Innovate:

Issue 09 2014

Innovation news

Energy research

Technical essays

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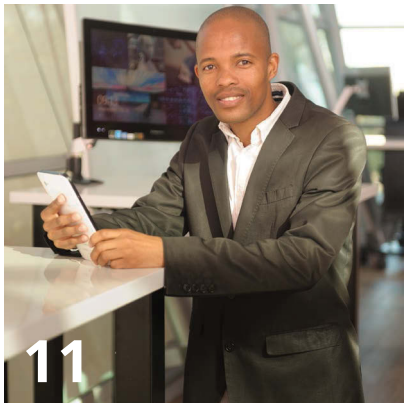
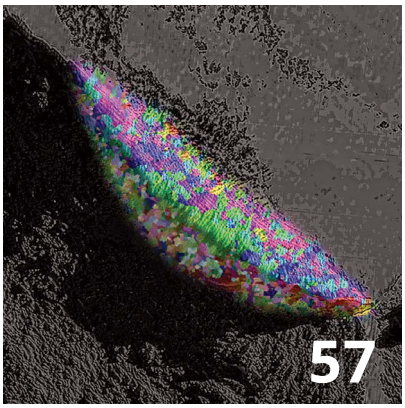
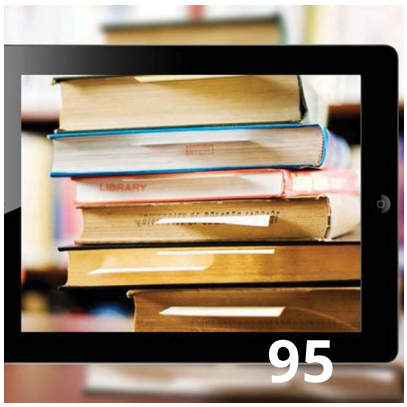
Content







ESSAYS

NEWS

LAST WORD

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Focus on research conducted as part of the University's Institutional Research Theme on Energy.
See feature articles on pages 21–56.

From VISTA to BRICS – opportunities for innovation?

In 2010, South Africa was invited to join the BRIC (Brazil, Russia, India and China) group of countries as a member. The invitation raised a spectrum of comments, some for and some against it. For South Africa, however, it was an elevation from the VISTA (Vietnam, Indonesia, South Africa, Turkey and Argentina) group of countries to the higher ranked BRICS (Brazil, Russia, India, China and South Africa) group. An interesting question is, of course, what opportunities the new elevated status could bring for South Africa, especially from a science and technology point of view.

In their criticism of the BRICS grouping in general, critics raised issues such as divergence in the goals of BRICS member countries, large differences in the size of their economies and economic performance, established networks with G7 countries that were too strong, and so forth. For South Africa, however, it was an opportunity to become part of a huge economic power block. It also created an opportunity to act as a representative and link for the sub-Saharan region to the other BRICS member countries.

An important potential benefit of membership is the opportunities that could be created for the development of technological capabilities and skills. Developing countries are characterised by their dependence on foreign technologies and skills. South Africa should therefore make use of opportunities created by the BRICS network to establish new science and technology collaborations.

Long-term economic development usually takes place through a series of strategies, starting with a labour-intensive economy, followed by a product-orientated economy and finally an innovation-driven economy. Strong technological capabilities and skills are important inputs to this economic growth strategy and South Africa should use its BRICS networks to enhance this growth process.

The University of Pretoria launched its Future Africa Initiative with the aim of playing an important role in the further development and strengthening of the region. Different faculties at the University initiated projects and programmes relevant to the needs of the region. From a science and engineering point of view, researchers at the University of Pretoria have much to bring to the table.

In this issue of *Innovate,* you will find interesting examples of research being conducted at the University. This research is not only highly relevant to the needs of our own region, but is also of international importance. There are contributions on cochlear implants, renewable energy, nuclear energy and so forth. In fact, there are quite a number of interesting contributions on the University's energy research projects. Some other fascinating articles examine the search for Noah's Ark and the roots of industrial engineering. I trust you will enjoy these contributions.

And on a final note: After 13 years as Dean of the Faculty of Engineering, Built Environment and Information Technology, Prof Roelf Sandenbergh has handed over the reins to his successor, Prof Sunil Maharaj. During his term as Dean, the Faculty has grown from strength to strength, especially in terms of its research output, the expansion of teaching and research facilities, the large number of research chairs, the growing number of publications in accredited journals and conference proceedings, and the development of national and international research networks and collaborations. From the colleagues in the Faculty, we say: "A job well done!"

Editor
Tinus Pretorius

Innovative app receives a Science Oscar

Anneline du Preez

The novel hearScreen mobile application (app), developed by the team of Prof De Wet Swanepoel and Dr Herman Myburgh, has received the 2013/14 National Science and Technology Forum (NSTF)-BHP Billiton Award for an outstanding contribution to science, engineering and technology through research leading to innovation in a corporate organisation or institution. These awards, known as the "Science Oscars", recognise the best and most influential researchers in South Africa.

Prof Swanepoel is associated with the Department of Speech-Language Pathology and Audiology in the Faculty of Humanities, and Dr Myburgh is attached to the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, Built Environment and Information Technology. While Prof Swanepoel is the audiology expert who had the idea, Dr Myburgh provided the technical expertise. This is an excellent example of the multidisciplinary research that is one of the strategic goals of the University of Pretoria.

The idea for the app came to Prof Swanepoel while he was looking for a solution to the unique problem of providing accessible audiology services to people in South Africa and Africa. The focus was on people in underserved rural areas, where health services are seldom available. Apart from the accessibility problem, hearing loss is a condition that can be easily alleviated and managed if detected early – in children and in adults.

Prof Swanepoel approached Dr Myburgh in March 2013 to assist him with creating a cellphone application that could perform hearing screening tests on children and adults. This was a new field for Dr Myburgh, but since modern-day smartphones have the same capabilities as a computer, he and David Howe (a final-year student in 2013) set about developing an Android app for the Samsung Galaxy Pocket Plus, an inexpensive phone with a retail price of approximately R900.

Numerous tests were done to determine suitable signal frequencies and hearing intensities, and to ensure that signals are correctly generated. Dr Myburgh was responsible for data analyses, and verified that the signals that were generated adhered to international hearing screening standards.

The phones are calibrated at 1, 2 and 4 kHz at different hearing intensities. In total, three tones are played in each ear, and if the person does not hear one of them, he or she is referred to a professional audiologist, who will perform further tests and implement interventions, if necessary. The phones' microphones are calibrated for a particular phone model, while each phone has to be calibrated with a unique headphone, due to slight variability in the output of the headphones.

The calibration did not, however, happen overnight. Dr Myburgh had to obtain some knowledge of audiology to understand the signals involved in hearing tests, and then had to ensure that the signals were generated correctly according to specifications. Initially, the phone could only be calibrated at intensities from 20 to 70 decibels in intervals of five. An easier way of calibration was sought, as existing audiometers are only calibrated at 70 decibels and a function is applied to automatically scale it down to lower intensities. Eventually, it was determined that the phones only had to be calibrated at 70 dB HL at 1, 2 and 4 kHz to render accurate dB increments up or down.

The research has shown that the phones are extremely consistent with regard to the calibration, which makes the calibration process uniform for a given phone model. Two more Samsung phones have been identified as potential phones for the app, and even if the app has

→ *Prof De Wet Swanepoel uses a cellphone to test the hearing of a toddler.*

→ *Prof De Wet Swanepoel (left) and Dr Herman Myburgh received the 2013/14 National Science and Technology Forum (NSTF)-BHP Billiton Award for the work of their team in developing this innovative app.*

to be upscaled to these devices, the calibration process stays consistent. The headsets, however, present less consistency when calibrated, but the problem is overcome by calibrating the phone and its particular headset together or as a pair. Furthermore, to ensure accuracy and adhere to calibration standards, the phone and headphones will have to be recalibrated annually.

Other than traditional equipment, the hearScreen product can detect background noise and indicate this to the person who is conducting the test. The test will then be taken at a later stage, or it can be taken in another venue. This feature was created by using narrowband noise at different intensities and adding the mathematical calculations to take this into account in the software.

A huge benefit and a novel development of the new technology is that the data of every screening can be uploaded to a central, secure database. The users, whether they are school nurses or community health workers, will each have an account on the database and will be able to access and monitor the data of their patients. It would also be useful for the Department of Health to have access to such a central database in order to identify specific regions where hearing problems occur. This database will have two options for users: a normal account and a premium account. The premium account will have more functionality than the normal account.

Background to the innovation

Recent statistics issued by the World Health Organisation (WHO) indicate that hearing loss is a significant healthcare burden worldwide. It is estimated that 360 million people across the globe, that is 5.3% of the global population, suffer from permanent disabling hearing loss. Included in this figure are 32 million children. As hearing loss is a condition that can be alleviated by various interventions, this burden of disease can be decreased if hearing loss is detected. The earlier it is detected, the better the outcome of the intervention, even in older people.

However, the impact of hearing loss may be the most devastating on children. They are at risk for delayed speech, language and cognitive skills, which lead to reduced literacy, academic and socio-emotional development, and higher risks of failure and fall-out in schools. In the end, these results can have a negative influence on a person's entire life and quality of life.

Prof Swanepoel has been involved in an advisory capacity with the Department of Education for quite some time. In his research and other work, he has always tried to improve access to health services, especially audiology services, for underserved communities. The Integrated School Health Policy, formulated by the national departments of Health, Basic Education and Social Development, and implemented in 2012, stipulates that all Grade 1 learners have to undergo a hearing screening test.

However, with an average of 1.1 million new Grade 1 learners every year, this is a mammoth task.

Another factor that decreases the probability that all these learners will be tested is the equipment needed for the screening. Traditionally, the machine that is used is heavy and has to be plugged into a power supply point to operate. Many schools in the underserved areas of the country do not have electricity. Furthermore, the equipment is expensive, and can cost up to R25 000 a unit. Another limiting factor is human subjectivity. The people operating the equipment are not necessarily trained in the same way and their interpretation of the results may differ. All these factors leave a fairly wide margin for error.

This probability of errors is almost completely eliminated by using smartphones and headphones that are each calibrated identically. The cellphone and set of headphones are also sold together, which further decreases the chances for error.

The largest selling point of this innovation is perhaps its price – it is estimated that the package of calibrated phone and headphones will be available for under R6 000.

The reason why a cellphone application was chosen is that there is a huge uptake of mobile devices in rural areas in South Africa, as well as the rest of Africa. In general, healthcare is increasingly moving towards the use of mobile health technologies (or m-health) to take healthcare to rural areas and to people who do not have access to more than perhaps primary healthcare facilities.

Outcomes and the way forward

A number of field trials and pilot projects are being launched to test and create awareness of hearScreen.

The University is involved in a field trial with the Department of Health, during which a planned pilot study of 80 phones will be rolled out to provincial school nurses to test learners over a period of a few months. Another research project will be conducted in Mamelodi in collaboration with the Department of Family Medicine in the University's Faculty of Health Sciences and the City of Tshwane Metropolitan Municipality. Community health workers will perform several electronic health assessments, including hearing screening, which will be uploaded on a number of phones to be issued. The aim is to do electronic health registrations and risk assessments. The inclusion of hearing tests will be the first time that a point-of-care health service like this will be delivered to people in their homes. Based on the findings, it is envisaged that these tests will later be upscaled and expanded to include the entire Tshwane area.

The first field trial on threshold tests – the next step in hearing testing – was to start in September 2014. This was to be done in collaboration with a Swedish colleague, Prof Claude Laurent, and a Swedish medical student from Umea University.

A huge boost for the research team is that the hearScreen product is set for commercialisation through Business Enterprises at University of Pretoria (BE at UP), the University's business entity. There is a strong possibility that venture capital will be provided to develop the product further.

The research needed to develop the product presents various research opportunities to final-year and postgraduate students in the fields of both computer engineering and audiology. Two PhD Audiology students are busy with studies in this regard for their theses.

Coupled with this, a few exciting developments and expansions of the mobile audiology product are set to follow. One of these is the adaptation of the product for use by the end-user; that is, for example, parents who would like to test their children's hearing.

Apart from the NSTF-BHP Billiton Award, hearScreen has also been shortlished for the South African Breweries Foundation (SAB) Social Innovation Awards.

The hearScreen product is the culmination of an ideal cross-faculty research project. True to the three pillars of a higher education institution, it involves learning, research and community engagement. This innovation, and what will follow on it, has the potential to have a profound socioeconomic effect and to improve the quality of life of many people.

Dr Herman Myburgh *is associated with the Department of Electrical, Electronic and Computer Engineering in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. His research interests are digital communication systems and artificial intelligence.*

Prof De Wet Swanepoel *works in the Department of Speech-Language Pathology and Audiology in the Faculty of Humanities at the University of Pretoria. His research focuses on access to health services for the underserved.*

Peering inside a cochlear implant user's head

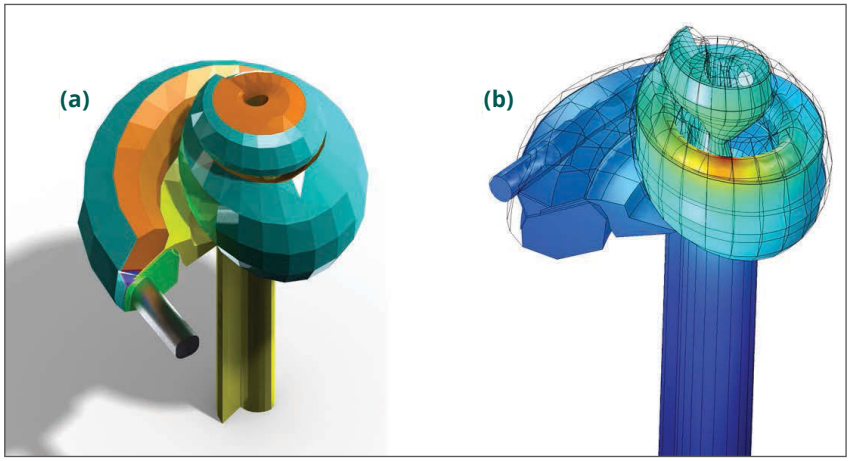
Tiaan Malherbe, Prof Johan Hanekom and Prof Tania Hanekom

The Bioengineering Research Group at the University of Pretoria has research interests in engineering, medicine and biology. One of the Group's major focus areas is the auditory system, normal hearing and electrically stimulated hearing (cochlear implants for the deaf).

A cochlear implant is the current treatment of choice for deafness in individuals who are suitable candidates. The device consists of a microphone, an external speech processor that converts the sound input from the microphone to stimulation parameters, a transcutaneous radio link that transmits data and power to the implanted electronics, an implanted stimulus generator, and the multicontact electrode array that is inserted into the inner ear or cochlea. Auditory information is electrically transmitted to the surviving auditory neurons via current injection through the appropriate electrode combinations. On average, speech perception in quiet is around 80%, irrespective of the implant manufacturer.

Despite the success of the intervention, its outcome is still highly user-specific, with benefits ranging from basic rhythm perception without much tonal content to the ability to appreciate music and converse via telephone. The age of the person receiving an implant (Hassanzadeh et al., 2002), the duration of hearing loss (Blamey et al., 1996), electrode design (Rebscher et al., 2007), electrode insertion depth (Finley et al., 2008) and pre-operative variables (Gantz et al., 1993) are some of the factors that influence the implant's perceptual outcome. The precise manner in which these factors interact to produce a user-specific perceptual outcome is still unclear and warrants further investigation. A modelling approach to investigate the factors that affect interperson variability is ideal, since the development of a model in itself provides information about the structure of the system, as well as the parameters that dictate its operation.

Computational models provide a simulated invasive view of the interaction between the

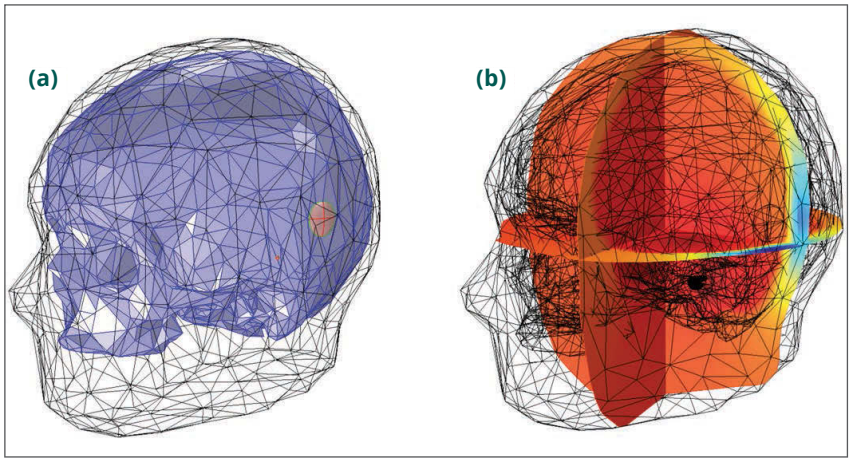


→ *Figure 1 (a): User-specific computational model of a cochlea showing the electrode array (grey cylinder) protruding from the scala tympani (lower duct of the cochlea shown in green). Figure 1 (b): A finite element solution of the electric potential field inside the cochlea as a result of stimulation with one of the electrodes. The red area indicates the location of the stimulating electrode and has the highest electric potential. The extent to which nerve fibres near this electrode will be excited depends on the specific spatial distribution of the potential field.*

cochlear implant technology and the peripheral auditory system, consisting of the cochlea's anatomy and its neurophysiological environment. This enables researchers to investigate the neurophysiological mechanisms that underlie the interaction between the cochlear implant and the biology (Malherbe et al., 2013). These models provide a computer-generated cochlear environment where neural responses to stimulation via the implant may be controlled through several interdependent parameters and can subsequently be analysed. They also provide a means to simulate an experimental environment that might not be feasible in reality, for example to "measure" (that is, to predict by the model) single-nerve fibre thresholds in the auditory periphery of living human users.

Prof Johan Hanekom and Prof Tania Hanekom from Bioengineering (in the University's Department of Electrical, Electronic and Computer Engineering) have been working in the field of cochlear implant modelling for more than two decades. Recent work on the development of user-specific models for cochlear implantees has been driven by the PhD research of Tiaan Malherbe. The work focuses on the construction of user-specific models for which the geometric parameters are extracted from computed tomography images of the cochleae of these users.

The models incorporate skull and brain volumes to provide an accurate description of current paths among the intra-cochlear stimulation electrodes and the extra-cochlear return electrodes. The potential benefits from the models include a description of the biophysical interface between the device and a specific user's peripheral auditory system, cues to support the customisation of the implant for an individual and diagnostics to probe complications that may arise after implantation, for example, facial nerve stimulation.



→ *Figure 2 (a): Visual representation of the finite element mesh of the full head model showing the external return electrodes in red. Figure 2 (b): Predicted potential fields as a result of intracochlear stimulation on two planes through the model. The cochlea can be seen as a dark area behind the vertical plane and below the horizontal plane.*

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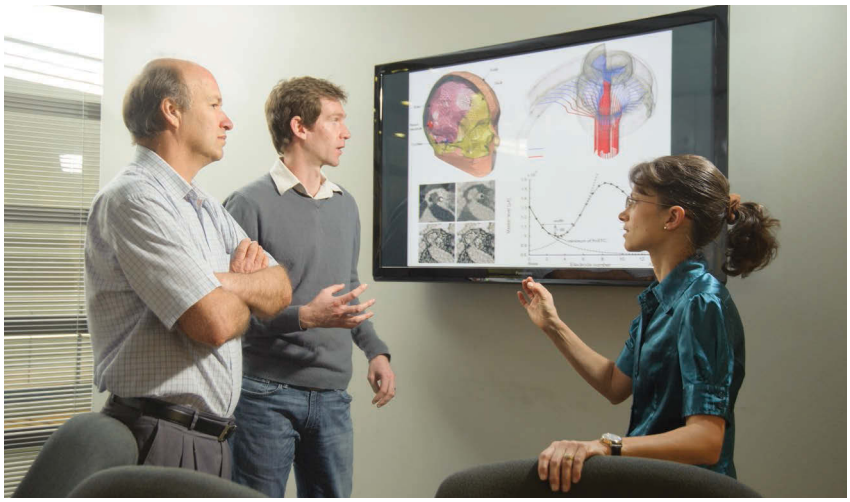


Prof Johan Hanekom (left) *is the Group Head: Bioengineering in the Department of Electrical, Electronic and Computer Engineering.*
Prof Tania Hanekom (right) *is associated with Bioengineering in the Department of Electrical, Electronic and Computer Engineering.*
Tiaan Malherbe (centre) *is a PhD candidate in the Bioengineering Research Group of the Department of Electrical, Electronic and Computer Engineering.*

Anti-cyber bullying software: Technology transfer at its finest

Helena Smit

In the innovation landscape, the commercial exploitation of inventions is the ultimate goal of practical research. This process of technology transfer is the mark of successful research inventions and affords the inventor the opportunity to actively contribute to the promotion of society in one way or another. Khutso Bapela, a BSc Computer Science graduate from the University of Pretoria, whose company resides at the University's research partner, the Innovation Hub, is one such inventor.

