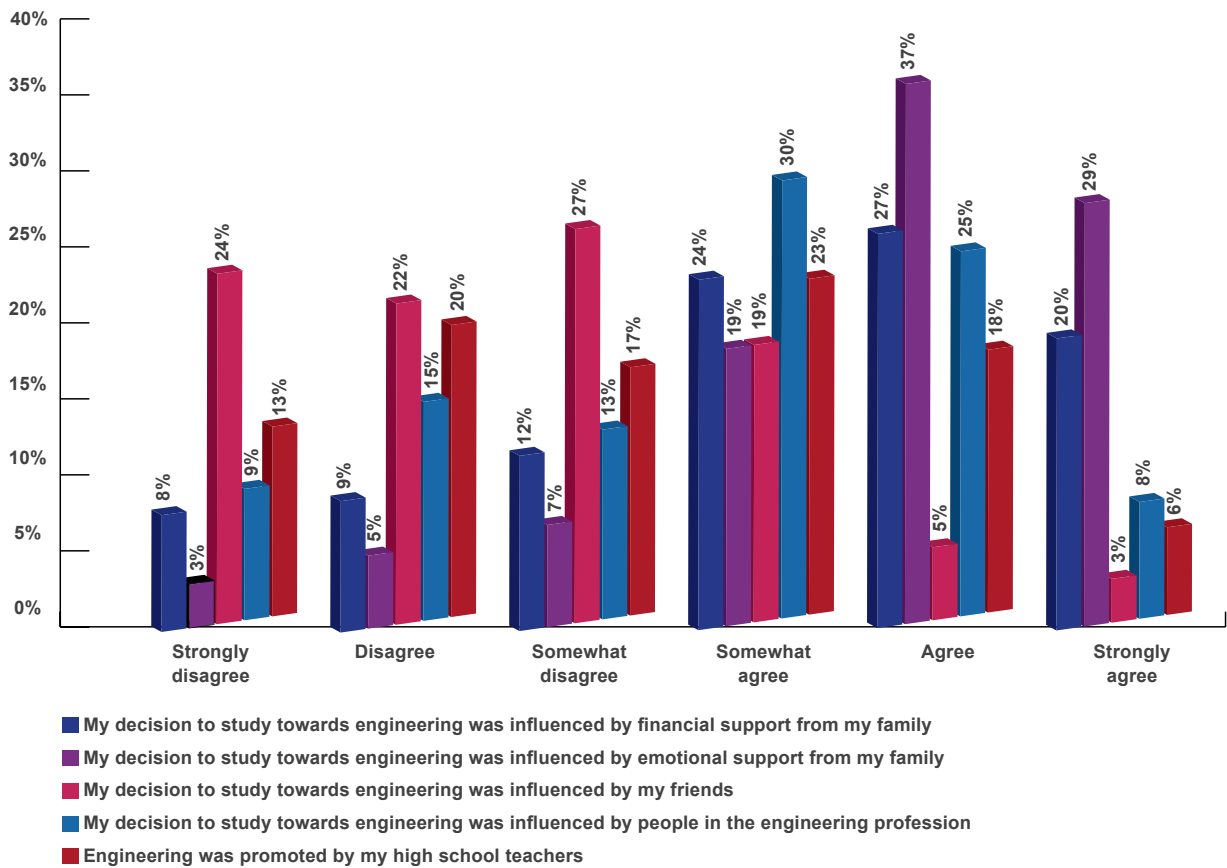
Figure 3 shows that the respondents' friends had less of an impact on the individual's career choice than was expected. The question remains whether this was due to the respondent making his or her own career choice, or whether the perception was created that "friends"

tried to persuade the individual to study towards a different career. Research has shown that professions such as medicine and law usually hold the greatest social status. It seems that, within the South African context, engineering generally has a great enough social status to draw people to the profession.

Engineering professionals have a significant impact on the career choices of many current engineering students. It might attract a lot of interest if current engineering professionals got involved in promoting engineering as a career to prospective students. One such option would be if current professionals could hold a road show, explaining what the career is about and making some more concepts tangible to prospective students. 🚀



→ Figure 2: Data captured relating to career focus



→ Figure 3: Data relating to social support and barriers





## Young alumnus heads engineering faculty

**Prof Saurabh Sinha, former Director of the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria, was appointed as Executive Dean in the Faculty of Engineering and Built Environment at the University of Johannesburg as of 1 October 2013.**

He holds a BEng degree in Electronic Engineering with distinction, an MEng (Microelectronic Engineering), also with distinction, and a PhD (Electronic Engineering) from the University of Pretoria, where he has been a member of the faculty staff since 2002.

Prof Sinha is recognised as an electrical engineer, a researcher and an educator of high calibre, who led the Electronics and Microelectronics Group at the University of Pretoria for more than a decade. He has authored over 65 publications in peer-reviewed journals and presentations at international conferences. He is also the managing editor of the *SAIEE Africa Research Journal* of the South African Institute of Electrical Engineers.

He has received professional recognition in the form of several awards. In 2007, Prof Sinha received the SAIEE Engineer of the Year Award. In 2010, he received the University of Pretoria Young Laureate Award. His contribution to the field of engineering education was also recognised by the Institute of Electrical and Electronic Engineers (IEEE) when he received the Meritorious Service Citation Award by the IEEE Educational Activities Board (EAB) at an award presentation ceremony in New Brunswick in November 2012.

He was the first South African to receive this award, and was nominated for the award for spearheading the incorporation of the Engineering Projects in Community Service (EPICS) Programme in the IEEE's educational activities and for expanding the programme globally.

Prof Sinha's research has received the support of the National Research Foundation (NRF), the Armaments Corporation of South Africa (Armcor) SOC Ltd, the Council for Scientific and Industrial Research (CSIR), Eskom and the Square Kilometre Array (SKA), as well as private industry. His current research interests involve mm-Wave integrated circuit (IC) design, and more generally, analogue and mixed-signal ICs.

He is also engaged in a number of large-scale regional and international research projects, including a national energy harvesting project.

The former Executive Dean in the Faculty of Engineering and Built Environment at the University of Johannesburg, Prof Tshilidzi Marwala, is also an alumnus of the University of Pretoria. Prof Marwala was appointed as the University of Johannesburg's Deputy Vice-Chancellor: Research, Postgraduate Studies and the Library earlier in 2013. [➔](#)

# Student aircraft designs put to the test



Not only do University of Pretoria (UP) teams steal the intervarsity spotlight on the sportsfield; they also put on a striking performance in the sky. A number of fourth-year aeronautical students took part in the annual Intersarsity Model Aircraft Fly-off Competition, which was held at the Swartkops Air Force Base on 27 and 28 October 2012, and resulted in an overall win for the University for the third year in a row.

This competition, organised by the Aeronautical Society of South Africa, aims to encourage interest in aviation and aeronautics in competitors and spectators alike. The goal of the competition is to conceptualise, design, construct and fly a radio-controlled model aircraft that is capable of taking off over as short a distance as possible and then to fly as slowly as possible over a short course, while carrying a pre-specified payload. This year, the payload was specified as a full 355 ml cooldrink can.

The challenge is aimed at two different groups of participants and is divided into two parts. The Inter-university Challenge is judged on the academic portion of the aircraft design, while the Open Challenge only includes the take-off and flight portion of the competition. The competition is open to teams of up to six competitors. Each team is allowed three model aircrafts, which are each significantly different in geometry. While anybody may enter as a team member, only a South African Model Aircraft Association (SAMAA)-approved pilot may fly the aircraft at the competition.

Models entered must be an original design, using no major components from existing model aircrafts. Designs are limited to fixed-wing aircraft configurations, which means that no rotary-wing aircrafts, like helicopters, autogyros or lighter-than-air systems are allowed. Participants are encouraged to design an aircraft that can fly largely on the aerodynamic effects of its wings. For the adventurous team, aircraft geometry changes like flaps and wing sweeps are allowed, provided that it is brought about by remote control.

University teams must produce an A1-sized poster for judging, which covers the design concept, the performance prediction, and the stability and control predictions. All these elements provide for a score out of 100 points. The combined score of the design presentation and the flight determines the winner. This year, the three overall winning teams, UP Superheroes, UP Fly Boys and UP AeroAddicts, were all from the University. ➔



→ Members of the University of Pretoria's teams: UP Superheroes, UP AeroAddicts, and UP Fly Boys.



→ Receiving the award for Best University from Rob Jonker are Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering (left), and Barbara Huyssen, lecturer in Aerodynamics.



→ Receiving the award for the winning team from Rob Jonker, former President of the Aeronautical Society of South Africa (AeSSA), are two members of the UP Superheroes team, EK Wamithi (left) and B Gwashavanhu (right).

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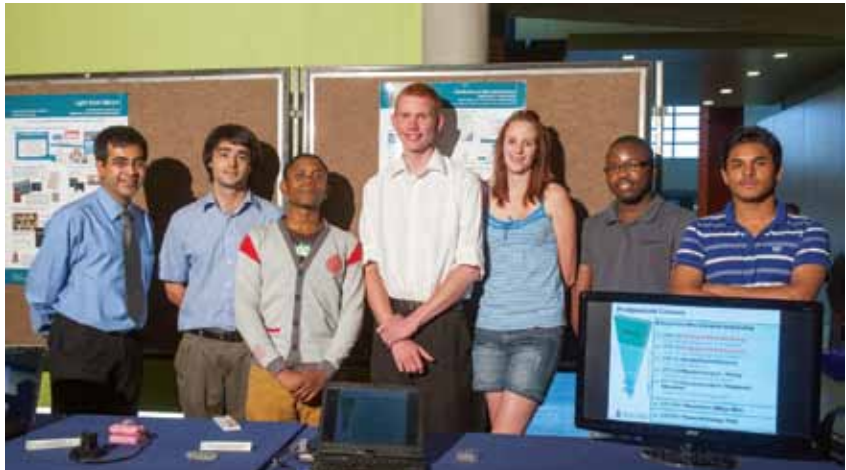
The MeerKAT is a radio telescope in development in South Africa and Australia. It uses radio waves instead of light waves to create a picture, and its ultimate goal is sensitivity to very small signals that originate in space.

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# Students develop solutions for the SKA project

The Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria is doing remarkable work on the Square Kilometre Array (SKA) project, which is scheduled for construction in 2016. It allows for research to be done on all academic levels and the Department has launched various initiatives in relation to this exciting project.



→ The research team at the Carl and Emily Fuchs Institute for Microelectronics is developing solutions for the SKA project.

The SKA project involves the development of the MeerKAT radio telescope. It uses radio waves instead of light waves to make a picture and its ultimate goal is sensitivity to very small signals, originating from natural sources in space, which will enable physicists to gain an additional understanding into the origins and workings of the universe. It will have a total collecting area of approximately one square kilometre and will operate over a wide range of frequencies. Its size will make it 50 times more sensitive than any other radio instrument and this will enable it to survey the sky more than ten thousand times faster than ever before.

A principal factor affecting the sensitivity of radio telescopes is the noise figure (NF) in its receivers. The low-noise amplifier (LNA) is the first electronic subsystem in the receiver and it therefore plays the dominant role in determining the NF of the receiver as a whole, affected by both its own internal NF and its gain. It is therefore crucial to the scientific objectives of the SKA that its LNAs achieve excellent noise performance and reasonable gain. Researchers at CEFIM are working on developing human and technology capacity for this international project.

Undergraduate student James Smith recently concluded a project entitled "Design of a hybrid-integrated wideband low-noise amplifier in SiGe BiCMOS for the SKA". He utilised the IBM 130 nm bipolar complementary metal-oxide semiconductor (BiCMOS), together with DuPont 951 low-temperature co-fired ceramic (LTCC) packaging to achieve a simulated NF of around 1 dB over the frequency range of 800 MHz to 1.4 GHz with an average gain of 27 dB.

Doctoral candidate Aba Bimana is conducting a project that looks at the wideband LNA for highly sensitive receivers using a differential architecture. A number of both theoretical and applied research outcomes are expected from this undertaking.