Bapela has successfully developed an anti-cyber bullying application (app) aimed at helping parents of young children in all South African communities to monitor their children's online activities in an attempt to prevent continuous unsurfaced cyber bullying. The Motswadi system (meaning "parent" system) is a specialised SIM card for modems and cellphones and an accompanying downloadable app. The system enables parents to regulate the online activities of children aged 9 to 15 in the overwhelming and ever-expanding world of the internet and social media.

The Motswadi system

While studying towards his Computer Science degree, Bapela started to entertain ideas for the development of a system that could not only prove commercially viable, but also improve the lives of South African communities at grassroots level. With the advent of the digital revolution, all facets of social life have moved towards incorporating the digital space to varying degrees. While this shift has many positive attributes in terms of education, business and technology, it has expanded the vulnerability of young children to new platforms. Cyber bullying, as well as access to masses of inappropriate and harmful information, poses a serious threat to the wellbeing of young children both in South Africa and the rest of the world.

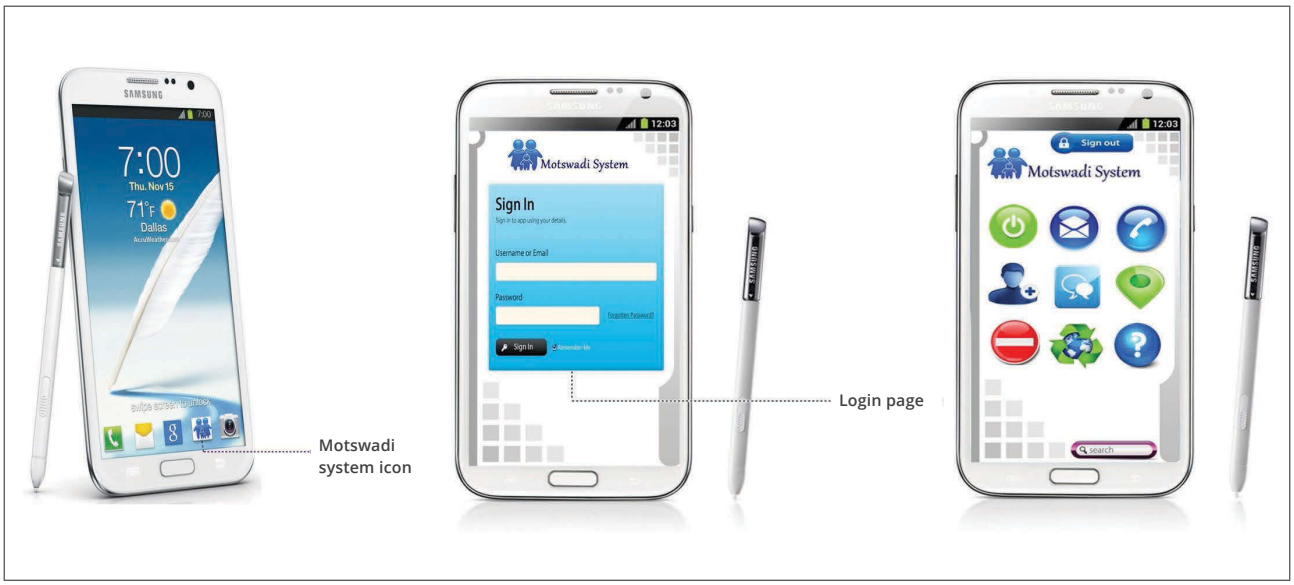
The Motswadi system employs an app algorithm that wirelessly picks up the specialised SIM card in a child's cellphone or modem. The app enables parents to set up an internet profile for each of their children that is tailored to each particular child's needs and vulnerabilities. Standard age group settings determine the level of protection that the system applies to a child's profile. These settings can then be customised at the parents' discretion. The app allows for restrictions in terms of time limits for features like internet use and WhatsApp messaging, the blocking of searches for certain keywords, the blacklisting and re-allowance of specific websites, the blocking of selected apps and the implementation of a web schedule, among others. The system also allows for the monitoring of a child's internet activities, SMSs, Facebook account via notifications and the child's location (updated every 15 minutes).

Innovation through technology transfer

The most important strategic goal of research is to increasingly address the innovation needs of the society in which it functions. To achieve this goal, the emphasis of research must continuously be on accelerating knowledge generation by fostering collaborative relationships with various external partners. In a university research environment, these partners are government, higher education institutions and the private sector. The primary way to ensure the practical implementation of research in society is to generate hybrid spin-off businesses led by innovative and passionate researchers.

In South Africa, it is important for researchers to concentrate on problems of national and/or regional concern in order to maximise local impact. By focusing on unique local opportunities, researchers can strengthen activities in areas of immediate national need and ensure that these fields, which ultimately affect human welfare and development, are addressed. When a researcher has isolated a need in his or her society and has successfully developed a product to serve that

→ *Khutso Bapela.*



The complete system on a smartphone.

need, the process of technology transfer is set in motion.

Technology transfer is the transfer of technology developed by researchers from universities and research institutions to the private sector. Its main goal 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. Private sector businesses look forward to the prospect of receiving new products and services, and universities and research institutions are motivated by the potential income stream from successful licensing agreements and greater employment opportunities that graduates may have with industry partners. Bapela's Motswadi system is a perfect example and embodiment of the successful technology transfer the University attempts to foster in all its students and graduates.

Bapela took part in the University of Pretoria Business Incubator (UPBI), a programme nurtured by the Department of Business Management since 2008. The incubation programme is designed to aid the successful development of entrepreneurial ventures by offering an array of support services and resources, based on the fundamentals of the entrepreneurial process, to student-driven entrepreneurial business initiatives. It does this by offering students an intensive three-month incubation programme from which they gather essential business skills and resources, such as business model generation. This challenges students to take their ideas and transform them into business opportunities. The experience and skills that Bapela built up through this programme, paired with the utilisation of the advice and expertise of a friend and manager for business development, enabled Bapela to proactively continue the innovation chain for his unique and practically implementable research invention.

The innovation chain

The innovation chain is the process that research, with the potential for technology transfer, follows from inception to commercial implementation. Firstly, researchers or inventors develop an idea.

It is important for them to safeguard their ideas until the necessary protection in the form of a patent is applied to the idea before they publish their research findings. For this reason, it is important for researchers and inventors to take a long-term approach rather than chase short-term benefits.

Secondly, an intellectual property (IP) strategy has to be formulated. This encompasses the identification of licensing and commercialisation opportunities, and brings about investigations with regard to patent opportunities both locally and internationally. At this stage, it is important for researchers and inventors to take a proactive approach to investigating commercialisation opportunities, including industry partners.

The idea then has to be evaluated in terms of its qualification for either a South African provisional patent or a Patent Cooperation Treaty (PCT). A patent is important, because it allows the researcher or inventor to safely conduct further research and develop his or her product for either 12 or 18 months without fear of compromising the research through publication. The most important consideration for the patent process is the novelty of the product. A patent is a standard way to protect innovators' IP assets.

Thirdly, a business plan or strategy has to be developed. This is essential for successful technology transfer. The two main strands of a business strategy are the commercialisation strategy (selling the product through an independent business entity) and the licensing strategy (selling the product to consumers through its lease to other companies).

→ *The complete system on computer.*

The way forward for the Motswadi system

The Motswadi system has been awarded a South African provisional patent through the Innovation Hub's patent package. This patent provides Bapela with a further 12 months to safely conduct additional research and development to perfect the system. Bapela intends to use this time to improve the system's functionality and the app's interface. Bapela intends to license the Motswadi system to mobile network providers in South Africa and other countries on the continent. He has already entered into conversations with leading South African network providers to commercialise the system on home soil.

As a young inventor, Bapela serves as an inspirational role model for undergraduate and young postgraduate students to strive for the development and optimal utilisation of practically implementable research. This proves that there is no minimum age limit to the integration of innovative thinking and a commitment to the improvement of society.

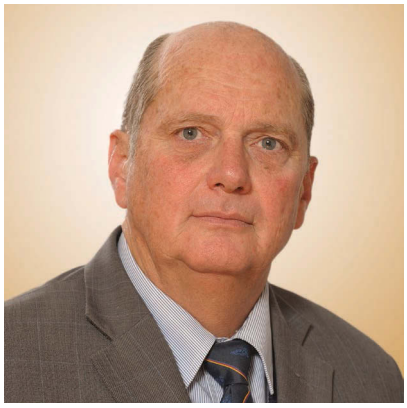
Khutso Bapela *is a BSc Computer Science graduate of the University of Pretoria. He has established his own company at the Innovation Hub.*

→ *Using the Motswadi system on a laptop.*

Prof Roelf Sandenbergh concludes an era as Dean

Janine Smit

October 2014 brings to an end the third term as Dean of the Faculty of Engineering, Built Environment and Information Technology for Prof Roelf Sandenbergh. He was appointed Dean of this newly restructured faculty in 2001, when the disciplines of engineering, the built environment and information technology were combined into a single faculty.



Prof Sandenbergh joined the University of Pretoria in 1974 as lecturer in the Department of Materials Science and Metallurgical Engineering. He became Head of the Department in 1996, and Chairperson of the School of Engineering and Dean of the Faculty in 2001.

He is a registered professional engineer, who obtained his undergraduate, as well as his postgraduate qualifications from the University of Pretoria. His academic qualifications include the degrees BEng (Chemical) (1972), MEng (Chemical) (1975) and DEng (Metallurgical) (1983). Furthermore, he is a fellow of the South African Academy of Engineering, a member and past Chairperson of the Professional Advisory Committee on Metallurgical Engineering of the Engineering Council of South Africa (ECSA), a member of the Academy of Science of South Africa (ASSAf), an honorary life fellow of the South African Institute of Mining and Metallurgy, and a member and former President of the Corrosion Institute of Southern Africa.

He contributes to teaching, research and consulting in the fields of extractive metallurgy, corrosion and failure analysis.

His vision as Dean was for the faculty to make significant local and international contributions to the training of professionals in the disciplines served by the faculty, and to the transformation of the University of Pretoria into a leading research-intensive university. As Dean, he encouraged the development of initiatives that would attract larger numbers of students to the programmes of the faculty, for the faculty to achieve higher success rates with its programmes and research activities, and to ensure the optimal utilisation of the faculty's cutting-edge facilities. He also focused on the development of the faculty's human resources, with the aim of having its alumni join the ranks of internationally recognised scholars and professionals. Many of the successful initiatives in the faculty were made possible through the attraction of external funds, which is testimony to the success with which the faculty achieved its objectives.

Prof Sandenbergh insists that he cannot take credit for all the achievements of the Faculty in the past 13 years, and that the role he played was merely one of catalyst. However, the accessibility of the Faculty's programmes to all population groups in South Africa, the growth in its postgraduate component, and its strengthened relationship with industry can be seen as highlights during his period at the helm of this strong faculty.

Since 2001, the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria has made a significant contribution to expanding South Africa's skills base through the leading role it plays in teaching, research and community engagement. This success has been achieved through sustained and dedicated teamwork between students and staff, and with the support and cooperation of its industry partners.

Ensuring excellence in engineering, the built environment and information technology

Prof Roelf Sandenbergh

At the beginning of the century, the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria set itself the goal of significantly increasing its contribution to the positioning of South Africa as a competitive research-intensive country and leader in Africa.

The plan was to build on the existing foundation of high-quality education at undergraduate and postgraduate levels, as well as its excellence in research, by increasing the student numbers, and research intensity and outputs of the Faculty. This was done in close collaboration and with the support of the University, government and industry to expand the Faculty's facilities and human resources.

As its name indicates, the Faculty serves the engineering, built environment and information technology professions with professional programmes in the major disciplines in these fields, with further specialisation at senior undergraduate and postgraduate levels. The focus on engineering and technology management was further strengthened in 2007 by placing these activities in a separate Graduate School of Technology Management.

Advisory boards were formed at both faculty and departmental levels to foster closer cooperation and alignment with industry. High-level participation in these boards has contributed significantly to the successful alignment of the Faculty with government and industry initiatives and has succeeded in attracting support and funding for new facilities and research chairs. It has also ensured that the programmes offered in the Faculty, together with the research conducted, are relevant to the market, while the experience gained by graduates can be applied in practice and meets industry requirements.

Growth in student numbers

The School of Engineering is one of the largest of its kind in South Africa, and produces by far the largest number of graduates in the country. It comprises seven departments: Chemical

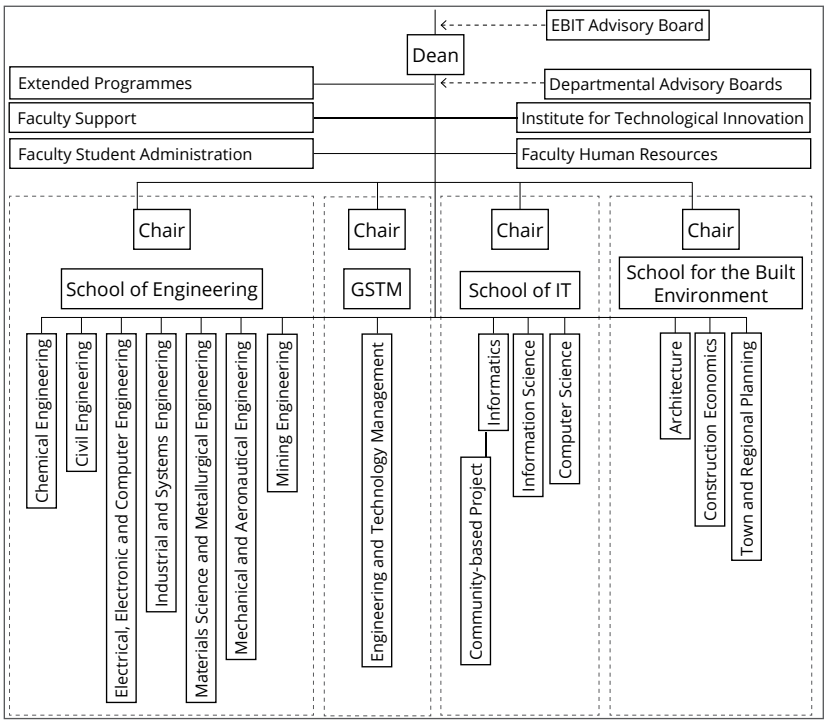


Figure 1: Structure of the Faculty of Engineering, Built Environment and Information Technology.

Engineering, Civil Engineering, Electrical, Electronic and Computer Engineering, Industrial and Systems Engineering, Materials Science and Metallurgical Engineering, Mechanical and Aeronautical Engineering, and Mining Engineering.

Student numbers in the programmes in engineering and engineering management have almost tripled since the turn of the century, from under 2 000 to almost 6 000. The growth can largely be attributed to the increased participation of black students. To accommodate this growth, significant support was obtained from government and the University Council to considerably expand the School of Engineering through the construction of additional lecture halls, as well as research laboratories.

The School for the Built Environment is also one of the largest of its kind in the country and covers the entire spectrum of programmes in the built environment. It comprises the departments of Architecture, Construction Economics, and Town and Regional Planning. Its programmes have all been redesigned to align them with international norms, and include professional qualifications in Architecture, Interior Architecture and Landscape Architecture. All the programmes in this School are internationally accredited, display a commitment to innovation, and strive to promote the equitable and sustainable development of a prospering, rapidly urbanising South African society.

The School of Information Technology is the first of its kind in South Africa and students have the advantage of an integrated approach to information technology (IT). It comprises the departments of Computer Science, Informatics and Information Science. Close links exist with the Department of Electrical, Electronic and Computer Engineering in the School of Engineering. The integration of these three academic departments into one school has brought considerable advantages for the academic programmes that are offered. It has an excellent and modern infrastructure to support teaching, sophisticated undergraduate computer laboratories and specialised research facilities.

The Graduate School of Technology Management (GSTM) presents postgraduate programmes in the Department of Engineering and Technology Management. It also offers internationally recognised management development programmes that address different needs in the fields of technology management, engineering management and project management. The aim of its programmes is to provide graduates with skills and knowledge on the management of engineering processes, systems and services. A strong focus on research ensures relevance to the market in terms of increased competitiveness, optimising product life cycles and technology transfer, and positioning technological context.

Teaching and learning

The language of instruction for the programmes offered is English, with most courses also offered in Afrikaans at undergraduate level. In some programmes, language

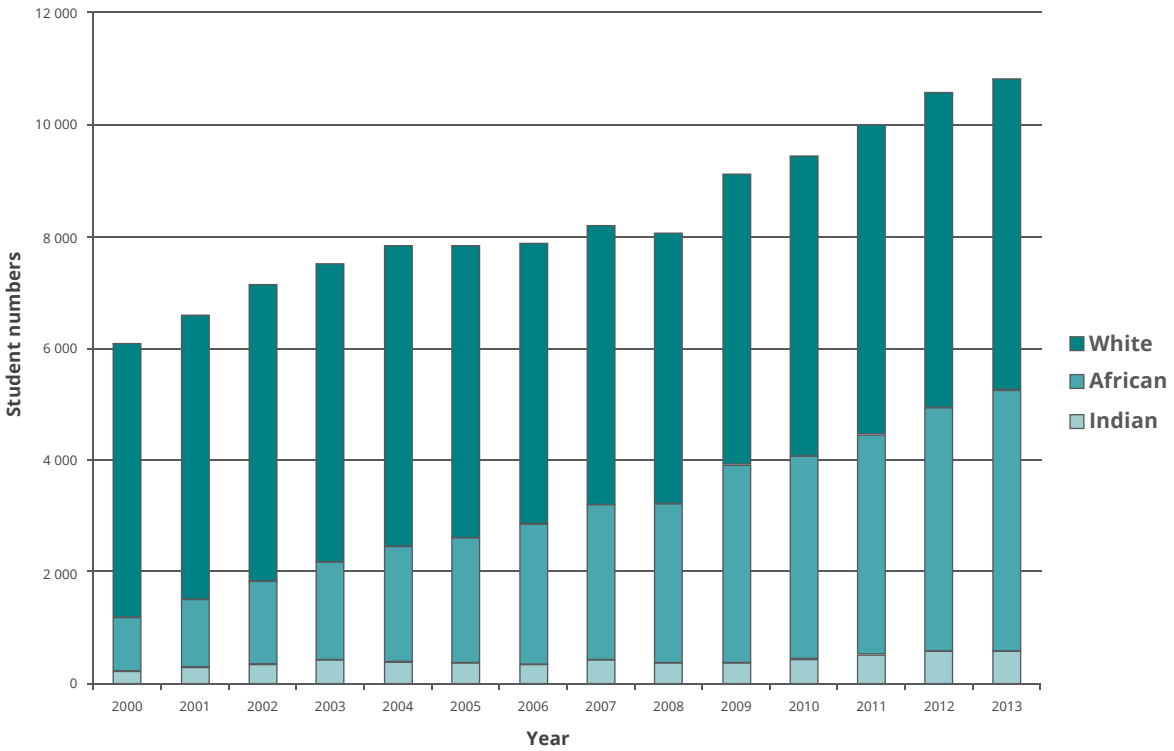


Figure 2: Composition of the student enrolment in the programmes offered in the Faculty.