To encourage research that can benefit the development of the SKA, at least four undergraduate students, mainly from previously disadvantaged communities in South Africa, are supported in their studies through a scholarship and a mentorship programme. Various SKA student grants, managed through the National Research Foundation (NRF), support this research. ➔



## Will robots ever replace humans? Japanese expert visits UP

Prof Hiroshi Ishiguro, Director of the Intelligent Robotics Laboratory at Osaka University, Japan, and leader in the development of the Geminoid series of humanoid androids, presented a public lecture at the University of Pretoria on 21 November 2012.

The lecture was hosted by the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, the Built Environment and Information Technology. It was facilitated by the Centre for Japanese Studies at the University's Gordon Institute of Business Science (GIBS) and the Japanese Embassy in Pretoria.

Japan leads the world in the field of robotics and androids. Prof Ishiguro's research focus includes the psychological and philosophical aspects of living with robots (androids). His android studies are well-known throughout the world, and his presentation addressed the question of whether robots will ever replace humans. This is a very pertinent question, as robots will soon be used everywhere: in manufacturing, mining, exploration,

navigation, medical care, home care, personal assistance and non-robotics-related research.

In his presentation, Prof Ishiguro explained that a significant limitation of existing robots is that they do not look like humans. In developing his androids (humanoid robots with human-like expressions, as well as human-like subconscious and reactive movements), he examined the characteristics of being human, and came to the following conclusion: "We are developing technologies, including robots, for understanding what it is to be human: it is a constructive way of understanding the human being." He anticipates that a future with humanoid robots will soon become a reality.

Advanced robotics is not just about engineering, and requires

Prof Ishiguro's research focus includes the psychological and philosophical aspects of living with robots (androids). His android studies are well-known throughout the world, and his presentation addressed the question of whether robots will ever replace humans.



→ Prof Ishiguro, Director of the Intelligent Robotics Laboratory at Osaka University, Japan, addressed an audience at the University of Pretoria.

an understanding of human mental states, developed by working with neuroscientists and psychologists. In his experiments, he tried to develop an android that looks like a human being, but also talks like one. During the course of his research, he found that humans interact with other human beings using their imagination, so the ideal android would be one without age or gender, with an imagined face. He calls this a telenoid. He also demonstrated the possibility of using an android for future communication through a kind of mobile phone-like telenoid known as an elfoid.

The lecture was concluded with a fascinating robotics show, in which he demonstrated the engineering behind the making of robots. 🌟



→ Prof Hiroshi Ishiguro shows the audience what a telenoid looks like and how it is capable of speech and interacting with human beings.

# Student joins school learners in the quest for earth observation solutions



→ Learners from St Alban's College with Phumudzo Bebwele (back row third from left), Mr Chris Mouton (back row third from right), Prof Saurabh Sinha (back row second from right) and Joe Valliarampath (back row far right).

A joint venture by the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria and St Alban's College in Pretoria aimed to design and implement a micro-sensor-based air-quality monitoring system. The project was an Engineering Projects in Community Service initiative of the Institute of Electrical and Electronics Engineers (EPICS-in-IEEE), a global programme that seeks vertical integration between university and pre-university students.

The programme worked with non-profit organisations and delivered community-oriented solutions. In this way, the programme supported the IEEE's motto: "Advancing technology for humanity".

Final-year electronic engineering student, Phumudzo Bebwele, who is an IEEE student member, led the project team. The rest of the team consisted of eight Grade 11 learners of St Alban's College, a private school in Pretoria, and Chris Mouton, an educator at this school.

The project utilised wireless sensor network nodes (WSNs) to sense

and transmit selected ambient air-quality parameters to a central node, which relayed the data to a folder on the "Google cloud". While Bebwele designed an analogous system by first principles, the learners used educational off-the-shelf air-quality micro-sensor components. The learners used an Android-based input/output sensor node to communicate to a mobile phone, which managed the upload to a Google Drive folder. The educational air-quality micro-sensor systems developed during this project will also serve as an educational tool for improving public understanding of air-quality, including a new national air-quality act in South Africa. 📍

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The learners used an Android-based input/output sensor node to communicate to a mobile phone.

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# Prestigious dti Technology Award for UP

Research conducted in the Sentech Chair in Broadband Wireless Multimedia Communication (BWMC) in the University's Department of Electrical, Electronic and Computer Engineering, has earned Prof Sunil Maharaj a Technology and Human Resources for Industry Programme (THRIP) Award in the Advanced Hi-Tech Research Category.



→ Prof Sunil Maharaj receives the THRIP Award in the Advanced Hi-Tech Research Category from Mr Lionel October, Director-General of the dti.

This award was presented to Prof Maharaj for his collaborative research work in wireless broadband communications.

The BWMC research group comprises about 20 students, ranging from final-year engineering design project students up to postdoctoral fellows working in the area of broadband wireless communications.

Their research has been largely in the area of multiple-input-multiple-output (MIMO) systems with orthogonal frequency division multiplexing (OFDM) technology in wireless communication systems and cognitive radio technology.

THRIP is funded by the Department of Trade and Industry (the dti) and is managed by the National Research Foundation (NRF) in the Department of Science of Technology (DST).

Its mission is to improve the competitiveness of South African industry by supporting research and technology development activities,

and enhancing the quality and quantity of appropriately skilled people.

The programme provides funding to support research initiatives that have industry participation and funding.

In 2013, after a rigorous review of all funded research projects across the country, Prof Maharaj's work was placed in the top three in the Advanced Hi-Tech Category.

This culminated in him being selected by a panel of judges and presented with a certificate of achievement and a plaque by Mr Lionel October, the Director-General of the dti, at a function held at the Durban International Convention Centre (ICC) in October 2013. ➔

# Leaders share insights into IT challenges

Dr Rennie Naidoo and Prof Awie Leonard

The Department of Informatics launched its inaugural Information Technology (IT) Management Symposium on 23 May 2013. The theme of the symposium was “IT management: Future challenges and opportunities”. The one-day symposium focused on IT management topics relevant to South Africa.

One of the key objectives of the symposium was to intensify cooperative education between academics and practitioners in the field of IT management. The goal was to create a platform for IT managers, academic staff and students to collaborate with each other.

The speakers included respected IT leaders, educators and PhD students. Mr Trent Rossini, General Dr Matie du Toit, Dr Peter Tobin and Mr Justy Range provided insights that provoked a lively discussion among the audience. The symposium also gave a few PhD students the opportunity to present their proposed research topics in a poster format.

The speakers echoed the strategic importance of IT. Mr Trent Rossini spoke about the pivotal role of IT in the development of new products and services for organisations. He spoke about the myth that successful IT leaders do not require a formal education, referring to “Steve Jobs and Bill Gates, as outliers”.

General Dr Matie du Toit focused more on the organisational challenges of the IT environment. He alluded to the importance of IT meeting its governance and compliance obligations. He insisted that aspects of risk and the value elements of IT are carefully considered by IT leaders.

Both keynote addresses touched on the importance of IT having closer relationships with business.

Mr Justy Range, a PhD candidate, provided some interesting insights into the importance of trust in the use of self-service technologies in the fresh produce market. He characterised the fresh produce market as one that relied on trust, given the almost informal arrangements between suppliers and retailers in the past. He discussed the intricacies involved in delegating and maintaining this kind of trust.

The posters presented by four other PhD students effectively promoted collaborative thinking and analysis. The topics covered were diverse – from IT project organising, business process management and enterprise resource planning (ERP) implementations to policy-making.

Ms Tendani Mawela facilitated a lively discussion where students had the opportunity to air their views about the major themes discussed by the keynote speakers. Dr Peter Tobin provided some useful direction for the road ahead. He spoke about the impact that the Indian and Chinese IT industry may have on local IT practitioners.

Dr Rennie Naidoo, a member of the organising committee, pointed out that it was apparent that IT leaders will be entering a world about which little is known. Strangely, it may be our ability to unlearn, rather than rely on old models, that may decide if an IT leader will be effective in the future.

He urged students to be proud about the skills that they learn at University, as it provides them with a distinctive advantage in coping with people and technology matters in organisations.

Prof Awie Leonard, the lead organiser of the event, was impressed by the turnout from the business community and graduate students, and is keen to turn this forum into a regular biannual event. “One of the key challenges for educators is to develop IT managers that are comfortable with interacting with people and using IT to create value for their organisations instead of only immersing themselves in technological matters,” he said.

The Department of Informatics hopes that the IT Management Symposium will soon earn the reputation as being an effective approach to improving collaboration between practitioner organisations, students and staff. 📍

# Recognition for UP computer science pioneer

Fritz Solms

Prof Derrick Kourie is one of the founding fathers of computer science in South Africa. In 2012, he received the South African Institute for Computer Scientists and Information Technologists (SAICSIT) Award for the pioneering role he has played in promoting computer science as an academic discipline in South Africa.



→ Prof Derrick Kourie is acknowledged for his groundbreaking work in computer science.

This award was initiated by SAICSIT in 2008 to annually recognise individuals who have played pioneering roles in promoting computer science and information technology as academic disciplines. Prof Kourie is the fourth recipient from the University of Pretoria to have received this acknowledgement since its inception. Other recipients include Prof Roelf van den Heever and Prof Judith Bishop, both associated with the University's Department of Computer Science. In 2008, the award was presented to Prof Dewald Roode, founder of the Department of Informatics at the University of Pretoria, for his pioneering role in information technology.

Prof Kourie is the editor of the *South African Computer Journal* and leader of both the Fastar Research Group on Finite Automata Systems and the Espresso Research Group on Software Engineering Principles and Practices. He has an extensive

publication record, having co-authored an authoritative book in the field of mission-critical and provably correct software, entitled *The correctness-by-construction approach to programming*.

In 2013, on the occasion of his 65<sup>th</sup> birthday, the Department of Computer Science decided to honour Prof Kourie's scientific and academic contributions to research and higher education by publishing a Festschrift. This publication contains ten chapters in four parts (logic, automata, stringology and programming), which cover many of Prof Kourie's own research interests in the area of theoretical informatics and formal aspects of computing.

All the authors and co-authors of the Festschrift are long-term scientific collaborators and academic colleagues of Prof Kourie, and all of them are experts in their related fields. ➔

# Publishing students join hands with the Presidency to build school libraries

As part of the JCP module of the Faculty of Engineering, the Built Environment and Information Technology, all Publishing Studies students are required to contribute 40 hours of community service to complete their degrees. The JCP module is unique, as it encourages students to participate in community development in their own areas, providing not only development for much-needed community infrastructures, but it also allows students to give back to the community, developing their personal skills.

This year, six schools that were in need of libraries were identified. From the beginning of June, the six student groups identified the needs of the libraries of Boikgantsho Primary and Pfundzo Primary in Mamelodi, Jakaranda Primary in Eersterust, Boschkop Primary in Boschkop, and Sunnyside Primary and Jopie Fourie Primary in Pretoria. By the start of the June recess, the students were ready to start painting and sorting books. Their first task was to identify which books the school already had that could be reincorporated into the library and which books were needed.

The aim throughout this process was to be as representational of all the languages in South Africa as possible. Invaluable support was received from several industry partners. Bargain Books Woodlands donated thousands of rands worth of stock in the classics, fiction and non-fiction genres. LAPA Publishers, NB Publishers and e-Books Lynnridge donated fiction in official languages, specifically English, Afrikaans, Zulu and Sepedi. With these donations, the students were able to start work on their libraries.

Being approached by the Presidency to make the project part of their Mandela Day celebrations opened doors to new donations and more volunteers. This partnership proved very fruitful, with over 70 volunteers from the Presidency arriving at the schools on Mandela Day to help finish off the libraries. The partnership allowed for increased government involvement in charitable activities and exposed the students to governmental processes.

The identified schools were treated to readings by Adult Basic Education and Training (ABET) personnel from the Presidency, who encouraged them to stay in school and embrace education as the only way to further oneself.

All six schools received donations of carpeting, heaters and pot plants from Builders Warehouse and shelving from the Presidency, as well as several book donations collected by the Presidency in African languages. This project serves as a shining example of what the partnership between industry and the University of Pretoria is capable of. It is only through these kind donations of industry partners that the project was successful. The students themselves are happy and satisfied with what they have achieved with the project, contributing not only to their own degrees and abilities, but also to their knowledge of their future reading market and their industry leaders.