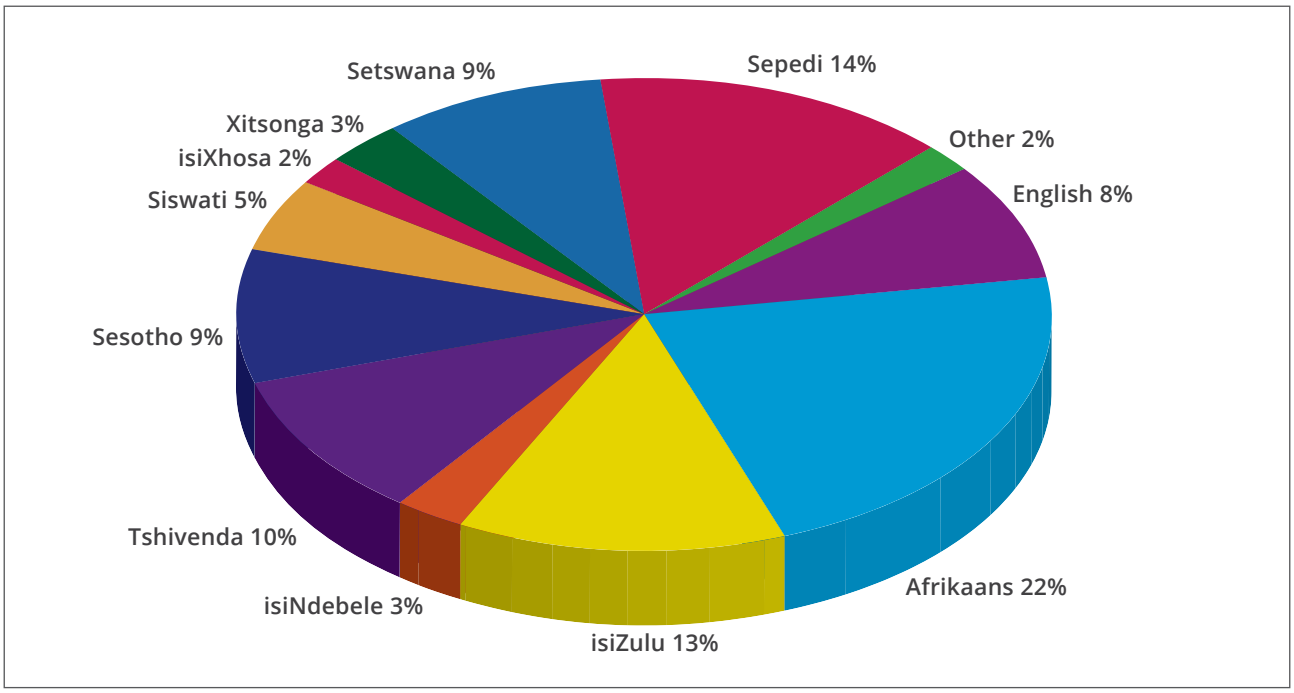


Figure 3: Home languages of the students enrolled for Mining Engineering in 2013.

proficiency poses a significant challenge, such as in Mining Engineering, where only 8% of the students in the 2013 cohort had English as their first language (see Figure 3). Significant success has been achieved to improve the communication skills of these students with the presentation of additional language and communication programmes. The programmes offered in the Faculty are reviewed on a regular basis to stay current and to optimise its offerings. A major review of the engineering programmes was undertaken to improve teaching and learning, promote alignment with international best practice, reduce teaching overload, increase commonality and reduce duplication, as well as to create space for more independent study and creative activities.

Access to and success in the programmes of the Faculty are enhanced by the Engineering Augmented Degree Programme (ENGAGE), in which the study period is extended by one year, with extensive support and additional modules required in the earlier years.

The increase in graduation numbers over time bears testimony to the success of these measures to ensure study success.

Community engagement

The ability of students in the Faculty to operate in complex and multicultural environments is strengthened by their participation in the compulsory undergraduate Community-based Project Module (JCP). The establishment of this module in February 2005 was a milestone for the Faculty.

Students are trained in community engagement protocols and have to conceive and execute a community-based project that involves working at least 40 hours in a community. They then reflect on their experiences through web-based systems and present their project to their peers and the programme leader.

Projects are aimed at achieving a beneficial impact on a chosen section of society by engaging with a community that is different from learners' own social backgrounds.

In the process, they develop an awareness of personal, social and cultural values, an attitude to be of service and a deep understanding of social issues, while developing important multidisciplinary life skills, such as communication, interpersonal and leadership skills.

Expansion of facilities

With the construction of the Engineering 3 Building in 2010, the facilities available to the Faculty have been expanded significantly and have been modernised to accommodate the growing student numbers and research requirements. This building has 2 300 lecture seats in a variety of configurations, undergraduate and research laboratories, and offices arranged to facilitate the functioning of research groups, as well as parking for close to a thousand cars.

Significant support has been obtained from government to expand the facilities of the School of Engineering.

The laboratories for Chemical Engineering are in the process of being expanded and modernised, and the facilities available to Mining Engineering have been expanded through the industry-funded Kumba Virtual Reality Mine Design Centre, which will create additional space for other activities of Mining Engineering, and Materials Science and Metallurgical Engineering.

The development of the Mining Industry Study Centre in 2013 further contributed to the success of the University's engineering students by providing study and groupwork facilities for close to 800 students in close proximity to the other facilities of the School of Engineering.

The expansion of the facilities in the Faculty was made possible by substantial support from and collaboration between government, industry and the University.

Research

Research and postgraduate studies are regarded as core activities of the Faculty, and steady progress has been made with the improvement of the qualifications of its teaching and research staff, as well as increasing the quantum and quality of its research outputs. Significant growth has been achieved with developing research activities in each department with the establishment of several new research centres and research chairs.

The Faculty currently has the following research centres:

- Institute for Applied Materials
- SANEDI Hub in Energy Efficiency and Demand-side Management
- Centre for New Energy Systems (CNES)
- Centre for Electromagnetism
- Carl and Emily Fuchs Institute for Microelectronics (CEFIM)
- Centre for Telecommunications Engineering for the Information Society (CeTEIS)
- Eskom Power Plant Engineering Institute (EPPEI)
- Specialist Centre in Plant Asset Management
- SAIW Centre for Welding Engineering
- Kumba Virtual Reality Mine Design Centre
- African Centre of Excellence for Information Ethics
- Institute for Technological Innovation
- Industrial Metals and Minerals Research Institute (IMRI)

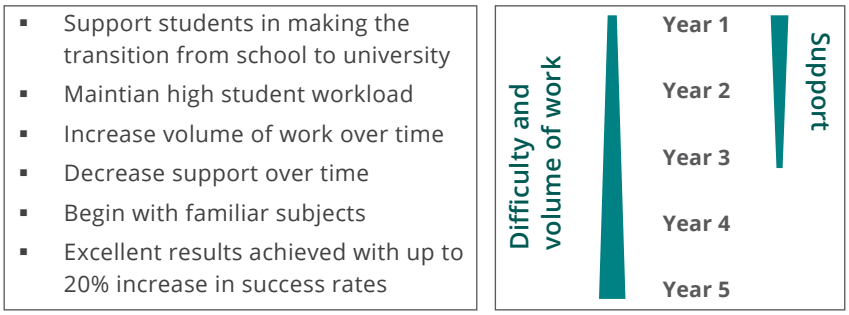


Figure 4: Structure of the ENGAGE degree programme.

The research chairs in the Faculty are as follows:

- SARChI Chair in Carbon Technology and Materials
- SARChI Chair in Fluoro-material Science and Process Integration
- SARChI Chair in Advanced Sensor Networks
- SARChI Chair in Artificial Intelligence
- Sedibeng Water Chair in Water Utilisation Engineering
- Transnet Chair in Railway Engineering
- Rand Water Chair in Civil Engineering
- Sentech Chair in Broadband Wireless Multimedia Communication
- Exxaro Chair in Energy Efficiency
- Electronic Defence and Radar
- CBI Low Voltage Chair in Power Electronics
- Chair in Maintenance Engineering
- Rand Water Chair in Mechanical Engineering
- Anglo American Chair in Pyrometallurgy
- Glencore Chair in Modelling of Pyrometallurgical Processes
- Tenova Chair in Minerals Processing
- Sasol Chair in Safety and Health
- Harmony Chair in Rock Engineering

Research output in the form of articles published in accredited journals, research reports and conference proceedings contribute to the University's ranking as a top research university. The Faculty's publication output has increased significantly over time, although some short-term decreases in output have occurred, resulting from increased emphasis on the quality rather than the number of outputs.

Significant progress has been made with the number of papers listed on the Thompson Reuters Web of Science, the number of citations and the citations per paper. The discipline of engineering at the University of Pretoria has maintained its position as the highest ranked in South Africa according to the Web of Science's worldwide rankings of the top 1% of engineering schools.

Considering the achievements of the Faculty against the goals set, good progress has been made and the contribution of the Faculty to the development of high-end human resources and research is on a high level.

However, it is also clear that, although a sound foundation for further development has been laid, much remains to be done, especially in terms of the pace of growth in research outputs, to significantly improve the Faculty's international standing.

The significant progress the Faculty has made in the fields of teaching, research and community engagement over the past 13 years provides a steady platform for sustained growth in the future.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EXIT


THUTO
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BUILDING

Energy research is elevated to a new level institutionally

Prof Tinus Pretorius

As a research-intensive university, the University of Pretoria believes that it can make a positive contribution to the economic and social development of the country. Its research agenda is focused on a number of carefully selected themes on which proven capacity exists within the University, and which build on the work of excellent researchers and research leaders. This has led to the establishment of a number of institutional research themes (IRTs), one of which is Energy.

A study by the University's Institute for Technological Innovation in the Faculty of Engineering, Built Environment and Information Technology found that the University was the most prolific publisher of energy research in South Africa over the period 1997–2007. This led to the establishment of the University's IRT on Energy, which was officially launched by the Vice-Chancellor and Principal in September 2012.

The IRT on Energy was designed to recognise and foster excellence in research, and is aimed at enhancing multi- and transdisciplinary research that cuts across faculties to strengthen the University's reputation as one of South Africa's leading research universities. The IRT aims to coordinate research being done in a number of faculties and partner institutions, which focuses on topics that are relevant to South Africa's future energy security. Such a focused and concerted research effort is necessary to ensure that the country succeeds in achieving the goals of government's Integrated Resource Plan 2010 (IRP2010).

In order to develop an appropriate strategy for the IRT on Energy, the IRP2010 was evaluated, together with other government energy policies and strategies. The main goal of the IRT on Energy is to concentrate on research related to electricity generation, transmission and distribution. A number of selected research subthemes include energy production (with the emphasis on clean coal, nuclear and renewable energy), energy distribution (smart grids and energy storage), energy optimisation, advanced materials, energy policy and economics, and ensuring a sustainable environment.

The IRT on Energy is in a position to create excellent opportunities for the development of research capacity at postdoctoral level, as well as for collaboration between different academic departments (especially in the faculties of Engineering, Built Environment and Information Technology, and Natural and Agricultural Sciences). Collaborations are also established with local and international organisations, universities and industrial partners.

The IRT on Energy strives to provide the best balance between the University's current research activities and the energy focus areas that are prioritised by government, with an initial focus on electrical energy.

A number of research projects that form part of the IRT on Energy are highlighted in this issue of *Innovate*, and illustrate the varied and interdisciplinary nature of the research that is being conducted under the auspices of this research theme, which will set the University on the road towards national relevancy as it searches for solutions to South Africa's energy problems.

The main goal of the IRT on Energy is to concentrate on research related to electricity generation, transmission and distribution.

Addressing energy problems in South Africa

Dr Jörg Lalk

During 2008, the South African economy suffered massive losses due to a steadily growing shortage of electrical energy, which reached a peak when widespread blackouts – also known as "load shedding" – became common. Most areas had to deal with at least four hours of load shedding a day.

As a result, the South African Department of Energy (DoE) developed a long-term roadmap, commonly known as the Integrated Resource Plan 2010 (IRP 2010). The IRP 2010 captured the government's vision of electrical energy capacity growth between 2010 and 2030 and envisaged an increase of installed capacity from approximately 42 GW in 2010 to approximately 85 GW by 2030 (Department of Energy, 2010).

During the development of the IRP 2010, which was a first for the South African government, some energy forecasting and modelling was conducted. An open-source tool, the Open Source Energy Modelling System (OSeMOSYS) (Howells et al., 2011) was used for this. After the publication of the IRP 2010, it became clear that the anticipated installed capacity of 85 GW by 2030 may not be realistic, as the economic growth figure of 4 to 6%, which was assumed during the initial modelling, will probably not be achieved. According to data that has been collected since 1994, it seems more reasonable to assume a growth figure of approximately 2.5%. This is further supported by the latest figure of only 1.9% for 2013. Forecasts for 2014 were in the region of 2.1% (see Figure 1).

With the latest prediction of only 1.5% by the South African Reserve Bank, it is evident that the South African economy is not growing nearly as much as anticipated. This scenario is affected by much higher electrical energy prices and an increased awareness of how South Africa's largely coal-based energy economy affects climate change.

A closer inspection of the complexities of energy analysis and planning at a national level reveals that one is not only dealing with the direct complexities of energy systems, but also with the impact of other factors, such as the national economy and climate change. Briefly, one is dealing with what can be classified as a "wicked problem". Such problems are difficult to formulate, have only "good" or "bad" solutions, have limited opportunities to learn by trial and error, and are essentially unique (Rittel and Webber, 1973, in Camillus, 2008). This explains why different analysis studies tend to show opposing results. It remains problematic to develop models of what is essentially a multidisciplinary and complex environment.

As part of the University of Pretoria's pursuit to produce world-class research, a number of Institutional Research Themes (IRTs) were identified, of which Energy is one. In order to expand research on the IRT on Energy, the Energy Analysis Research Group was established in the Graduate School of Technology Management. The Group attempts to address many of the problems related to national energy issues. An important aspect of the Group's research is that a proper systems approach, which makes it possible to deal with the wicked problems of energy analysis, is being followed. Since its inception, the Group has attracted some 23 postgraduate research students and two postdoctoral researchers, who are working on a number of subtopics in the energy analysis domain.

Two of the Group's research focus areas, system modelling and analysis and climate/energy system interaction, are particularly important. The latter is concerned with the impact of climate change on energy systems, as opposed to studying the benefits of so-called environmentally friendly energy systems, such as wind and solar power. The Group is focusing on studying the influence climate change has on renewable energy systems, as well as coal, hydro- and nuclear power systems.

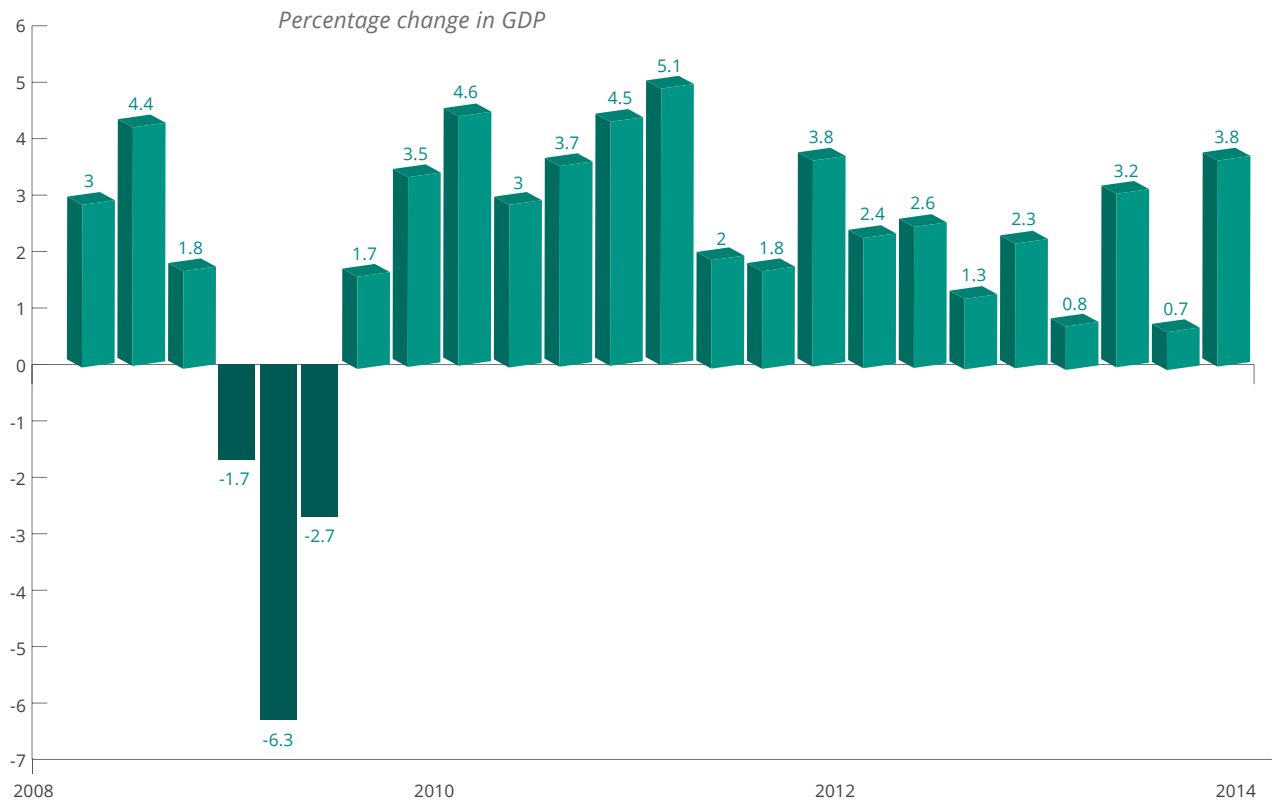


Figure 1: Historical data of South Africa's gross domestic product (GDP) growth rate. (Source: www.tradingeconomics.com.)

The starting point of the research is that climate change is a certainty, irrespective of how much human activity contributes. Ignoring this fact may lead, for example, to wind farms being positioned in areas where, in a few decades, the prevailing wind patterns shift so much that they can no longer effectively produce electrical energy.

Studies that analyse the impact of climate change on wind resources usually only model changes in wind speed. The Group's study took this a step further by determining how different wind speeds affect annual energy production (AEP) and power density. The research provides a more accurate description of how altered wind speeds could affect the most important factor of a project's feasibility: the electrical energy output.

When determining the AEP in the Wind Atlas Analysis and Application Program (WAsP)™ software simulation tool, the power curve, of whichever turbine(s) occur in the area-assessed resource grid, is determined (Herbst and Lalk, 2013). For this study, only wind speed was modified. If the climate changes, a number of other factors may also be affected, possibly also influencing electricity output from individual wind turbines and/or wind farms. During this project, an initial study was completed that used information from existing wind sensor masts operated by the Council for Scientific and Industrial Research (CSIR) (Herbst and Lalk, 2013).