The students and the Publishing Studies Department in the School of Information Science intend to continue the project in the future with the help of the Faculty of Engineering, the Built Environment and Information Technology and the JCP module.

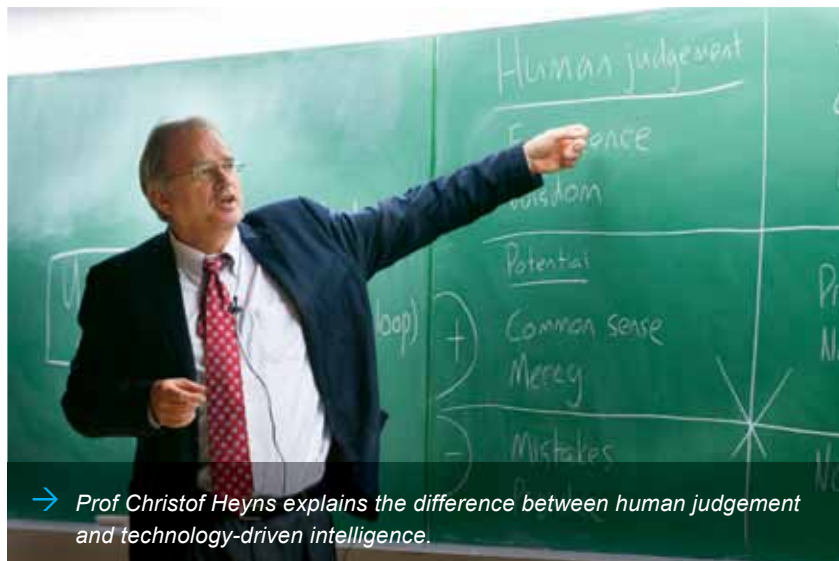
Students, staff and industry partners were encouraged to contribute what they can to help the community and provide access to books and basic literacy in underdeveloped schools, as literacy is a basic and invaluable right of all children in South Africa. As Erin Rennie, one of the students involved in the Boikgantsho Primary school library stated: "We know how important reading and literacy is and we want to encourage it from a young age. If you can help, you should, especially with something as important as this."

The Department of Publishing Studies hopes to rely on its current industry partners in future and involve this group of students as mentors. It is vitally important not only to build libraries in needy communities, but also to encourage a sense of the importance of community engagement in our students and industry partners. 📖



# Lethal autonomous robotics: Coming to a theatre near you?

The use of drones (unmanned armed vehicles) by the United States government against targets in northwest Pakistan along the Afghanistan border since 2004 has brought the technical, ethical and legal aspects of lethal autonomous robotics under the spotlight. This was also the topic under discussion at the annual Hendrik van der Bijl Memorial lecture, presented on 14 August 2013 by the University of Pretoria and the South African Academy of Engineering (SAAE).



→ Prof Christof Heyns explains the difference between human judgement and technology-driven intelligence.

The guest speaker, Prof Christof Heyns, is pre-eminently qualified to consider this subject, as United Nations Special Rapporteur on Extrajudicial, Summary or Arbitrary Executions, professor of Human Rights Law at the University of Pretoria, and Co-director of the Institute for International and Comparative Law in Africa (ICLA).

Prof Heyns explained the distinction between the two different kinds of unmanned systems. In the case of drones, although the armed vehicle itself is unmanned, it has a human operator via remote control. However, in the case of lethal autonomous robots (LARs), human beings are out of the loop; an onboard computer takes the decision to deploy the force.

LARs are weapon delivery systems that, once activated, can select and engage human targets without further intervention

by a human operator. LARs were developed with a number of advantages in mind, including the protection of one's own people. In

addition, one can achieve more with fewer people, and one is able to eliminate the weakest link (the human factor) and achieve results faster.

The general concern with the use of LARs, however, is that we may be overestimating the abilities of computers. Other specific concerns that need to be considered include the fact that using LARs might make it easier to go to war. With LARs, there is also an uncertain legal responsibility in terms of who is actually responsible for wartime deaths. In this respect, LARs may not comply with the prescripts of International Humanitarian Law. While LARs may be used outside armed conflict situations, there are implications for states without LARs. The actual legal-ethical

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Ultimately, the dilemma is an ethical one that revolves around decisions regarding the right to life.

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complexity comes in when one takes human decision-making out of the equation in armed conflict, and many questions related to humanitarian

and other issues arise, such as the psychological effects of distance killing, and the effect of a war without valour, in which there is no direct engagement.

Prof Heyns concluded his presentation by weighing up the pros and cons of human judgement vs. computers. While human judgement has the advantage of experience, wisdom and qualitative evaluation, computers have the advantage of statistics, algorithms and quantitative evaluation. While human judgement has the benefit of common sense, mercy and compassion, human beings also make mistakes, can be prejudiced, and may commit crimes. Computers, on the other hand are precise and fast, and have no fear of revenge. However, computers do not have the benefit of common sense and compassion.

The Hendrik van der Bijl Memorial Lecture is an annual event that is presented jointly by the University's Faculty of Engineering, the Built Environment and Information Technology and the SAAE. It is delivered by a prominent personality under the general theme of the role of engineering in society. This lecture is of particular significance to both the University of Pretoria and the SAAE, as Dr Van der Bijl was the Chancellor of UP from 1934 to 1948 and he made a huge contribution to the industrial and scientific development of South Africa. The first Hendrik van der Bijl Memorial Lecture was delivered in 1963 by Dr MS Louw (who represented Sanlam), and ever since, these lectures have been delivered by eminent personalities who have made their mark in South Africa.

### More on Hendrik van der Bijl

Hendrik van der Bijl was born in Pretoria in 1887 and attended school in the Cape Province during the Anglo Boer War. After studying at the Victoria College (which would become the University of Stellenbosch), he continued his studies overseas, specialising in electronics. He was working for the American Telegraph and Telephone



→ Prof Bob Pullen, President of the South African Academy of Engineering (SAAE), introduces Prof Christof Heyns as the guest speaker at the annual Hendrik van der Bijl Memorial Lecture.

Co. in New York as part of a selected group of research scientists that spearheaded American technological development when General Jan Smuts requested him to return to South Africa.