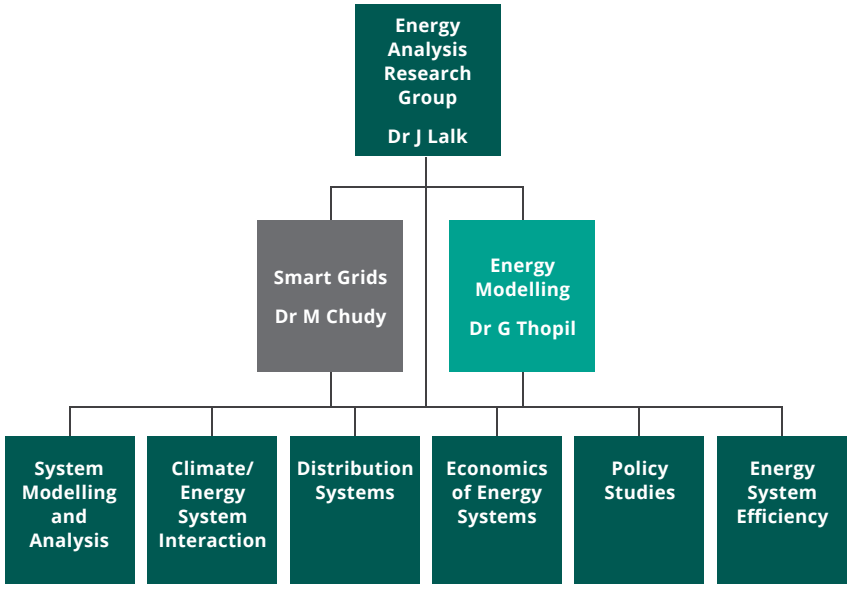
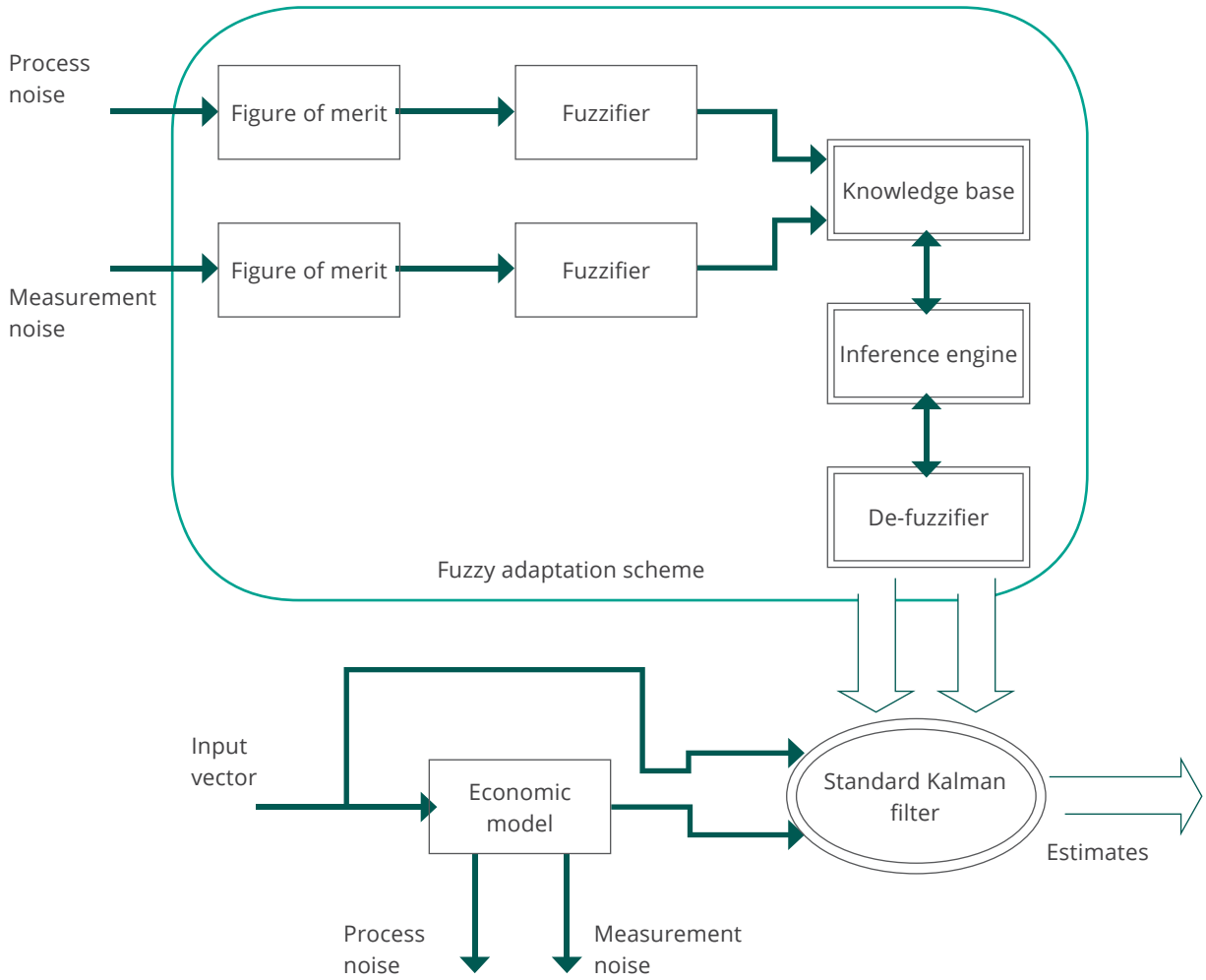


Figure 2: Subtopics being examined by the Energy Analysis Research Group.

In 2014, this research has been extended in collaboration with the University of Stuttgart and the CSIR to cover other energy resources.

System modelling and analysis involves advanced modelling techniques applicable to the analysis and long-term forecasting of energy needs.



→ *Figure 3: A fuzzy adaptive Kalman filter (KA-KF). (Adapted from Lalk, 1994a; Lalk, 1994b.)*

There are two main types of forecasting techniques: qualitative and quantitative methods. The qualitative technique is subjective and relies mainly on the "opinions" of expert individuals using the well-known Delphi method (Dalkey, 1969). The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method that relies on a panel of experts. Although this method is useful when little historical data exists, it is open to individual manipulation and individual bias. The quantitative method is more common and is especially useful where historical data exists.

In conjunction with a (statistical) forecasting model, this method identifies trends in the historical data and uses these to forecast a certain future (using the forecasting model embedded in the forecasting tool).

Although a number of forecasting tools are available, the trend is to use an advanced estimator such as a Kalman filter. The Kalman filter is a set of mathematical equations that provides an efficient computational way of estimating the state of a process in a way that minimises the mean squared error. In statistics, the mean squared error (MSE) of an estimator measures the average of the squares of the "errors"; that is, the difference between the estimator and what is estimated.

The Kalman filter was initially used widely in weapon systems, in particular anti-aircraft systems, where it is critical to predict a target's position in space at a certain future time to ensure a direct hit on the target aircraft or missile.

Some of the Group's current work focuses on a type of Kalman filter that is particularly well suited for so-called wicked problems, such as South Africa's national energy system. Artificial intelligence techniques, such as fuzzy logic, are used in this research. Previous experience and research has illustrated that such an estimation scheme not only allows for more accurate estimation results, but provides the ability to dynamically adapt to changing economic parameters by using fuzzy logic schemes as adaptation schemes for a standard Kalman filter.

The underlying work for such a scheme was performed by Lalk (1994a, 1994b). This work has shown that the application of fuzzy logic has a number of benefits. A typical scheme is illustrated in Figure 3. Of course, the actual estimation scheme is substantially more complex than shown in Figure 3. Although a standard Kalman filter is being used, the scheme's complexity lies in the setup of the fuzzy adaptation scheme, including the design of a workable figure of merit algorithm.

Many of these details will be covered by future publications as the research progresses.

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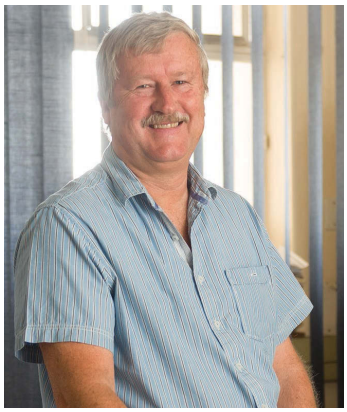

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World's top solar thermal specialists share their expertise

South Africa is making increasing advances in the field of solar thermal energy. During the past few years, more plans for concentrated solar power (CSP) plants have been seeing the light. One such project is the Karoshoek project near Upington in the Northern Cape. Solar thermal experts from across the world have recognised South Africa's potential to develop sustainable solar thermal energy plants because of the country's high solar radiation levels.

In response to this realisation, some of the world's top solar thermal experts offered a specialist workshop on solar heat for industrial applications at the University of Pretoria in February 2014. The workshop was presented by the Southern African Training and Demonstration Initiative (SOLTRAIN), a three-year project to enhance solar thermal technology in Southern Africa.

The aim of the project is to support Southern African Development Community (SADC) countries to develop sustainable renewable energy plants. The 36 delegates were limited to persons who had attended previous SOLTRAIN courses, or who have experience of large solar-heated water systems in Lesotho, Mozambique, Namibia, South Africa and Zimbabwe. This train-the-trainer workshop was sponsored by the Austrian Development Agency and was coordinated by the Sustainable Energy Society of Southern Africa (SESSA).

"South Africa and the SADC region urgently need this expertise," says Prof Dieter Holm, regional SOLTRAIN coordinator for Southern Africa, "and this is a cost-effective way of creating decent long-term jobs." The Austrian project leader of SOLTRAIN, Werner Weiss, concurs: "Southern Africa has twice Austria's sunshine."

The University of Pretoria is the SADC leader in the use of solar water heating in its student residences. The University is also building a thermal demonstration unit for practical experiments by students. The Hatfield Campus falls in SOLTRAIN's Solar Thermal Flagship District, where various installations can be visited by technical tourists and political decision-makers.

Southern Africa boasts 59% of the world's best winter sunshine areas, but does not rank among the global solar thermal power leaders. "Not yet," says Prof Holm, "but, given enabling legislation and leadership by example in government buildings, we could create a sustainable and competitive solar water heating industry in the region. A strong local solar water-heating industry will earn forex, decrease our chronic regional electricity problem, reduce pollution and contribute to achieving our environmental commitments."

Conduit hydropower: An alternative sustainable renewable energy source

Marco van Dijk

A project of the University of Pretoria to investigate the potential of conduit hydropower development recently received the Community Renewable Energy Innovations Award at the *Mail & Guardian* Greening the Future Awards. These awards embrace technological innovations and forward-thinking green technologies that help combat climate change, encourage renewable energy and foster the strategic management of natural resources.

A few years ago, after it became clear that South Africa is facing critical energy shortages, Prof Fanie van Vuuren and Marco van Dijk, both of the University's Department of Civil Engineering, started to consider ways of harnessing potential energy in water distribution systems. After a scoping study, the Water Research Commission (WRC), with Jay Bhagwan (Executive Manager: Water Use and Waste Management) as the project leader, commissioned the University to test the feasibility of this principle with a pilot project.

"Conduit hydropower" refers to a method of using the mechanical energy of water as part of the water delivery system through man-made conduits to generate electricity. Generally, the conduits are existing water pipelines, such as those in bulk water supply and distribution systems.

Although the conditions in South Africa do not completely lend themselves to large-scale hydroelectricity plants such as the one at Cahora Bassa, the energy and pressure of water in existing water distribution systems can be harvested to power small plants or perform specific smaller tasks, such as providing power for telemetry, security and flow measurements. Similar to energy saving, every bit of power that does not have to come from the grid will alleviate pressure on the infrastructure and resources needed to generate electricity.

The application of hydropower is divided into four categories, depending on the amount of electricity that can be generated:

- At pico-level, a maximum of 20 kWh is generated, which can be used to supply a few domestic dwellings.
- At micro-level, 20 to 100 kWh can be generated, which can be used to supply a small community with commercial or manufacturing enterprises.
- At mini-level, 100 to 1 000 kWh can be generated, which can supply 1 000 suburban households with reliable electricity.
- At small level, 1 to 10 MW can be generated. This generation is synchronised with the municipal or national grid frequency.

In 2010, a scoping investigation by Prof Van Vuuren indicated considerable potential for power generation at the inlets to storage reservoirs. South Africa has 284 municipalities and several water supply utilities and mines, and all of them own and operate gravity water supply distribution systems that could be considered for small-, mini-, micro- and pico-scale hydropower installations.

The principle according to which conduit hydropower "generation" works is that a turbine (or a pump functioning as a turbine) is installed at the inlet to the reservoir, and because the water is distributed at such a high pressure, the energy already inherent in it generates electricity as the turbine turns. Furthermore, the use of turbines supplements and reduces the requirements for pressure control valves.

Five potential locations for energy extraction in water distribution systems were identified:

- At dam releases into bulk supply lines
- At water treatments works (raw water), where the bulk pipeline from the water source can be tapped
- At inlets to service reservoirs where pressure-reducing stations (PRSs) are used to dissipate the excess energy – potable water
- In the distribution network itself where excess energy is dissipated
- In cases where the treated effluent has potential energy based on its elevation above the discharge point

Pilot projects

Three pilot plants were identified for the development to showcase the application: Pierre van Ryneveld in the City of Tshwane Metropolitan Municipality, Brandkop at Bloemwater, and Newlands 2 reservoir in the eThekwini Municipality. The City of Tshwane Metropolitan Municipality, eThekwini Municipality and Bloemwater were all collaborating organisations and supplied expertise and funding.

Pierre van Ryneveld

The Pierre van Ryneveld conduit hydropower pilot plant was installed on top of a reservoir in the Country Lane Estate, using a cross-flow turbine and synchronous generator. The generated power is used for lighting, alarm systems and communication. Three extensive field tests indicated that there was sufficient pressure and flow to generate power at the pico-level. The estate uses the power generated for the above purposes.

The results of this project indicated that a pico-hydropower plant may be viable for on-site utilisation. Experiencing the advantages of the project at a practical level, the homeowners' association of Country Lane Estate indicated that it would also like to utilise the power for street lighting. On 29 November 2011, the 15 kW Pierre van Ryneveld Conduit Hydropower Plant was launched, and all the site lighting was switched from the conventional municipal grid to the hydropower generated on site.

This project was done in collaboration with the City of Tshwane Metropolitan Municipality, which is committed to developing more renewable energy sources.

Excluding the man hours of the staff and students of the University of Pretoria and the staff of the Tshwane Metropolitan Municipality for the construction of the hydropower plant, the total cost of the plant was R546 000.

Bloemwater

The Bloemwater project, which is the flagship pilot plant of this research

→ *Marco van Dijk at the Bloemwater installation, the flagship project, where research was conducted at the Brandkop Reservoir.*

study, was constructed at the Brandkop Reservoir in Bloemfontein. This is also where Bloemwater's head office is located. A micro-hydropower plant was constructed at ground level this time. A 96 kW Banki cross-flow turbine, imported from Italy, was used.

The turbine has sufficient capacity to supply the entire Bloemwater head office with clean renewable energy, using its own water supply infrastructure. The estimated cost of building the Bloemwater plant is R3 075 000. When Bloemwater's spending on municipal electricity accounts is considered, the project has a payback period of approximately 72 months or six years. This is a relatively short period for a return on this kind of investment. Considering that the installed technology can last for more than 50 years, it is an attractive option.

eThekwini Municipality

The third pilot pico-level hydro-power plant – Pelton turbines – was installed at the Newlands 2 reservoir in Durban, in the eThekwini Municipality. In the case of this particular project, two 1 kW turbines were installed to show the technology, one being a stand-alone unit supplying the site with electricity, and the second feeding the hydro-generated power into the municipal grid. The estimated cost of the project amounted to R282 000, excluding the man hours of the eThekwini Municipality staff to design and construct the plant.

Conduit hydropower

The world is still – to a large extent – dependent on fossil fuels, mainly coal, to generate electricity. South Africa is no exception. In fact, approximately 90% of the country's electricity is generated in coal-fired power stations. Because of the relative abundance, availability and low mining cost of coal in the country, other forms of generating electricity have been largely unfeasible until now. Owing to this, together with the fact that the infrastructure for coal-based electricity generation already exists, it will remain an attractive energy source from a financial perspective.

However, nuclear power stations, hydroelectric schemes, pumped storage schemes, open-cycle gas turbines and wind farms are utilised to generate electricity in South Africa.

According to the latest numbers available to the United States Energy Information Administration, South Africa consumed a total of 218.3 billion kWh of electricity in 2011. A report published by Statistics South Africa in 2008 provided the latest breakdown of GWh produced by different electricity-generating technologies as recorded in 2006. It indicated that Eskom produced 95% of the country's electricity, while the remaining 5% was generated by a small group of private individuals for their own use. Eskom has eleven coal-fired power stations, six hydroelectric power stations, two pumped storage schemes, a nuclear power station, a wind farm and four open-cycle gas-fired turbines that are used only for peak supply.

The conduit hydropower plant at the City of Tshwane, which generates power to be used for lighting, alarm systems and communication.

These statistics would definitely have changed since that time. As was clearly shown by the rolling blackouts in 2008 and again more recently, electricity demand is exceeding the energy supplied by Eskom, and the need to increase supply has become imperative.

Cabinet has approved the Integrated Resource Plan 2010 (IRP 2010), according to which low-carbon options are preferred to align energy supply with the long-term mitigation scenarios to which government aspires. It is anticipated that by 2030, 30% of electricity will be generated from carbon dioxide-free sources. In the meantime, many private concerns and researchers have investigated alternative and renewable sources of energy – solar, biomass, wind and hydropower – and have submitted proposals for these.

There is potential for all forms of hydropower development in South Africa, and although the country has a number of hydroelectric installations, conduit hydropower definitely has a role to play in the overall energy generation and distribution picture of South Africa.

Conduit hydropower has no carbon footprint and can provide electricity relatively inexpensively and easily. A number of requirements that hold for larger and more complex sources of energy will not necessarily have to be met when setting up such a "plant". No water licensing is needed, as this can be seen as a continuation of an existing lawful use (National Water Act, Act 36 of 1998). Because existing infrastructure and resources are used, there is not always a need to conduct environmental impact assessments, and a basic assessment will suffice, as stipulated in the National Environmental Management Act, Act 107 of 1998. In certain cases, the use of the generated electricity is limited to lighting and electric fencing (as in the Pierre van Ryneveld project), which is classified as "own use". This category of use is exempt from licensing by the National Energy Regulator of South Africa (Nersa) in terms of the Energy Regulation Act, Act 4 of 2006.

In the case of the Pierre van Ryneveld project, however, a public participation process should be followed. This entails displaying a noticeboard that meets the requirements of Government Notice 543 of 18 June 2010 on the boundary fence of Country Lane Estate, and holding public hearings if complaints are received.

The way forward

Several water utilities, municipalities and even Eskom are considering conduit hydropower development.

After the pilot project, the City of Tshwane Metropolitan Municipality expressed an interest in further studies to investigate the application of this technology. Consequently, the municipality appointed the University of Pretoria to investigate development possibilities at the top five sites in Pretoria: Garsfontein, Fort Klapperkop, Heights in Valhalla,

Jay Bhagwan, Executive Manager: Water Use and Waste Management of the Water Research Commission (left), joins Marco van Dijk (centre) and Prof Fanie van Vuuren of the Department of Civil Engineering in receiving the Community Renewable Energy Innovations Award at the Mail & Guardian *Greening the Future Awards.*

Waverley and Akasia/Soshanguve. The principle on which this would function is that electricity generated in the municipality's water distribution systems would be channelled to its grid.

Another application that is being investigated in the City of Tshwane is supplying a reservoir with only the small amount of power that is generated at that reservoir. This can be particularly useful, as everything – such as sensors that indicate water levels – is stripped from reservoirs by criminals. This results in the municipality having to send out three workers at a time (it is unsafe for even two people to go) twice a day to monitor the reservoir. If a turbine can be situated inside the reservoir, together with the necessary recording and sensory devices, the problem of theft would be eliminated and the municipality will have the ability to monitor the conditions at its reservoirs at all times.

eThekwini Municipality also followed up on its project, and several other organisations are conducting studies. Rand Water Services (Pty) Ltd is busy with a project that could potentially generate 15 MW of hydropower electricity.

Furthermore, the University was appointed by the WRC and the Department of Science and Technology (DST) to evaluate the potential of small-scale hydropower development for rural electrification and to create a mini-grid for a few houses. The most important uses for this electricity will be lights, charging cellphones and listening to the radio or watching television in the evening, and perhaps supplying power to a community centre in the day.

An article in the *Journal of the South African Institution of Civil Engineering* and two chapters in an international book have been published on this research, and several postgraduate students have done research on hydropower projects for their dissertations and theses. A postgraduate student, Ione Loots, developed a world-first conduit hydropower development decision support system as part of her studies and has joined the University as a lecturer, further strengthening the Water Division's expertise.

The award by the *Mail & Guardian* created awareness around this project and may stimulate more funding for it. It also provides credibility to this research – it is research with real-life applications that can increase electricity supply in a world in which energy is a scarce commodity.

The next research project will investigate the viability of generating electricity at the point where treated effluent is released at sewerage works. Other possibilities are the reserve environmental flows released by dams and irrigation systems on farms. The comprehensive findings of this research project are published in reports by the WRC.

Prof Fanie van Vuuren *and* ***Marco van Dijk*** *are associated with the Department of Civil Engineering in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria.*

Fault-tolerant high-power LED lighting systems capable of driving multiple independent loads

Prof Njoroge Gitau

In most developed countries, and in South Africa, lighting loads have consumed up to 20% of all generated electricity. Until recently, most lighting luminaires were incandescent or fluorescent lamps that employ magnetic ballasts. In the last decade or so, these luminaires have been replaced with compact fluorescent lamps that employ electronic ballasts. This has led to a reduction in luminaire power consumption per output lumen (unit for measuring the total "amount" of visible light emitted by a source) by as much as 80%.

A luminaire is a complete lighting unit, consisting of one or more lamps (bulbs or tubes that emit light), along with the socket and other parts that hold the lamp in place and protect it, wiring that connects the lamp to a power source, and a reflector that helps direct and distribute the light.

With the development of high-power light-emitting diodes (LEDs) with good lighting characteristics, LED-based lighting systems have recently been introduced to the market. This has seen further reductions in luminaire power consumption per output lumen. The introduction of LED-based lighting systems has therefore made it much more economically viable to supply lighting loads from renewable energy sources.

In addition to low power consumption per output lumen, it also implies much lower energy storage requirements when compared to incandescent or compact fluorescent lighting systems. Energy storage costs form one of the largest – if not the largest – cost components of stand-alone renewable energy power supply systems. Taking into account the fact that storage batteries have to be replaced approximately every four years, the need to reduce storage requirements becomes even more important.

As the prices of high-power LEDs continue to fall, it becomes more economical to provide lighting systems fed from renewable energy sources, even in poor communities in most parts of the world. At the moment, commercially available LED lighting systems are based on a dedicated driver per lighting point. Some applications, however, require several lighting points to be supplied from a single source or driver. Furthermore, in some applications, there is a need to switch individual lighting points on or off or to dim some of the lights while leaving others at full brightness. In automotive applications, for example, it might be necessary to switch on just the parking lights, use only indicator lights or have all of the lights on at the same time. To achieve such functionality for LED lighting systems, it is necessary to develop LED drivers capable of supplying multiple independent loads.

LED-based lighting luminaires are normally constructed by connecting several LEDs in series to form a string. Several strings are then connected in parallel to form an array. LEDs are current-driven devices. The level of brightness is proportional to the magnitude of the current flowing through them.

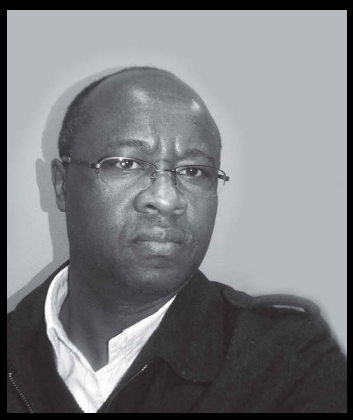
Consequently, when supplying an LED array, it is very important to ensure that each string is fed at the correct current level, even in the event that a parallel-connected string is lost. This requires the driver of the array to sense faults (or loss of a string) and adjust output current accordingly to maintain currents in the remaining strings at the desired levels.

The introduction of LED-based lighting systems has improved the economic viability of supplying lighting loads from renewable energy sources.

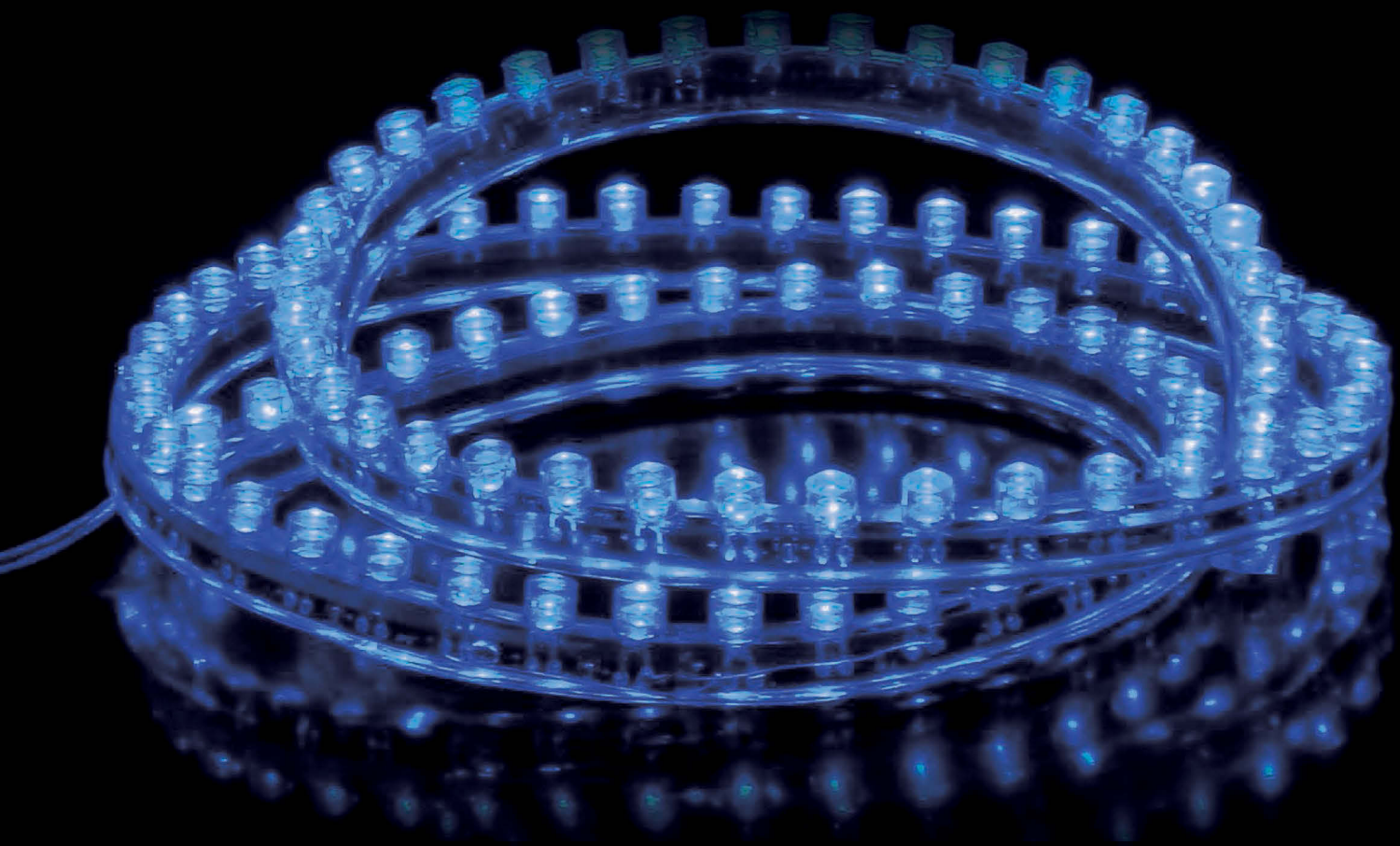
When supplying several loads that have to be switched on or off independently, it is important to ensure that the various lighting points are always supplied with the correct current levels as the number of lighting points changes. Illumination levels and LED life spans will be affected if currents through the LEDs are allowed to vary with changes in the number of parallel strings in an array or the number of lighting points fed from a driver. This suggests that there is a need to develop drivers capable of regulating LED currents to remain within desired levels.

Moreover, a driver should continue supplying remaining parallel strings or lighting points at the desired current levels, even in the event of losing a string in an array or a lighting point due to a fault.

During the last few years, the Power Research Group in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria has developed LED drivers that are suitable for supplying multiple independent loads that are also fault-tolerant. The developed drivers allow the use of a single driver to feed several independent loads that could be found in large halls, automotive applications, or even multiple lighting points in a building with multiple rooms. Such a driver should help to bring down the costs of implementing lighting solutions that use LEDs, as well as improve the reliability of LED drivers and maintain the long life spans of LEDs.



Prof Njoroge Gitau *is associated with the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria. He is the Group Head of Power Electronics.*



Power processors for interfacing renewable energy resources to a DC-bus

Prof Njoroge Gitau

Nowadays, most governments around the world accept that alternative and, especially, renewable energy sources have to be part of the energy mix. The realisation that the world cannot rely on fossil fuel sources forever has added to the urgency to find other viable energy sources.

The key obstacle to exploiting most renewable energy sources is that their raw output is not well suited to direct connection to the existing transmission and distribution grids. The output is also not suitable for feeding practical loads. The output voltage levels of these sources are too low to feed conventional loads. Furthermore, output voltage levels vary widely as irradiation levels, ambient temperature, wind or wave speeds vary. Renewable energy sources include solar, wind, tidal, hydro-, geothermal and biomass energy. Solar, wind and tidal resources are intermittent and statistical. Therefore, it is necessary to incorporate power processors to condition the outputs of systems that are used to convert these resources into electrical energy before supplying most practical loads.

Energy from the sun can be harnessed in a variety of ways. Photovoltaic (PV) panels have been used to convert solar energy into electrical energy for a few decades now. The output voltages of commercially available PV panels are in the range of 6 V to 70 V. However, most commercially available solar PV arrays are built using 12 V or 24 V panels. PV panels' voltage-current characteristics are such that ambient and panel temperature influences the output voltage, whereas irradiation levels affect panels' output current.

Solar PV farms consist of groups of PV panel arrays. An array is constructed by connecting a number of PV panels in series to form a string, and several strings are connected in parallel to form an array. The number of panels connected in series to form a string and the voltage rating of an individual panel determines the array's rated terminal voltage.

An array's rated output current is the total sum of currents from all the strings connected in parallel. Most practical single-phase loads fed from inverters require DC-buses that operate between 300 V and 450 V. Three-phase loads, however, require the inverters to be fed at between 700 VDC and 800 VDC. An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).

In order to meet DC-bus rated voltage, there is a need to have many PV panels connected in series to form a string. For example, at least thirteen 24 V panels would be required to realise a string with a terminal voltage of 300 V. The number of panels required more than doubles if 12 V panels are used or DC-bus voltage is increased to 700 V.

Given the physical size of a PV panel, a large area will be needed to erect a string of an array. Consequently, there is a very high likelihood that not all panels in a given string will be exposed to identical environmental conditions at all times. This is even more so when PV arrays are erected in highly built-up areas. In such environments, there is a possibility that the shadows of trees or buildings can affect only some at a given time. Even in instances where PV arrays are erected in open spaces, there are still chances of clouds, dust or a combination of the two only affecting some of the panels in a given string of an array. Furthermore, it is likely that the characteristics of the panels in a given string will not be perfectly matched due to the high number of panels involved.

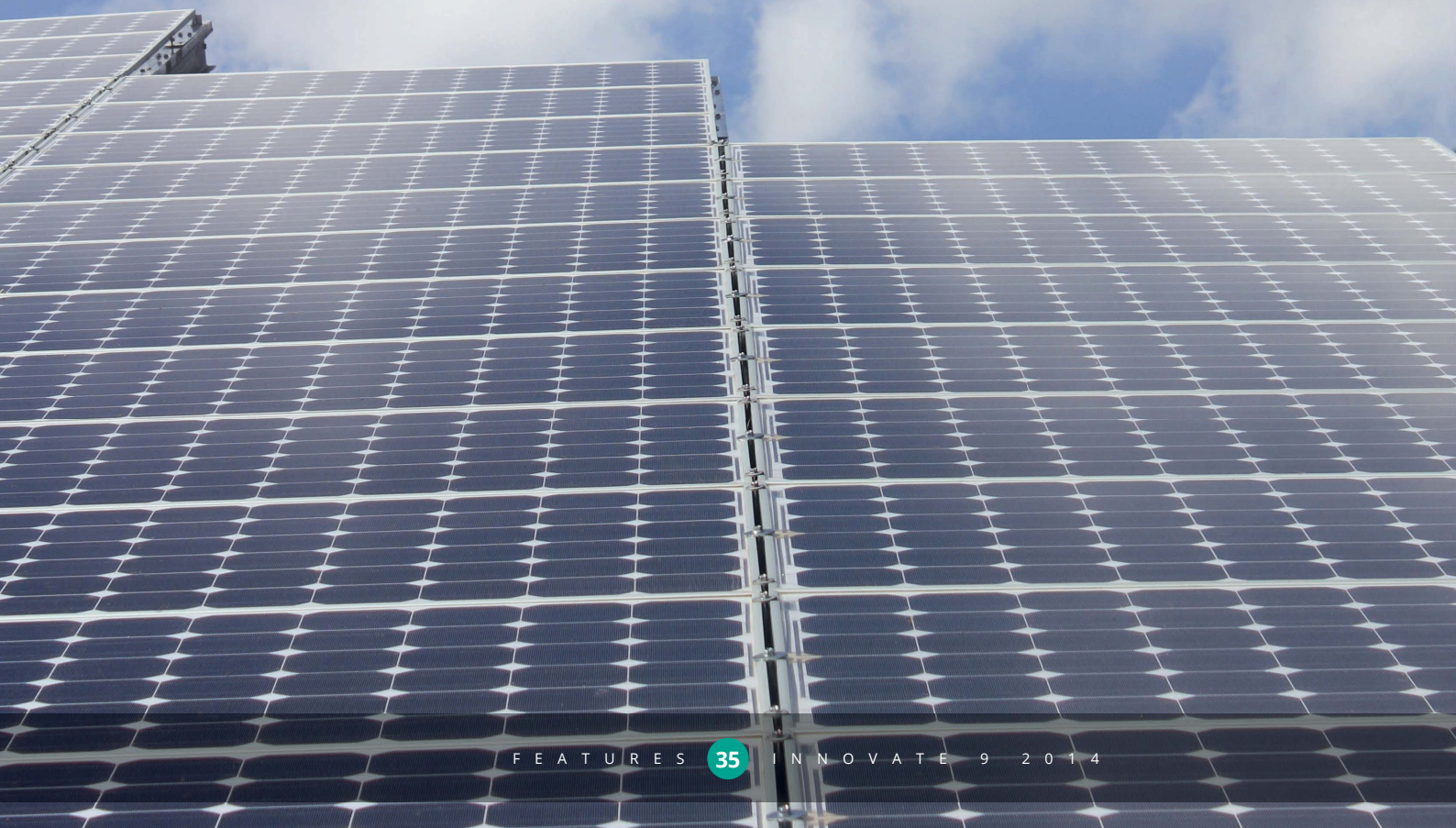
When panels in a given string are exposed to different levels of solar irradiation because of

shading or dust on some of them, their output currents will differ. This creates a problem due to the series connection of the panels. The result is that the string current will be equal to that of the panel with the lowest current. Inevitably, string power output is reduced. Because panel surface temperature affects the terminal voltage generated, the terminal voltages of parallel-connected strings that have their panels subjected to differing temperatures will differ, giving rise to voltage differences between parallel-connected strings. A shorted panel would also lead to differences in strings' terminal voltages.

Unless appropriate measures are taken at the design stage, the voltage differentials will cause one string to circulate current through another. This inevitably leads to additional power losses in the array and a reduction in the available output power. Moreover, an open-circuit fault in any one of the panels in a given string will cause that string to be lost. At the moment, most installations employ diodes to bypass any panel that has an open-circuit fault or is shaded. This avoids a situation where an entire string is lost due to open-circuit faults or a panel in the shade. Diodes are also connected in series with each string to prevent one string circulating current through another when their terminal voltages differ. The downside to this approach is increased cost, complexity and losses, as well as degraded overall system performance.

An alternative approach to overcome the shortcomings of PV arrays using long strings with many series-connected panels is to use shorter strings and increase the number of parallel connections to meet load power requirements. This method of array implementation makes it easier to group panels in a given string in much closer physical proximity, which reduces the chances of the panels in a string being exposed to differing environmental conditions. Consequently, such a configuration helps to keep an array's power output as high as possible, even when the panels are subjected to different environmental conditions.

The downside to this approach is that it is necessary to incorporate an electronic power processor to boost the array's terminal voltage to match that of the DC-bus feeding loads (assuming the DC-bus voltage is constant, irrespective of whether a long or short string is employed). The voltage-current characteristics of PV panels are such that, for a given set of environmental conditions, the amount of power that can be extracted depends largely on the



panel's terminal voltage. Moreover, for a given set of environmental conditions, there is a terminal voltage that leads to maximum power extraction from a panel.

As a result, it is routine to employ electronic power processors to ensure that maximum output power is tracked at all times. This is achieved by operating the power processor in such a manner that the panel's terminal voltage corresponds to the voltage that guarantees that maximum power is extracted from the panel. In most practical implementations, however, it is uneconomical to track the output power of each individual PV panel. Instead, it is assumed that all the panels have identical characteristics and that the environmental conditions to which all panels are subjected are identical.

This approach has the drawback that localised maximum power points of individual panels are not necessarily tracked and, as a result, the maximum output power may not necessarily be extracted. With fewer series-connected panels in a string, more accurate tracking of maximum power becomes possible, which leads to higher output power. The power processor needed for maximum power point tracking (MPPT) can also be utilised to boost the array's terminal voltage to match that of the available DC-bus if an appropriate converter topology and control strategy are selected or identified.

At the moment, implementations of PV arrays and the converter topologies employed to build power processors for implementing MPPT are not capable of very high-voltage boost ratios, and when they are, they have a number of shortcomings. Some of these shortcomings include complex magnetic component design, low efficiency, complex control schemes and high input- and/or output-side current ripple operation.

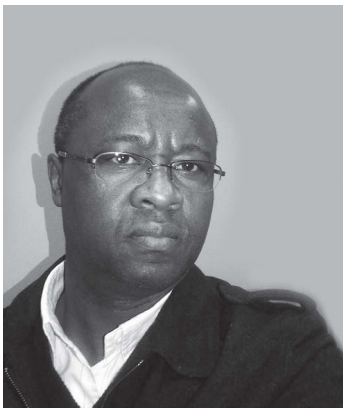
The latter requires the use of filter circuits comprising capacitors and inductors. Moreover, PV panels and, generally, most of the renewable energy sources are not suited to operating with fast current dynamics, for example, those encountered when supplying pulsed loads or when feeding power electronics converters that draw pulsed currents or currents with high ripple content. The voltage-current characteristics of PV panels are such that supplying fast-changing current will cause the terminal voltage to deviate from the nominal value, and in turn will lead to output power variations.

Operating under such conditions makes it difficult for the panel to deliver maximum possible output power. To ensure MPPT, even when supplying loads with fast-changing currents, it is necessary to use electrolytic capacitors as sources of the fast dynamic currents. Electrolytic capacitors are known to have a few shortcomings. Some of these include high cost, bulky size and short lifetimes when operated in high ambient temperature environments. A need therefore exists to develop efficient, compact and affordable high-voltage boost ratio power processors that do not draw currents with high harmonic content.

During the last few of years, the Power Research Group in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria has developed power processors that are suitable for interfacing renewable energy sources with the DC-buses used to feed loads. These power processors are capable of operating with high-voltage boost ratios, high efficiency, and low input- and output-side current ripple. The research has led to the development of power processors with voltage boost ratios of more than 20 times, while maintaining full-load efficiency above 77%. This performance is much better when compared with the high boost ratio power processors that are currently available.

Most transformerless topologies are not capable of boost ratios of more than ten times, and efficiency is rarely above 80%. On the other hand, those with transformers draw pulsed currents with a high ripple content. The power processors that were developed had an efficiency rate higher than 85% for boost ratios of 17 times. This means that the power processors can be used to interface a single 24 V PV panel with a 400 V DC-bus or a 48 V panel with an 800 V DC-bus. Compare this with the need to connect at least seventeen 12 V panels in series to realise a 400 V output. Low input- and output-side current ripple operation makes it possible to build power processors with only small capacitors, which makes them cheaper, more compact and lighter, while improving performance.

Some of the team's research findings have been published in the *Journal of Power Electronics,* as well as in the *Proceedings of the IEEE IECON 2014 Conference*.



Prof Njoroge Gitau *is associated with the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria. He is the Group Head of Power Electronics.*

Synthesis of silicon carbide nanoparticles in a microwave

Jean van Laar

In recent years, there has been a flood of scientific papers on the synthesis, processing and applications of the new – yet old – material called silicon carbide (SiC). This specific combination of silicon and carbon has been known since 1824, when it was first synthesised by Jöns Jacob Berzelius. Since then, the popularity of SiC has periodically varied. As modern technology developed, however, so did interest in SiC. The reason for this is the gradual discovery of its physical properties that are ideal for high-power, high-frequency and high-temperature applications.