In 1920, he joined the South African government as Technical Advisor, and laid the foundations for the development of South African industry. He established and became the Chairperson of Eskom, Iscor and the Industrial Development Corporation.

The outstanding organising ability and leadership qualities he displayed during the Second World War enabled him to use this opportunity to stimulate and facilitate the second

stage of rapid industrial development in South Africa. In later years, Dr Van der Bijl turned his attention to the private sector of the economy. One outcome of this was the establishment in 1947 of Safmarine, of which he was the first Chairperson.

The foundations for the industrial development of South Africa were laid by Hendrik van der Bijl, the scientist, industrial leader, engineer and entrepreneur. His achievements have been recognised internationally and locally. He was elected a Fellow of the Royal Society and he received honorary degrees from both the University of Stellenbosch and the University of the Witwatersrand. Vanderbijlpark was named after him. ➔



# The roots of industrial engineering – Francis Galton: The gentleman explorer

Compiled by Prof Paul Kruger

Galton is mainly, possibly unfortunately, known as the father of eugenics. This name was coined by Galton for his theory that the physical and mental makeup of the human species may be improved by selected parenthood. This theory has been severely misinterpreted and misused to the detriment of Galton's otherwise immaculate reputation. Using numerous observations and experiments, he proved his own theory wrong, and in the process discovered and formulated the very important statistical concept of regression to the mean. This concept is sometimes used, wrongly so, as the reason why the human race, countries and even business enterprises are doomed to regress over time to a state of mediocrity.

Francis Galton (1822–1911) was born in Sparkbrook (near Birmingham), England. He was raised in a high-class intellectual environment and was the youngest of nine children. The Galtons were a famous and highly successful Quaker family of gun manufacturers and bankers. His father, Samuel Tertius Galton, was a wealthy banker with close family links to both the Barclay and the Wedgeworth families. Galton's grandfather, Samuel John Galton, was principally responsible for the family fortune and was a Fellow of the Royal Society. His other grandfather, Erasmus Darwin, was a medical doctor, polymath and naturalist of repute. Erasmus Darwin and Samuel Tertius Galton were founding members of the famous Lunar Society of Birmingham.

Galton showed promising mathematical skills at an early age, but originally attended King's College in London to study medicine. He became frustrated and discontented with his studies when he was confronted with his first cadaver, much like his first cousin Charles Darwin, and in 1840, went to study the Mathematical Tripos at Trinity College, Cambridge. After suffering through three years of studying, he obtained a BA and was awarded an MA, but a nervous breakdown terminated his further studies. In February 1844, Galton became a freemason at the Scientific Lodge, held at the Red Lion Inn in Cambridge. In the same year, his father died and left him and his siblings a large inheritance.

Galton was therefore independently wealthy and became a charming social snob who never had to work a day in his long life to earn a living. However, he probably did more than anyone else in history to transform mathematical statistics. It changed from a somewhat esoteric mathematical pastime, mainly applied to gambling and astronomical problems, to a tool for analysing the

technological and social problems of the everyday world. He was obsessed with counting, measuring and making observations. This included counting the number of times people fidgeted as they listened to a lecture, measuring and comparing the height of fathers and their sons, and classifying the degree of attractiveness of the girls he passed on the streets of London. As a maniac for classification, he developed a "Beauty Map" of the British Isles, based on how many pretty women he encountered. He gave London the highest score and Aberdeen the lowest. He made statistical inquiries into the efficacy of prayer, which attracted some criticism from the religious Victorian society. He found that those people frequently prayed for, like monarchs, lived no longer than anyone else. In a letter to *Nature* in 1879, entitled "The average flush of excitement", Galton recounts a visit to the derby. He noted that he was able to assess what he called "the

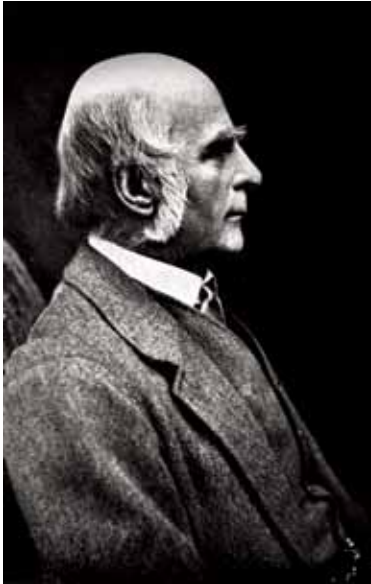
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"Whenever you can, count."  
– Francis Galton

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average tint of the complexion of the British upper classes" by observing the distant crowd through his opera glasses. He observed that, after the race started, the crowd became "suffused with a strong pink tint, just as though a sunset glow had fallen upon it". Galton claimed that he could work out the mood of a mass of people even without being able to distinguish one person from the next. Although somewhat weak in mathematics or any other scientific discipline, his ideas strongly influenced the development of statistics. These ideas include his formulation and application of regression analysis and his proof that, as a consequence of the central limit theorem, a mixture of normal distributions is in itself normal.





**“[Statistics are] the only tools by which an opening may be cut through the formidable thicket of difficulties that bars the path of those who pursue the Science of Man.”**

**– Francis Galton as quoted by Karl Pearson**

After quitting university, Galton, possibly having inherited some athletic abilities from his Barclay ancestors, spent two years being a full-time athlete. Thus, he may have been one of the first semi-professional athletes. Thereafter, he decided to become an explorer and travelled extensively through Europe, the Middle East and North Africa. The famous trip by his first cousin, Charles Robert Darwin, on the HMS Beagle, may have inspired him to explore southern Africa. He used his own money to fund two expeditions in 1849 with the purpose of opening the way to Lake Ngami in what is now northern Botswana. On both occasions, he didn't set out from the Cape as would be expected, but from Walvis Bay. He claimed he was warned about the “fierce Boers” that he might encounter in the interior. He was accompanied by Karl Johan Andersson, the Swedish explorer, but both expeditions failed.