Recently, the focus has shifted towards the nanoscale of this incredible substance. SiC nanoparticles exhibit properties different from the bulk material, encouraging the creation of new materials. Many different synthesis methods for the creation of SiC nanoparticles have been studied, for example, carbothermic reduction, pulsed-laser deposition and sol-gel processes. Each of these methods presents certain advantages. Microwave-induced plasma synthesis has now stirred the interest of a few researchers at the University of Pretoria.

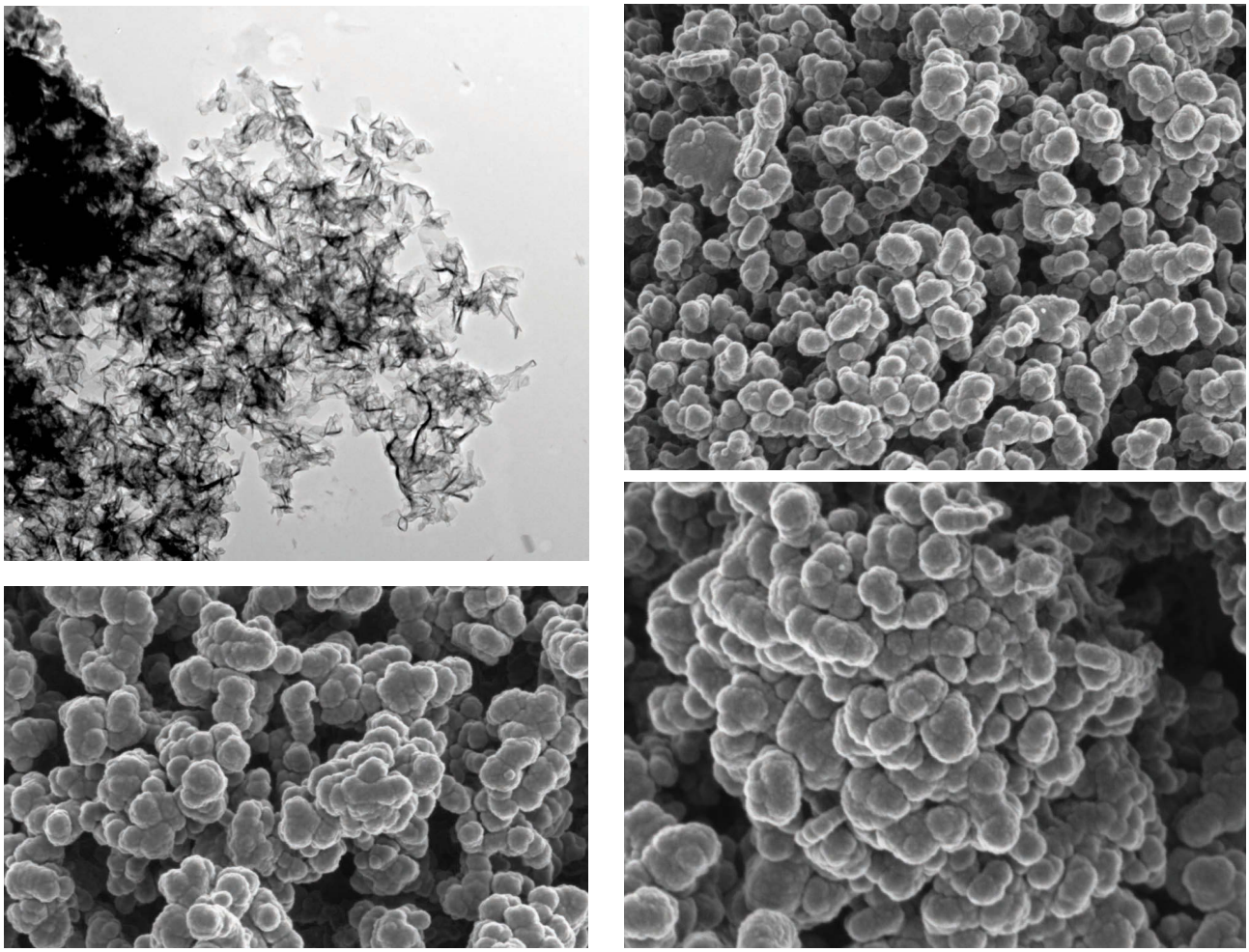
Plasma, often called the fourth state of matter, is by far the most common form of matter in the universe (if dark matter is excluded). Plasma is defined as an ionised gas that displays collective behaviour. The term "ionised" implies that some of the electrons are not bound to an atom or a molecule, but move freely among such atoms or molecules. These electrons couple with the applied oscillating electric field, called the microwave field, and undergo impacts or interactions converting atoms or molecules into positively charged molecular and atomic ions and/or fragments. There are other techniques, such as radio frequency induction and direct current arcs, to induce plasma. Each technique uses different physical mechanisms and provides different operating conditions.

In a joint project with the Nuclear Energy Corporation of South Africa (Necsa), the departments of Chemical Engineering, and Mechanical and Aeronautical Engineering at the University of Pretoria have successfully synthesised SiC nanoparticles in a microwave plasma. With the use of methyl trichlorosilane as an organic precursor and argon as the carrier and ionising gas, it was possible to create ideal conditions for the conversion of the precursor to SiC nanoparticles. A typical product is shown in the image of the scanning electron microscope on the opposite page. In situ agglomeration of the particles has been a problematic hurdle to overcome, along with the challenge of mechanically separating the particles at nanoscale.

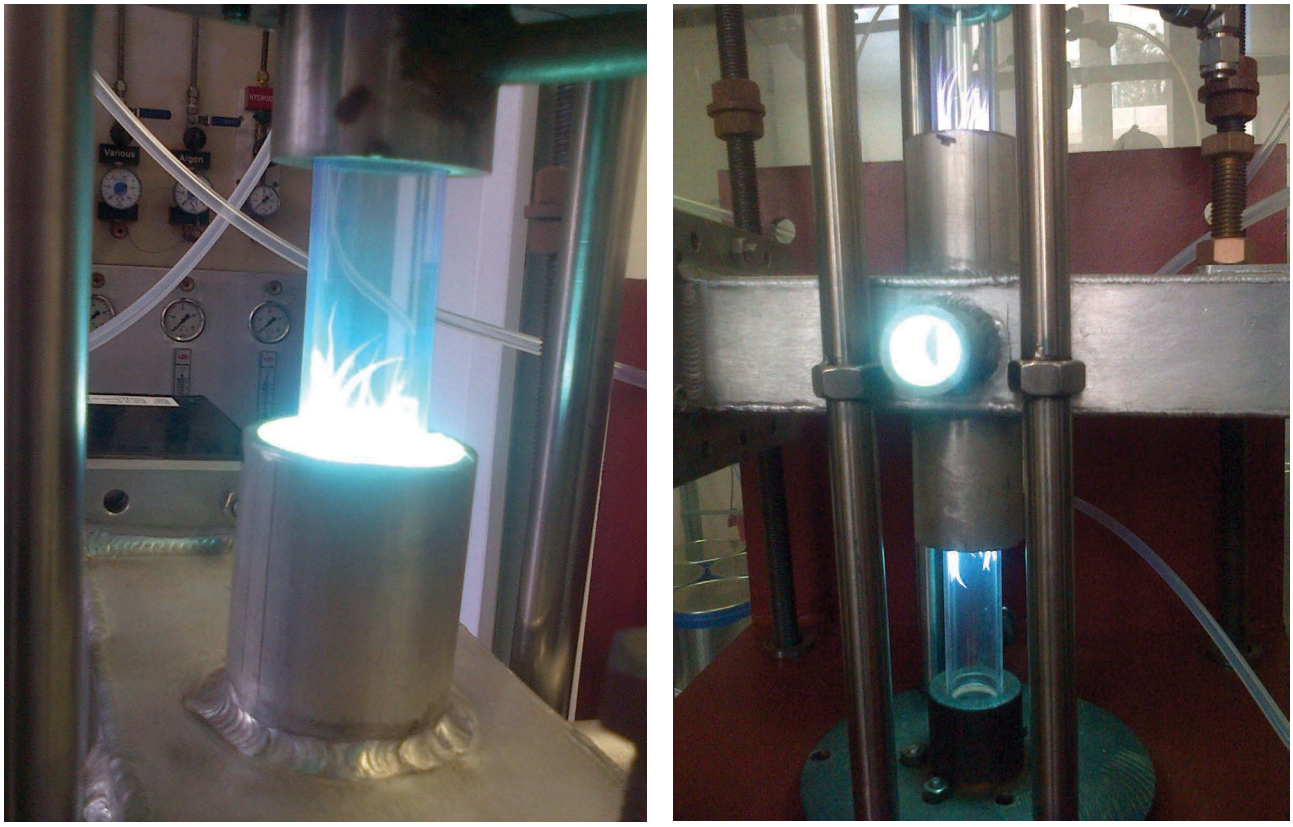
SiC research will continue over the next few years in cooperation with Necsa, and it will focus on the immobilisation of radioactive waste. SiC is already used in tristructural-isotropic (TRISO) fuel particles used in high-temperature reactors (HTRs) via thermal chemical vapour deposition. Furthermore, SiC shows promise as a replacement for the zirconium alloy tubes in the fuel elements of the current generation of water-cooled reactors. The use of plasma technology presents many advantages, but has its challenges. For example, the technology can be adjusted to yield either gas phase particulates or strongly adhesive coatings.

Scientists and engineers are excited to see what the future holds for this interesting and fast-paced field.

***Jean van Laar** is currently completing his MEng degree in Mechanical Engineering at the University of Pretoria and has been appointed doctoral scientist at the Nuclear Energy Corporation of South Africa (Necsa).*



→ *A typical product is shown in the image of the scanning electron microscope above.*



→ *Microwave-induced plasma and instruments.*

From scrap tyres to clean renewable energy

Dr Heinrich Badenhorst

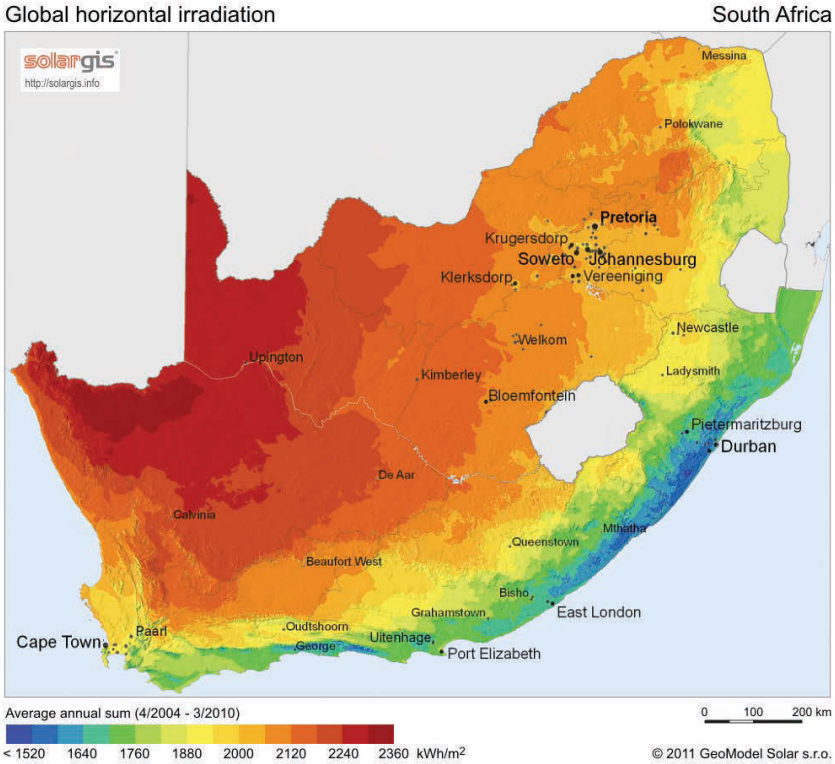
The University of Pretoria recently initiated a process designed to identify the unique research strengths of the institution and to support the development of strong multidisciplinary research groups clustered around the identified strengths. The University's Institutional Research Theme (IRT) on Energy focuses on all aspects of energy. One of these is the use of clean, renewable energy technologies, specifically solar energy.

Students of the South African Research Chair Initiative (SARChI) Chair in Carbon Materials and Technology in the Institute of Applied Materials are developing novel materials and creative new uses for old materials in this field. Carbon black reclaimed from recycled scrap tyres is being employed in a variety of solar collectors, while graphite nanoparticles are being drawn on as additives in solar energy storage devices.

The world is a very strange place when it comes to using energy. Each year, carbon, in the form of coal, is burnt at an efficiency of less than 30% in power stations around the globe. This carbon took millions of years to form. Apart from producing electricity in an inefficient manner, coal-fired power stations pump huge amounts of carbon dioxide into the atmosphere, potentially affecting the global climate negatively. When carbon is mentioned in an energy context, it usually has a negative connotation. At the SARChI Chair in Carbon Materials and Technology, a lot of hard work is going into changing this perception of carbon and carbon materials.

South Africa has some of the highest solar energy fluxes on the planet. To put it in perspective, the sun radiates enough solar energy onto the earth in one hour to provide all the energy consumed by humanity in a year. It is clear that this natural resource is underutilised.

In order to make use of this resource, it first has to be captured. This can be done by burning scrap tyres. Through a technique known



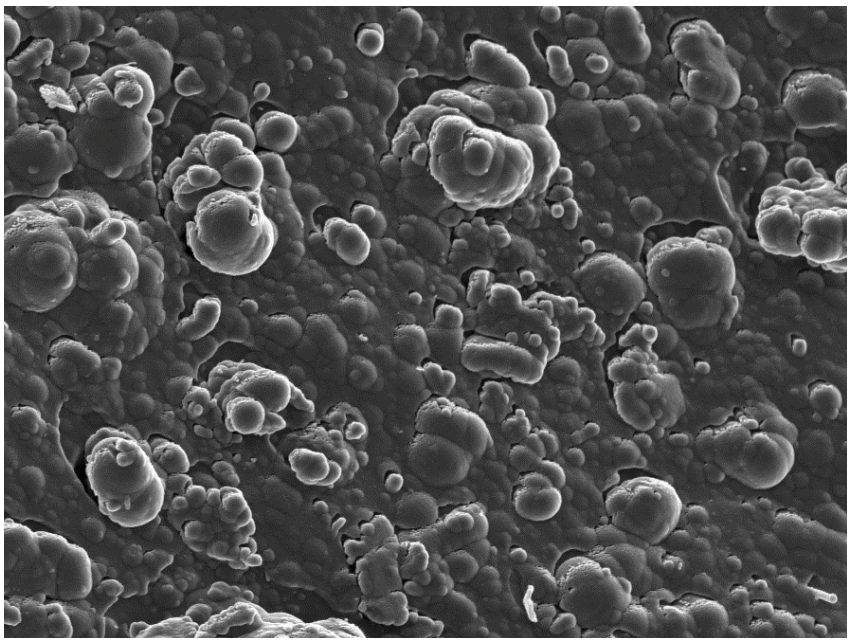
→ *Solar irradiation map of South Africa.*

There are approximately 60 million scrap tyres in South Africa.

as pyrolysis, the tyres are "burned" in the absence of oxygen. This produces a gas that can be used to heat the ovens in which the pyrolysis takes place, which means the process does not consume energy. A liquid that can be used as a fuel oil in industrial burners or that can be further refined into other petrochemicals is also released. In addition to these products, the process creates a solid residue very similar in appearance to the charcoal used by millions of South Africans over weekends. The residue is called carbon black and has a unique property; it is an excellent absorber of electromagnetic radiation, such as sunlight. This material is so effective that the American military uses it to coat stealth planes. Carbon black absorbs any incoming radio waves, making it virtually undetectable to radar.

To recycle the millions of scrap tyres in the country, the South African government recently implemented the Integrated Industry Waste Tyre Management Plan. This means that a large amount of low-quality carbon black will soon be produced. If this material can be utilised to capture solar energy, it will not only generate clean, renewable energy, but will solve a major waste problem at the same time.

Carbon black can collect solar energy in a variety of ways. The first is in pressed sheets that are similar to the solar panels on roofs. Carbon black is mixed with exfoliated graphite and pressed



Carbon black film.

The new parabolic trough design.

onto a suitable substrate. In a preliminary investigation, this mixture was pressed onto a small copper disc. The disc was connected to an insulated water reservoir through tubing, which created a small solar geyser. The system was left in the sun to collect energy, and the temperature of the water was monitored. At its peak shortly after midday, the water temperature had risen to 45 °C. This meant that around 4 kW.hr.m^{-2} of solar energy had been collected. This was an excellent result, since the average expected irradiation is around 6 kW.hr m^{-2}, which implies an efficiency of around 75%. The use of carbon black is currently being tested in many other applications.

The first promising application that is being tested is a central collection tube in a new version of the so-called parabolic trough collectors. Traditional trough concentrators use a single mirror shaped in a parabola to concentrate sunlight onto a central receiver. There are two significant drawbacks to this approach. Large mirrors tend to break or crack, and the manufacture of these mirrors is limited worldwide. Thus, it is not possible to procure these mirrors in South Africa. They have to be imported at great cost and a risk of breakage.

Pieter de Bruin, a local engineer from the Western Cape, has come up with an innovative solution to the problem of finding suitable parabolic mirrors in South Africa. He has developed a segmented mirror design in which the large single mirror has been broken down into roughly 100 smaller mirrors. If any single mirror breaks, it can easily be replaced at a low cost. Furthermore, the parabolic steel framework is cheap and easy to manufacture. Therefore, it is possible to manufacture the framework locally from readily available materials with little or no input from international suppliers.

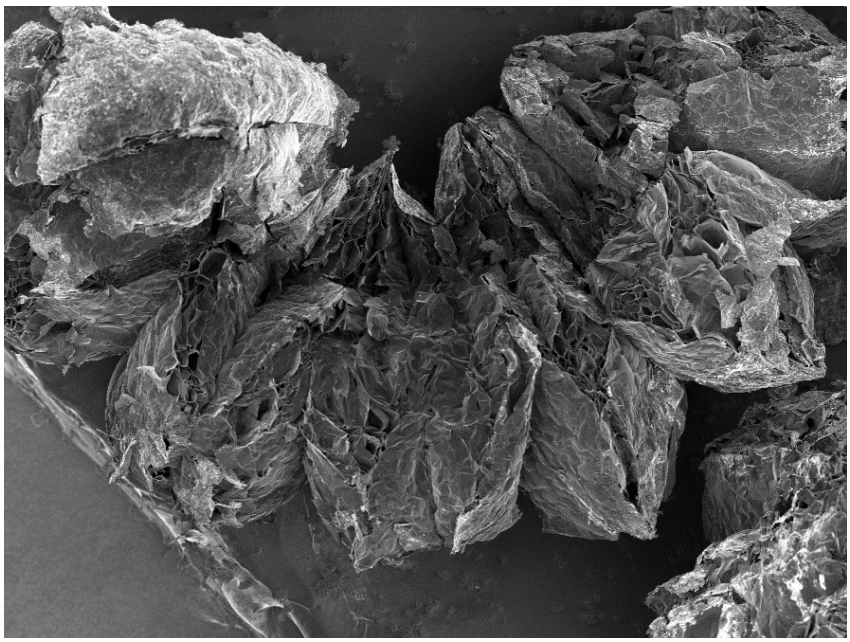
Another innovation is the stationary collector tube. In traditional assemblies, expensive flexible couplings are required to link the ends of the tube to the fixed piping system. Furthermore, the segmented design allows better airflow. Consequently, the construction is far less susceptible to wind damage. Once operational, carbon black will be used to optimise the central receiver that harvests the solar energy and maximises, for example, steam production, which can be used to generate electricity.

The second application that is being tested is very unusual and involves solar distillation. Work is underway to treat the carbon black in a way that modifies the surface, making it easy to disperse in water. The carbon black still absorbs the sunlight and heats up the water. Two prototypes are being tested. The first uses a thin film technique to evaporate the water under non-equilibrium conditions. This approach is very simple and may result in an inexpensive system that operates with little supervision and low maintenance.

The second trial combines the carbon black dispersed in water with a low-cost solar concentrator (a Fresnel lens). This compound lens can be used to focus the sunlight onto a very small focal point. In fact, the process is so effective that it can almost immediately induce microscopic boiling. Both techniques can be used to desalinate seawater or to purify brackish water. Once these concepts have been proven on a laboratory scale, they will be taken to the pilot level.