Nevertheless, he had some interesting experiences on which he reported in detail. For example, he went in search of “a remarkable nation” that was deficient in joints both at the elbows and knees. They were therefore unable to lift anything to their mouths by themselves, but “when they dined, they did so in pairs, each person feeding his *vis-à-vis*”. While he was in Damaraland, he was intrigued by the physical characteristics of some of the women he encountered. He remarked that they seemed to be very well adapted to one of the ladies' fashions (the “Victorian Bustle”) that were in vogue in England

at the time. As he was a keen amateur anthropologist, he was interested in obtaining some measurements. Since he was a gentleman as well as an innovator and he didn't want to cause offence or suffer embarrassment, he took measurements from a distance using his knowledge of trigonometry and his sextant.

On his return to England he wrote a book entitled *Narrative of an explorer in tropical South Africa* (1853). This book was very well written and illustrated with numerous colour plates produced from the sketches made by the artist that accompanied Galton. The book proved to be a huge success and may be one of the reasons why Galton was elected as a Fellow of the Royal Geographical Society in 1853 and a Fellow of the Royal Society in 1860. At this time, it was Galton's conviction that “character and ability are inherited”. This conviction served him well, given his own impressive pedigree. He produced and published a family tree of his ancestry, featuring the Darwin, Galton and Wedgeworth families. He identified those members who, according to him, showed significant signs of genius. Galton seemed to have had no qualms about including himself in this illustrious group. On 1 August 1853, Galton married Louisa Jane Butler. Somewhat ironically, he had no children and therefore escaped the humiliation of seeing his own offspring possibly not conforming to his pet hereditary theories.

Galton is best known for his interest in inheritance. His book, *Hereditary genius*, is sometimes said to have founded the study of human genetics. Concentrating on the transference of “genius” from parent to child, he coined the phrase “nature versus nurture” in 1883 and invented the word “eugenics” (of good birth) for the process of improving the physical and mental makeup of the human species by selected parenthood. Eugenics fell into disfavour after the perversion of its principles by Nazi ideologists, and in the process, maybe unfairly, bringing Galton's work into disrepute. Galton first thought that breeding two smart people would produce an even smarter person. He also thought that breeding two tall people would produce an even taller person. In an effort to prove his theories, Galton established an anthropometric laboratory at the International Health Exhibition in London in 1884. Some 9 000 visitors to this laboratory were quite happy to pay three pennies apiece to undergo 17 body measurements (including height, skull size, hand strength and the power of one's punch), and in return, receive a “score” indicating the person's fitness and health. In this way, Galton was able to collect a large set of data for different individuals on which to base his research. However, the results of the analysis he performed proved that the idea of eugenics was not plausible. Galton used experiments with peas to augment his observations of the stature of parents and their children. With what may only be described as

a brilliant “mind experiment”, Galton discovered and formulated the phenomenon known as “regression to the mean” or, according to the title of the relevant publication, *Regression towards mediocrity in hereditary stature*. However, the most important part of Galton’s work had nothing to do with eugenics, for he was one of the first to realise that science (biology as much as physics) needs mathematics rather than words. The collection, classification and analysis of large amounts of anthropometric data may be seen as the beginning of the science of ergonomics. In a similar way, one may see his penchant for collecting, storing, analysing and using huge amounts of data as a contribution to the science of information technology.

Galton maintained a close friendship with Darwin despite occasional strain. Galton accepted Darwin’s theory of evolution, but decisively refuted Darwin’s theory of pangenesis. Darwin adhered to a blood-mixing account of inheritance, in which “gemmules” in the blood transmitted human traits and characteristics. Galton put this to the test by performing blood transfusions on rabbits; experiments that Darwin enthusiastically followed. The rabbits paid no attention to “pangenesis” and Galton was forced to conclude that Darwin was wrong. Darwin took this painfully.

Although he was a life-long sufferer of occasional bouts of severe depression, it seems as if Galton never considered a possible link between depression and genius, but made some remarks concerning a possible relationship between genius and insanity: “Men who leave their mark on the world are very often those who, being gifted and full of nervous power, are at the same time haunted and driven by a dominant idea, and are therefore within a measurable distance of insanity.” When he was suffering from depression, Galton referred to himself as “the man with the sprained brain”. For somewhat different reasons, his wife referred to him as “the man who counted everything except calories”.

Galton developed a system consisting of a set of three dice and a table for the generation of standard normal

random variates. As a result, he laid some of the foundations for stochastic simulation modelling. He discovered the uniqueness of human fingerprints, using some of the data he collected in his laboratory. He was able to show that fingerprint patterns remained constant as the person grew older, and he devised characteristics of the fingerprints that could be used as unique identifiers of the person, based on grouping the patterns into arches, loops and whorls. His identification system became the basis for the classification system of Sir Edward R Henry, who later became Chief Commissioner of the London Metropolitan Police. The Galton-Henry system of fingerprint classification was published in June 1900, and began to be used at Scotland Yard in 1901 as an identifier on criminal records. It was soon used throughout the world in criminal investigations. Galton was also a meteorologist and the first person to identify the anticyclone (as opposed to the cyclone). In 1875, he was the first person to publish a weather map in the *Times* newspaper. His book, *Meteorographica* (1863), was the first systematic attempt to gather, chart and interpret weather data on a continental scale, a fundamental work of modern scientific meteorology. Interested in measuring human intelligence, Galton devised the first scientific methods for measuring mental faculties, and thereby founded psychometrics. He also introduced the use of questionnaires and surveys for collecting data, thus paving the way for modern market research and opinion polls. Galton was also a very innovative designer and builder of a plethora of scientific measuring instruments to support his research. For example, in an effort to measure the range of frequencies that could be heard by various animals and for testing differential hearing abilities in humans, Galton invented the so-called dog whistle in 1876.