A significant drawback is that there is no sunshine during the night or when it rains. The key to the effectiveness of solar systems on an industrial scale is the efficient storage of the collected energy. There are several solutions to this problem, but one is becoming increasingly widespread: phase change materials. These are materials that undergo a phase change and store the energy in that way, for example, ice that melts to form water. Commonly used materials in the solar field are salts that either melt at low (-50 °C) or high (300 °C) temperatures, depending on the application. Regrettably, these salts generally have a very low thermal conductivity, meaning that it is difficult to transfer the energy into them, and they take a very long time to melt. However, there is another form of carbon – graphite – that has excellent thermal conductivity. It is a natural mineral that can be mined in the form of small flakes. To make the most of the available graphite, it has to be converted into graphite nanoparticles.

The first step in this process is to intercalate the graphite. This process uses a variety of techniques to insert foreign atoms in between the layers of graphite. Upon heating, these atoms are liberated and explode into the gas phase, making the graphite pop into an exfoliated form that looks very similar to a stretched accordion. This is known as the exfoliated graphite mentioned earlier.



→ *Exfoliated graphite.*

It is extremely light and quite flexible, so it can be used together with carbon black to make sheets, or it can be broken into nanoparticles through sonication. This method uses ultrasonic vibrations to create microbubbles that tear the graphite layers apart. The research group associated with the Chair is currently investigating a variety of techniques to find the most efficient and effective way of producing these graphite nanoparticles or nanoplatelets.

These nanoplatelets can be added directly to the salts to enhance their thermal conductivity. Preliminary testing has shown that the time needed to melt low-temperature salts can be reduced by up to 80%. An experimental rig that allows the testing of this additive together with salts at much higher temperatures has been built. A combination of sodium nitrate and potassium nitrate is being used to test the thermal stability of the composite at temperatures around 300 °C.

Ultimately, the aim is to incorporate the carbon black directly into the salt/nanoplatelet composites. This will enable the direct melting of the salt, drastically reducing the losses and costs associated with conventional systems, where the heat must be transferred from collection to storage. Scientists hope to extend this work to include so-called seasonal energy storage. In this case, the harvested solar energy is stored in the form of a chemical reaction. When the energy is needed, the reaction is reversed and the energy is released for use. This process works much like a battery. In this way, all aspects of solar energy harvesting, storage and use are being explored, while using local resources and expertise to solve the issues that prevent a truly renewable energy-based society.

Dr Heinrich Badenhorst *is a senior lecturer in the Department of Chemical Engineering at the University of Pretoria. His team is working on developing new materials from local resources and designing innovative solutions to the barriers of using solar energy for industrial applications and electricity generation.*

Investigating more efficient solar power

Prof Ken Craig

Renewable energy sources, unlike biomass energy, have not yet been fully exploited in South Africa. Domestic solar panels and geysers are becoming more widespread, but these provide only local power and are therefore not suitable for large-scale power generation. As a result, there is a need for renewable power plants that are capable of large-scale power generation.

Prof Ken Craig and his research team in the Department of Mechanical and Aeronautical Engineering at the University of Pretoria focused their research on the sun and the energy it can provide. The research team decided to focus on concentrated solar power (CSP).

The concept of concentrating the sun's rays is not new. The ancient Greek mathematician and physician, Archimedes, devised a weapon that used the sun's rays. During the siege of Syracuse a few centuries BCE, he aimed a group of mirrors at enemy ships and destroyed them with fire. CSP uses this same principle to focus the sun's rays to heat a transfer fluid that stores and transports thermal energy.

Parabolic troughs are the oldest and most established CSP technologies in the world. These troughs (often more than a kilometre long) focus the sun's rays onto a line at the focal point of the parabola-shaped reflector. Although the heat transfer fluid is usually synthetic oil, new research is investigating other liquids that are more environmentally friendly. Another linear-focus CSP concept uses the idea of a Fresnel lens, which is based on the work of the French engineer Augustin-Jean Fresnel in the 1800s. This CSP technology is called linear Fresnel reflection, and Prof Craig's research team is particularly interested in these reflectors. A series of long, flat mirrors are each aimed at a downwards-facing receiver located above them, each tracking the sun throughout the day to remain focused on the receiver.

As shown in Figure 1, the mirrors are located on a horizontal plane and reflect the solar rays onto the cavity receiver. This receiver has a glass cover like a glass greenhouse to trap the heat from the sun. It lets the sun's energy through, but blocks some of the energy that is radiated from the hot pipes. The research is aimed at improving the efficiency with which heat from the sun's rays is transferred to the liquid inside the pipes.

The researchers are using computer simulations called computational fluid dynamics (CFD) to accomplish this. These computer programs solve the equations that describe how fluids flow and how heat is transferred through radiation, conduction and convection. Coupled with optimisation software, these simulations allow the researchers to seek the best geometry for the cavity and mirror array, as well as investigating different coatings on the cavity surfaces that will soak up as much of the sun's heat as possible without losing too much of it to the surrounding air.

Another CSP technology that is used for large-scale power production is that of a solar power tower. The largest solar power tower in the world is located in the Ivanpah Dry Lake, California. The plant can produce close to 400 MW of electricity a year. For this technology, a central receiver is located on a tower in the middle of a field of mirrors. These mirrors are called heliostats. Each heliostat tracks the sun, much like Archimedes' sun weapon. This means that the sun's heat is focused on one spot, rather than on a linear focal point as in the parabolic troughs and linear Fresnel reflectors. In this way, much higher temperatures (easily more than 1 000 ˚C) are reached.

Designing a receiver that can withstand high temperatures and conduct the heat to a steam plant where electricity is generated without radiating too much of it back to the surrounding air is extremely challenging. The research team is collaborating with researchers in

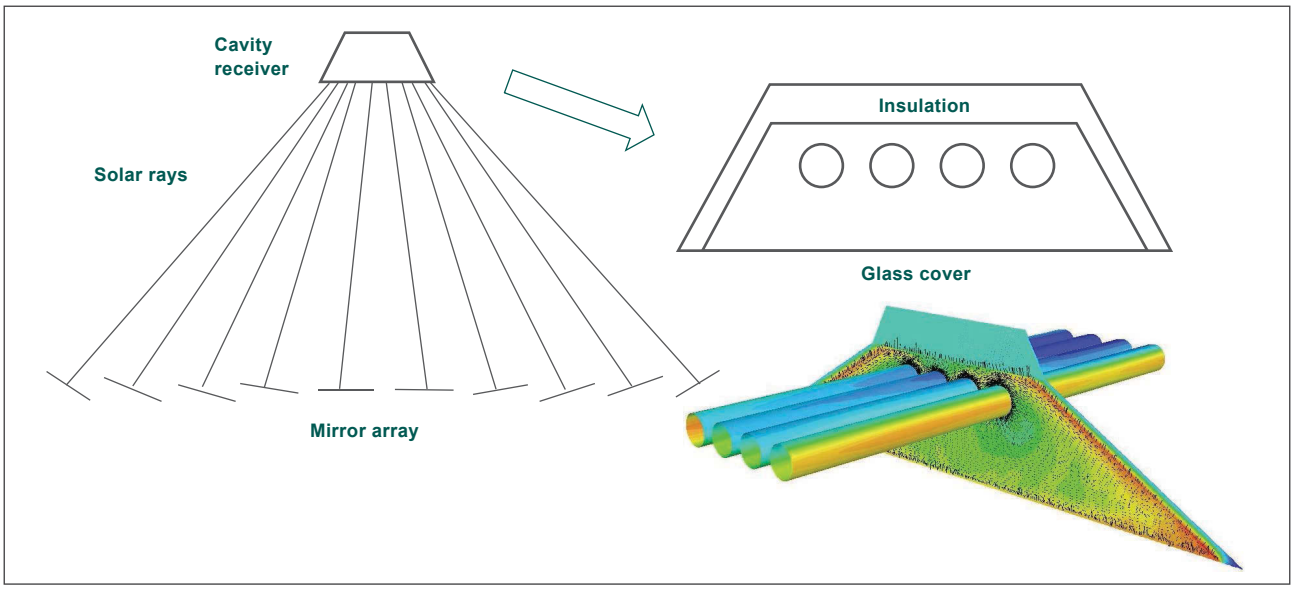


Figure 1: A linear Fresnel reflector with a cavity receiver and computational fluid dynamics solution of temperatures in the cavity and pipes that carry heat transfer fluid.

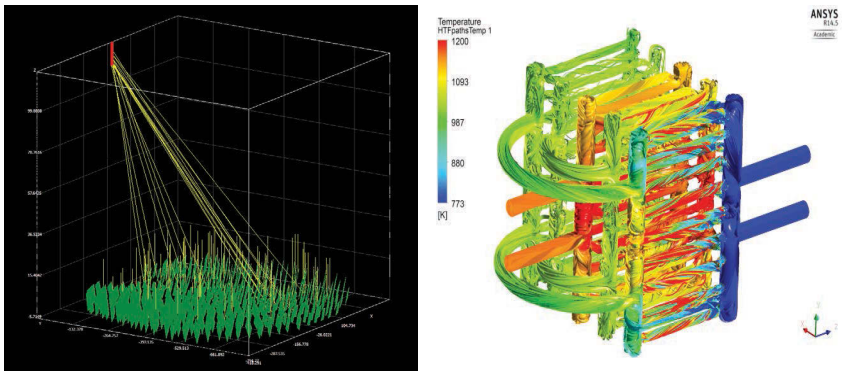
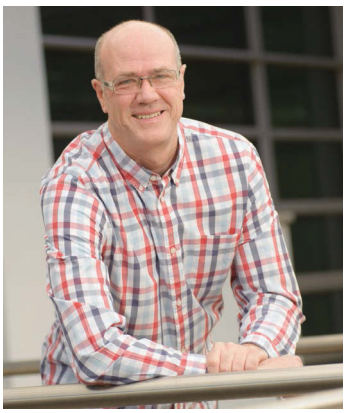


Figure 2: Simulation of the sun's rays onto a central receiver using SolTrace and a CFD simulation using ANSYS® Fluent software. Pressurised air is being heated by the sun's rays in a hybrid cavity receiver.

the Solar Thermal Energy Research Group (STERG) at Stellenbosch University. CFD is used to investigate innovative concepts of central cavity receivers and is then optimised to maximise the optical and thermal efficiency of these central receivers. It is particularly difficult to model the sun's rays and the way in which they are absorbed, reflected and transmitted. Prof Craig's team is researching new ways in which CFD software can simulate the radiative properties of the receiver surfaces for different temperatures and different wavelengths of the sun's energy. Other optical software, such as SolTrace from the National Renewable Energy Laboratory (NREL) in the USA, is also linked with CFD software to provide the thermal energy of the sun as a boundary condition.

The heliostats that make up the combined reflectors in these solar tower power plants can number in the hundreds of thousands and their cost could be half that of the initial costs of such a solar plant. Obviously, if each heliostat can be made lighter and cheaper, the overall savings could be significant. As these heliostats or mirrors are located outside and are exposed to a variety of environmental conditions such as high winds, hailstorms and dust storms, depending on their location, they need to be designed to withstand these conditions for the duration of the solar plant's life, which is often more than 20 years. Several undergraduate and postgraduate students are using both CFD and finite element analysis (FEA) software to design cheaper lightweight heliostats that are strong and capable of withstanding wind loads and other environmental conditions.

Along with the computer simulation of these interesting CSP topics, plans are underway to establish experimental research facilities where these designs can be evaluated. Several UP buildings are being evaluated as possible sites for such facilities. These would not only provide much-needed laboratory space in the form of rooftop labs, but could also assist in reducing the University's carbon footprint by providing thermal and electric energy to the buildings from a renewable source.



Prof Ken Craig *is associated with the Department of Mechanical and Aeronautical Engineering at the University of Pretoria.*

Energy optimisation through the use of heat exchangers using nanofluids

Prof Josua Meyer

The University of Pretoria has been actively researching thermofluid systems since the early 1980s. The Thermofluids Research Group in the Department of Mechanical and Aeronautical Engineering has launched a project, as part of the University's Institutional Research Theme (IRT) on Energy, to develop advanced measuring setups that can be used to experimentally obtain accurate data and develop design correlations for flow through different types of heat exchangers.

Since the early 1990s, there has generally been a growing emphasis on computational research in the thermoflow field. Applications of thermofluid include electronics cooling and industrial computational fluid dynamics (CFD).

Heat exchangers are critical components of processes that generate energy, such as in concentrated solar, nuclear and fossil fuel power processes. It is also used, for example, in the processing, manufacturing, mining, aerospace, transportation, ventilation and air-conditioning industries.

Normally, two flow streams at different temperatures are involved in a heat exchanger. The function of the heat exchanger is to move heat (energy) from one stream to the other. Usually, the two streams are separated by a thin wall with a high thermal conductivity to allow better heat transfer. To ensure efficient heat transfer between two flows at different temperatures, it must be possible to estimate the heat transfer and pressure drop behaviour. This behaviour is very complex and is influenced by several factors.

The first factor is the development of flow regimes and, specifically, the boundary layer of the flow close to the wall that separates the two streams. The flow associated with the boundary layers may be laminar, transitional or turbulent in nature. All these flows have different flow and heat transfer characteristics.

The second factor that influences heat transfer and pressure drop behaviour is the surface geometry of the channel used in the heat exchanger, as the geometry determines the available heat transfer area. The geometry of the surface and objects in and on the surface can also be used as heat transfer enhancement techniques. Examples are extended surfaces, such as fins, surfaces with dimples and pin fins, swirl-flow devices, and thin, twisted plates.

A third factor is the nature of the flow. A single-phase flow behaves very differently to a flow that changes phase. The temperatures of a single-phase flow change in direct proportion to the heat transfer. This can reduce the temperature, as the fluid potential of heat transfer rates remains high as the fluid flows through the heat exchanger. If the pressure drops are not significant, the temperatures of phase-changing flows (boiling, evaporation and condensation) remain constant and have a significant amount of latent heat. Therefore, these flows ensure more efficient heat transfer. Another technique that can be used to improve heat transfer in a heat exchanger is to use fluids with high thermal conductivity.

Heat exchangers are critical components of processes that generate energy, such as in concentrated solar, nuclear and fossil fuel power processes.

The abovementioned factors contribute to the fact that it is very complicated to design an effective heat exchanger, and it can only be done if accurate design information is available.

Heat transfer correlations have been developed, but because of a poor understanding of the fundamentals and less than accurate instrumentation, the best correlations for single-phase flow have errors of approximately 20%. For flows with phase change, it is about 40%. This is not good enough if heat exchangers have to be as cheap and efficient as possible. Over the past few years, heat transfer coefficients of heat exchangers with errors of less than 10% and empirical equations that can be used by engineers to optimise their designs have been developed. Unfortunately, methods or instrumentation to measure the required data are not commercially available.

During a research project conducted by Kersten Grote, a master's degree student at the University of Pretoria, advanced measuring setups were developed that can be used to experimentally obtain accurate data and to develop design correlations for flow through different types of heat exchangers. These can be used by engineers to design better heat exchangers and optimise their efficiency. Over the past 12 years, several such setups have been designed, built and commissioned under the leadership of the Thermofluids Research Group. A recent example is a setup that has been developed to measure the heat transfer and pressure drops of nanofluids. Nanofluids are liquids that contain suspensions of nanoparticles. These fluids are known for substantially higher thermal conductivity than the effective medium theories anticipate.

The reason for considering nanofluids is that water, as a fluid that is used in most heat exchangers, has a relatively low thermal conductivity of 0.58 W/mK at 25 °C. Many studies have investigated methods of improving the heat transfer conductivity of fluids by using mixtures of micrometre-sized particles in base fluids such as water and oil. The studies found that, although higher conductivity and higher heat transfer capabilities are possible in practice, problems are experienced with clogging, sedimentation and increased potential damage of systems due to abrasion.

During the past 25 years, much research on colloidal dispersions of solid nanoparticles in nanofluids, as a new class of heat transfer fluid, has been conducted. Studies found that a fluid's conductivity could be enhanced by adding nanoparticles, such as aluminium oxide, titanium dioxide or copper oxide. The potential enhancements are high, as the thermal conductivity of aluminium oxide is 30 W/mK and that of carbon 3 000 W/mK. These values are respectively 50 and 5 000 times higher than that of water.

This project focused on the measurement of average heat transfer and pressure drop characteristics in the transitional flow regime. The potential of different concentrations of multi-walled carbon nanotubes was investigated. The researchers also took measurements in both the laminar and turbulent flow regimes.

The concentrations were 0%, 0.33%, 0.75% and 1%, and the nanofluids were multi-walled carbon nanotubes. They were stabilised with gum Arabic powder and were sonicated. The carbon nanotubes had outside diameters of 10 nm to 20 nm, inside diameters of 3 nm to 5 nm, and lengths of 10 µm to 30 µm. Thus, the length-to-diameter ratio of the nanofluids was very long, with an order of magnitude value of approximately 1 000. It was expected that the nanofluids, which became entangled with each other in the water and looked like "spaghetti" when enlarged with a scanning electron microscope (SEM), would significantly disturb the velocity and thermal boundary layers.

The pH, thermal conductivity, viscosity of the water and gum Arabic powder, as well as the volume concentrations of carbon nanotubes, were measured separately as a function of temperature. The densities and specific temperatures were

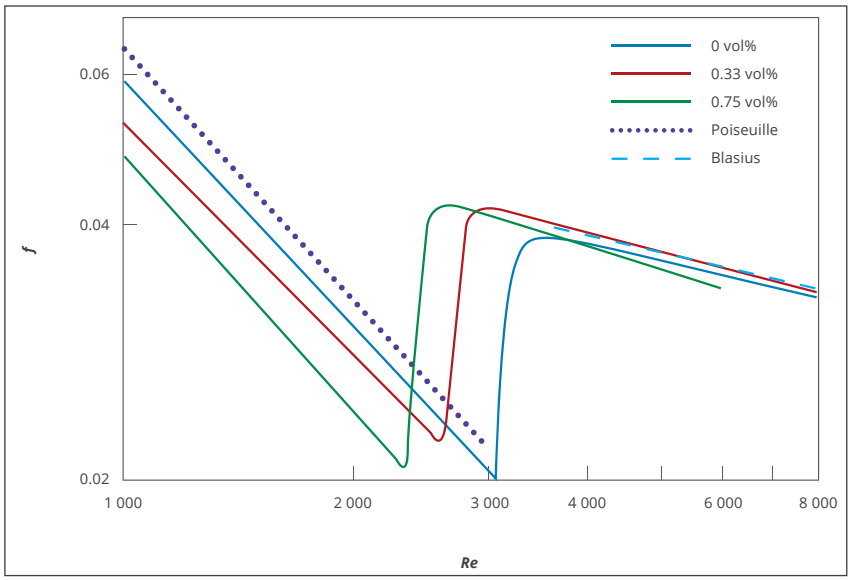
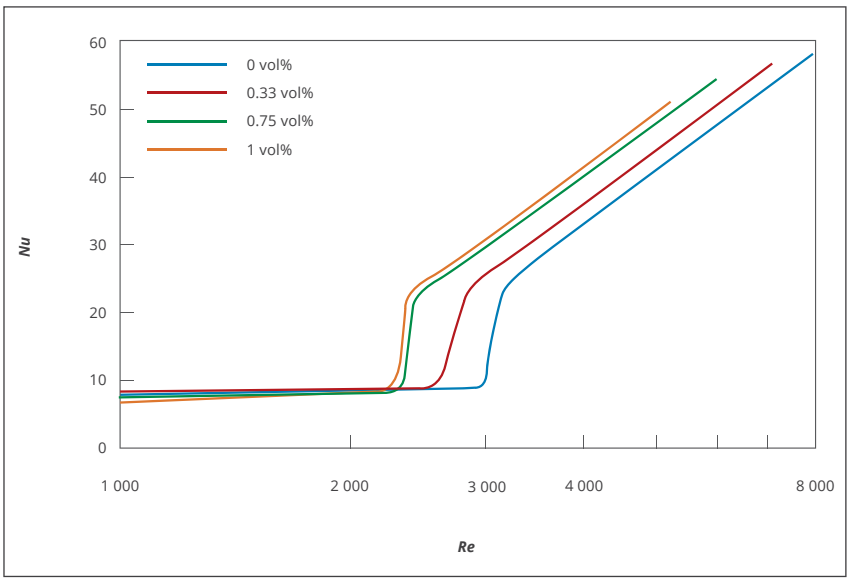


Figure 1: Diabatic friction factors for different concentrations of multi-walled carbon tubes as a function of the Re number. Results for a concentration of 1% could not be taken, as it blocked the pressure ports.