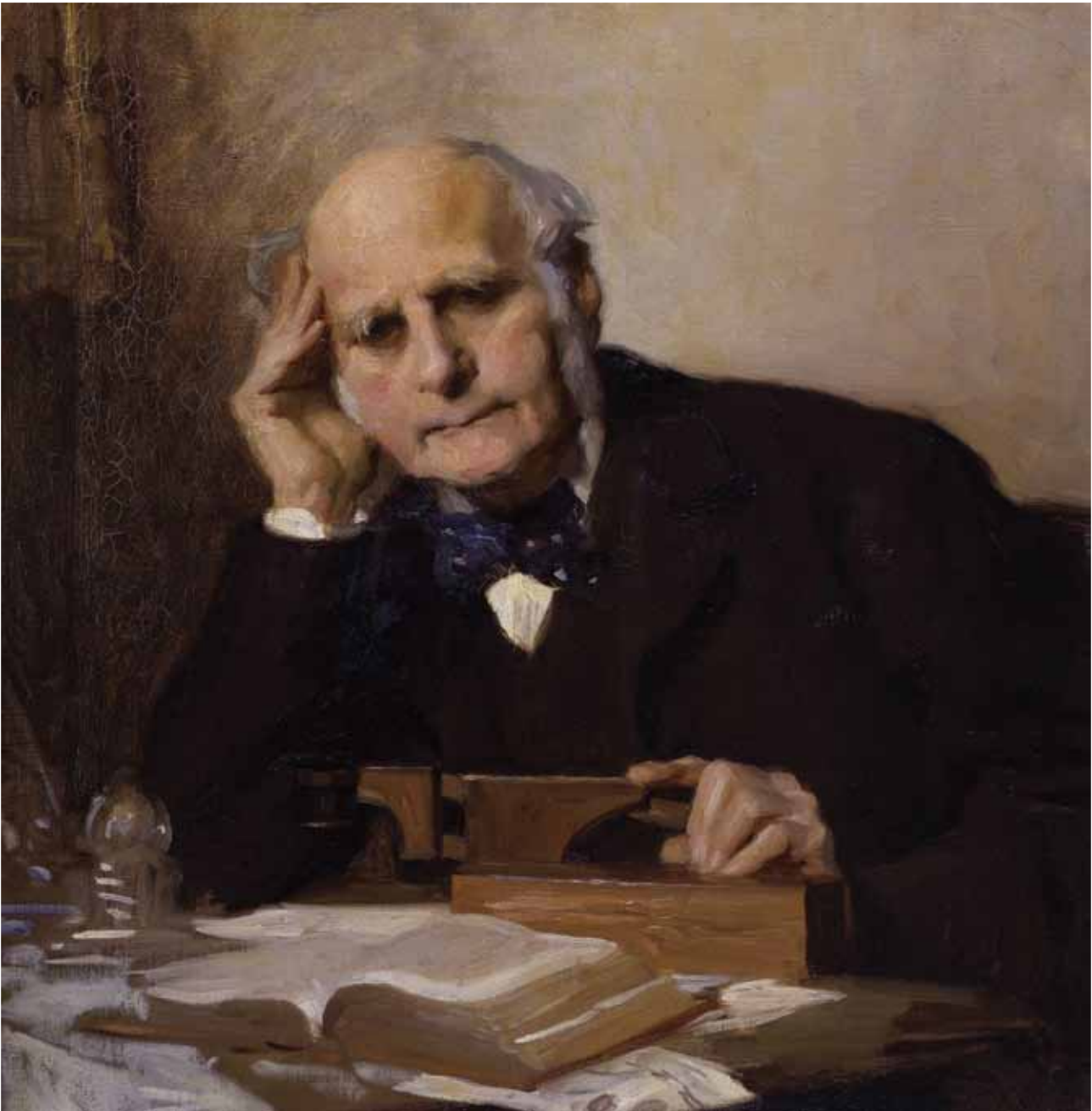
He saw “bell curves” wherever he went and was principally responsible for the transformation of the normal distribution (he coined the word

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“normal”) from being a “law of error” used mainly in astronomy to a “law of nature” applicable to almost every facet of commerce, industry and everyday life. With his gadget, the quincunx, he demonstrated and to some extent proved the tendency towards “normality” in nature. Together with Quetelet, Edgeworth and Pearson, he brought mathematical statistics into the realm of the social sciences and invented the concept of statistical correlation. He insisted that variety is ever present, but that there is often order in what may seem chaos and sometimes there is at least some structure in the seemingly unpredictability of random events. In the late 1860s, Galton conceived of a measure to quantify variation: the standard deviation. In the 1870s and 1880s, he was a pioneer in the use of the normal distribution to fit histograms of actual tabulated data. Galton devoted many years of study to the use of “composite portraiture”. This concept entails combining photographs of different subjects through repeated limited exposure to produce a single blended image. Galton perfected the technical details of the method by repeated trial and error over many years, using apparatus of his own design. He was especially interested in the use of these composites to test if there was a recognisable criminal type revealed by them, but his experiments in this direction proved that, within the range of data available to him, no such type revealed itself. The portraits of criminals tended to blend away into normality. This research, together with his work on fingerprints, eventually led to the development of pattern recognition techniques such as the bar code identifications used in warehouses and supermarkets today.



→ *Sir Francis Galton by Charles Wellington Furse.*

In his will, Galton bequeathed the then enormous sum of £45 000 for the establishment of a Chair in Eugenics at the University College London. Karl Pearson, his life-long friend, protégé, co-worker, biographer and co-founder of the highly influential journal *Biometrika* (1901), was the first professor incumbent and Ronald Fisher was the second. The Chair was later renamed the Galton Chair in Genetics, and is still in existence today.

Galton was a truly multitalented scientist. He was a polymath,

anthropologist, eugenicist, explorer, geographer, inventor, innovator, meteorologist, protogeneticist, psychometrician and statistician. He made significant contributions to all of these disciplines. He will be remembered and revered for these contributions. The well-known and prestigious medical journal, *The Lancet*, published a special article in 2011 entitled "The legacies of Francis Galton" to commemorate the centenary of his death. Similarly, the University College in London mounted two exhibitions as part of the Legacies of Galton:

*Centenary Programme at UCL.* Galton published over 340 papers and books during his long life. He was knighted in 1909 at the age of 87.

Sir Francis Galton, Fellow of the Royal Society (FRS), died on 17 January 1911 in Haslemere of unspecified causes and was buried in Claverdon, England. 📍

Adapted primarily from *Against the gods: The remarkable story of risk* by PL Bernstein; *The wind makes dust* by Ben MacLennan; *The life, letters and labours of Francis Galton* by Karl Pearson, <http://galton.org>, <http://www-history.mcs.st-and.ac.uk> and <http://en.wikipedia.org>, as well as many more easily accessible websites.