→ *Figure 2: The non-dimensionalised heat transfer (Nu numbers) as a function of the Re number.*

determined from well-known correlations. Experiments were conducted in the Rayleigh (Ra) number range, ensuring that forced convection and friction factors, as well as heat transfer coefficients, were determined as functions of the Reynolds (Re) number. The Re number is a dimensionless quantity that is used to help predict similar flow regimes in different fluid flow situations.

The diabatic friction factor results in Figure 1 indicate that, in the turbulent flow regime, the friction factors did not significantly differ from those of water. In the laminar flow regime, however, the friction factors differed significantly. The reason for the decrease was that the addition of nanofluids changed the viscosity of all the fluids significantly. Pressure drop comparisons at the same fluid velocity indicate that the pressure drop will increase when nanofluids are added. The results in Figure 1, however, show how the critical Re number changed significantly as the concentration of nanoparticles increased. The higher the concentration, the sooner transition will occur.

The heat transfer results in Figure 2 show a significant number of (non-dimensionalised heat transfer coefficient) enhancements of approximately 30% in the turbulent flow regime. The enhancement is caused by the increase in the thermal conductivity of the base fluid. This enhancement occurred because of the addition of the nanofluids, which had a high thermal conductivity of 3 000 W/m°C, compared to the water thermal conductivity of approximately 0.61 W/m°C. In the transitional flow regime, the results of the Nusselt (Nu) number (the ratio of convective to conductive heat transfer across the boundary) show that transition as a function of the Re number occurred earlier as the concentration of nanofluids increased.

It can be concluded that heat exchangers are critical components used in energy production. Normally, two flow streams of nanofluid are used in a heat exchanger. Researchers working on a heat transfer project in the University's Department of Mechanical and Aeronautical Engineering developed advanced measuring setups that can be used to obtain accurate data and develop design correlations for flow through different types of heat exchangers.

The heat transfer results showed significant Nu number enhancements in the turbulent flow regime. The enhancements occur because of the increase in the thermal conductivity of the base fluid, which had a high thermal conductivity compared to the water's thermal conductivity. In the transitional flow regime, the Nu number results showed that transition as a function of the Re number occurred earlier as the concentration of nanofluids increased.

Over the past 12 years, several heat exchanger setups have been designed, built and commissioned under the leadership of the Thermofluids Research Group.

Prof Josua Meyer *is Head of the Department of Mechanical and Aeronautical Engineering at the University of Pretoria. He is also the Chairperson of the School of Engineering and an NRF-rated researcher.*

Is silicon carbide a solution to safer light-water reactor fuel?

Prof Johan Slabber

On Friday, 11 March 2011, a nuclear facility that was up to that moment rather unknown to the public all over the world was forced into the limelight by an earthquake of a magnitude of 8.9 on the Richter scale and a subsequent tsunami. This facility, a boiling-water reactor complex in the Fukushima prefecture on the north-east coast of Japan, sustained considerable damage to three of its operating units, as well as one unit that was shut down.

For many years, designers have designed reactor structures to withstand the forces created by site-specific earthquakes of certain magnitudes. The reactor at Fukushima was no exception and responded reliably to the forces created in the structures due to the accelerations. The three operational reactors were made subcritical by the earthquake-sensing devices, as required under such circumstances. Up to that point, everything went well, but just more than an hour later, it was as if the curtain on the nuclear centre stage was raised when a tsunami wave of 14 m above normal sea level struck the north-east coast of Japan. It drowned the essential emergency cooling and power systems of the reactors. The nuclear drama that was set to commence then started playing its overture by shedding the protective cladding on the structures of the reactors in a spectacular number of explosions.

The current safety objective

The safety analyses performed for reactors worldwide have to provide answers to three main questions. These questions are whether the reactor will, following an upset event, shut the nuclear chain reaction down, whether the fuel elements will be provided with sufficient cooling to protect them from releasing radioactivity, and whether the radioactivity present in the plant will not be released into the environment.

If the safety analyses of the reactors at Fukushima have provided sufficient proof that these questions could all be answered satisfactorily, why did the event unfold in such a spectacular way? In order to provide an answer, it is necessary to first introduce a number of important concepts.

A reactor core that has been operating for some time does not cease to produce heat when the nuclear chain reaction is shut down. It behaves like a car when the engine is turned off. The engine structure is hot due to the heat stored in it. After the engine has been turned off, it slowly cools down due to natural or temperature-activated cooling processes. In a reactor, the heat after shutdown behaves in a similar way, but the heat that is stored in the structures, as in a car, is not the only heat that must be removed. There is also the additional energy that must be removed from the decay of the highly radioactive products that were created while the reactor was operating.

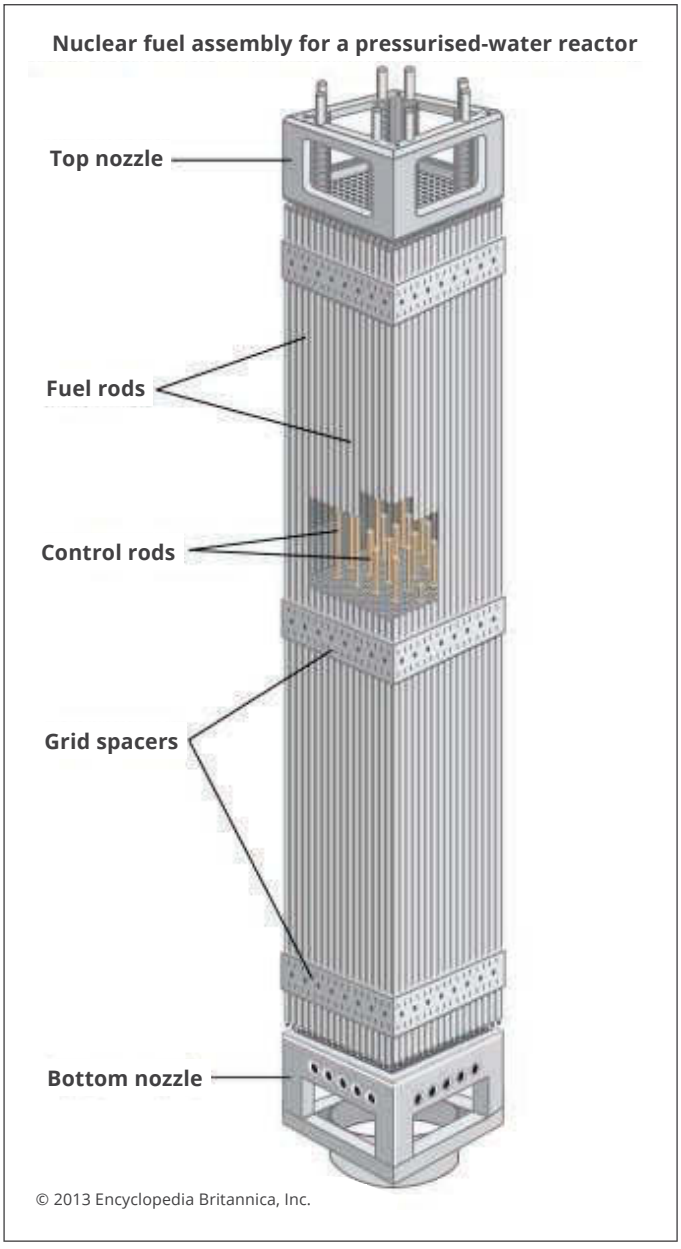
As part of the safety objective to contain the radioactivity in a nuclear facility, the fuel material in a reactor core is surrounded by cladding material that keeps the radioactivity produced from being released and protects the fuel material from reacting chemically with the cooling medium. The heat generated by the fuel material during operation is transferred to the cooling medium, which in turn transports it to the power conversion system during normal operation. The design of the cooling system attempts to provide the most economical transfer of heat from the heated fuel elements to the power conversion system. The transfer of heat requires the temperature of the heated surface to be optimised for the maximum thermodynamic efficiency of the power conversion process. The high temperature on the surface of the cladding material must, however, be kept sufficiently low to prevent a reduction in heat transfer due to bulk boiling occurring. Such a reduction in heat transfer can cause the cladding to overheat and consequently lose some, or all of its capability to retain radioactivity.

The design of the cladding and heat removal system is optimised to have a sufficient margin against a degradation of its integrity during normal operation, and also following upset events that may cause the cooling to be reduced.

Figure 1 shows a generic image of the fuel element of a pressurised water reactor. The detail in the image shows the fuel rods that consist of the fuel material, typically uranium dioxide in a tube of zircaloy, an alloy of zirconium.

The tubes are sealed on both ends by zircaloy end plugs. This material has been under development during the last five decades of reactor operation worldwide.

If the forced cooling in water-cooled reactors is interrupted by some event, it can be shown that the decay heat immediately after shutdown is sufficient to boil the reactor dry, causing the fuel cladding to be grossly degraded unless replenishment of the water inventory is provided. The provision of water replenishment systems is therefore a safety requirement for all current-day water-cooled reactor designs. If this water replenishment should fail, however, the fuel cladding may become exposed due to the boil-off of the water inventory in the reactor vessel. When the hot zircaloy cladding material becomes exposed, an exothermic oxidation reaction takes place between the zirconium and the steam that is generated. This reaction produces hydrogen.



→ *Figure 1: Construction of a typical pressurised water reactor fuel element.*

The rate of energy released in this reaction was calculated for a reactor with a thermal power of 3 800 MW. The results are plotted in Figure 2. Also shown in this figure is the heat produced by the decay of the fission products. It can be seen that when this reaction takes place, its rate of heat production is approximately four times the rate of the heat produced by the decay of fission products. This has a compounding effect on the rate of total heat released and consequently accelerates the rate at which the cladding degrades.

When the above progression of a typical cladding degradation event is compared with the chronology of the Fukushima event, it is not difficult to imagine the entire sequence of reactions that took place, with the hydrogen eventually being released and dramatically exploding to signal the commencement of the core meltdown sequence. By just looking at this explosion and knowing that an open path was somehow created from the fuel to the environment, it was not difficult to predict that at least part of the radioactivity in the fuel would find its way into the environment – an event that eventually cost more than US$20 billion to clean up.

Improvement of reactor fuel to enhance safety

Some years before the accident at Fukushima, the reactor designers and regulators were developing a roadmap towards making reactors safer and more economical, reducing the production of waste, as well as making reactors more (weapons) proliferation-resistant. This roadmap is now being rolled out with the main focus currently on the improvement of the safety features, and specifically towards

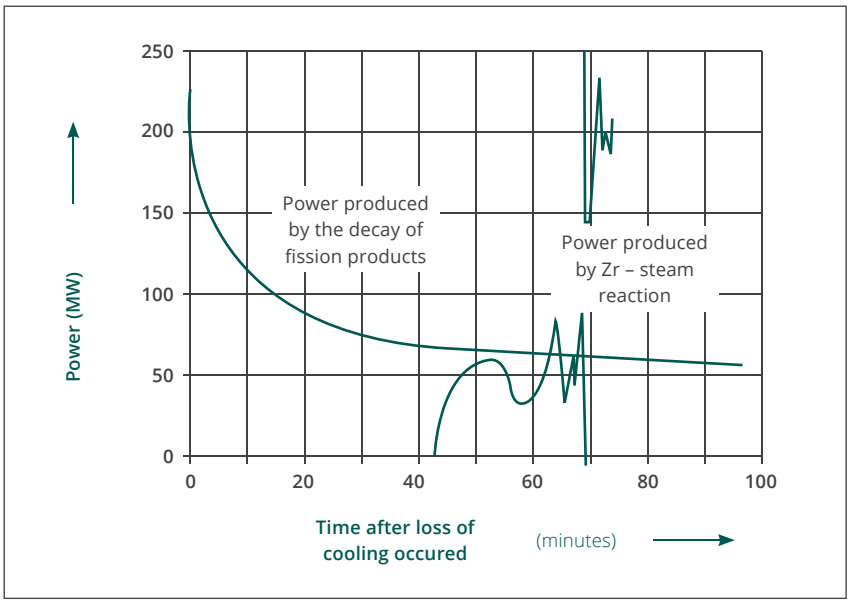


Figure 2: Power produced by the decay of fission products and the zirconium – steam reaction following a loss of cooling accident in a 3 800 MW (thermal) reactor core.

enhancing the passive safety features of all reactors. Naturally, the immediate objective is to start with the fuel and focus on the cladding material. The lessons learned from the high-temperature reactor programmes with the excellent fission product retention barrier that silicon carbide (SiC) provided in those designs are now being considered as a possible solution.

In an international collaborative development, which started in 1959, fuel was developed for high-temperature reactors that utilised SiC as the main fission product barrier. This material has many superb characteristics compared to the metallic fuel used in light-water reactors. It has shown its predictable behaviour in many fuel irradiation tests and high-temperature reactor operations worldwide since the start of its development. The fuel testing included conditions that would be prevalent in reactor accidents caused by a loss of cooling capability.

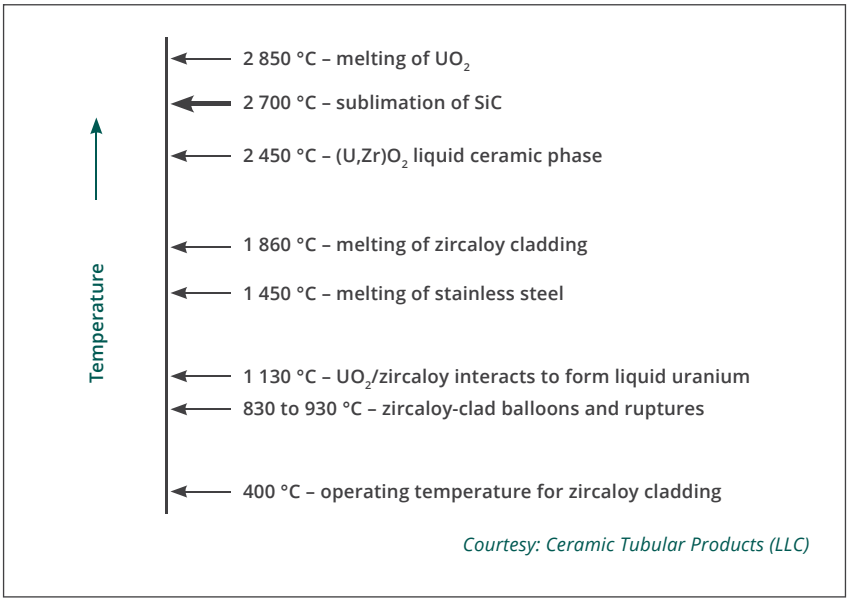


Figure 3: Temperature behaviour of a composite SiC (Triplex®) compared to that of other current core materials.

In the fuel geometry used in high-temperature reactors, the cladding geometry is a very small spherical pressure vessel with an outside diameter of ~0.92 mm, of which the wall consists of a composite structure of pyrolytic carbon/silicon carbide/pyrolytic carbon. This small pressure vessel surrounds the actual fuel, which is typically a small ~0.5 mm diameter particle of a uranium compound, such as uranium dioxide. Of the composite structure, the SiC is generally regarded as the main fission product barrier. SiC is a brittle material and, although it functioned very well in a small particle, it cannot be seen to be directly applicable in a tubular geometry of much larger dimensions.

SiC fuel cladding

One of the companies in the USA at the forefront of the development of SiC tubes for light-water reactor cladding is Ceramic Tubular Products (LLC), which is developing a dense leak-tight composite tube called Triplex®. This tube consists of an inner layer of dense leak-tight SiC and an outer SiC layer called a corrosion barrier. Embedded between these two layers is a composite intermediate layer of SiC fibres. The wall thickness of the Triplex® composite is ~ 0.3 mm. Testing is currently underway to determine its characteristics in comparison to zircaloy. The initial results of the mechanical testing so far have shown a fundamentally different behaviour pattern, as indicated in Figure 3.

The results of other development testing carried out thus far are as follows:

- The inner layer holds the fission gases up to 54 MPa.
- There is no shrinking (creep) of the tube, as occurrs in the zircaloy tubes, where it shrinks onto the fuel pellet during irradiation.
- In case of a severe power excursion, the inner layer may start leaking, but the central composite layer retains the tube in shape up to strains in excess of 8%.

- No ballooning due to high-temperature and high-fuel burn-up (high fission gas pressure) occurs and there is no possibility that an exothermic cladding/steam reaction would take place.

Testing is currently being carried out on un-irradiated and irradiated specimens of the SiC cladding at the Massachusetts Institute of Technology (MIT), the Idaho National Laboratory and other proprietary laboratories in the USA. The University of Pretoria is engaged in SiC production research and the study of heat transfer from the surface of SiC cladding tubes.

Benefits of changing to SiC cladding

The temperature of the cladding is dependent on the power produced in the fuel pin and the heat transfer coefficient on the surface of the fuel cladding. If the SiC cladding should exhibit a higher heat transfer coefficient than zircaloy, the surface temperature will be lower for the same power produced in the fuel tube. If the designer of the fuel chooses to keep the cladding temperature the same, the power produced in the fuel pin can be raised, which means that the reactor can operate at a higher power level. This has an economic advantage to the operator of the plant. As can be seen in Figure 3, SiC can operate at a much higher temperature than zircaloy before any degradation of mechanical properties should become a problem, so the temperature of the fuel may even be allowed to be higher than that of the zircaloy, which means that the power can be raised even more.

Other benefits of using SiC in light-water reactor fuel may come from its smaller neutron absorption characteristics, which means that the enrichment of the fuel in the core can be lowered. If the enrichment of the fuel stays the same, a higher burnup can be achieved, which can have a sizeable economic benefit. Due to its excellent thermal properties, the power density in the core can be raised.

→ *The flow loop for testing heated fuel pins.*

These two aspects will positively impact on the cost of power production.

In addition to the normal operational benefits gained from using SiC cladding, the ultimate benefit will come from its safety characteristics.

This option should, however, not be seen as a short-term "fix". There are challenges, such as the production of the SiC tubes to exacting specifications and the joining of the sealing end plugs to the tube body. Furthermore, although SiC has been qualified as a nuclear material in high-temperature reactor programmes, regulators will require qualification and demonstration of safe operation before a licence can be issued for the general use of this revolutionary fuel. An estimate of the time scale until final approval is granted can be anything between 22 and 24 years from now.

In order to conduct the heat transfer studies, the Department of Mechanical and Aeronautical Engineering at the University of Pretoria has designed a flow loop where electrically heated fuel pins can be studied in three orientations relative to the flow direction of the water coolant. The flow loop was constructed using funding from the Institutional Research Theme (IRT) on Energy. The photograph above shows the loop when commissioning testing was being performed.

With all of this in mind, the question that has to be answered is whether SiC is a solution for safer reactor fuel. The answer is most probably a very positive "yes". But, to get to the point where it is generally accepted by regulating authorities and the general public, a huge amount of research and development is still required.

The University of Pretoria is proud to be part of this initiative.

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Putting nuclear power into perspective

Prof Johan Slabber

South Africa has on a number of occasions announced its intention to include nuclear power generation in its future power generation mix. The world's attention was captured when another announcement about South Africa's intention to explore nuclear possibilities was made within days of the Fukushima Daichii nuclear disaster on 11 March 2011. Subsequently, there were a number of similar confirmations of South Africa's nuclear endeavours.

Typically, every announcement stirs opposition to nuclear power and the media is usually flooded with statistics that claim that nuclear power has one or other flaw that is intentionally hidden from the public. These statistics span a wide variety of specialist fields, from economics, safety and sustainability, to weapons proliferation and waste. After some time, the panic subsides until the next announcement is made. Before branding nuclear power as a viable option, one has to objectively examine the main issues that are normally raised. These are safety, economics and waste.

Safety

In terms of nuclear power's safety, experts often wonder how it can be measured objectively. It seems that the most obvious way is to determine how many lives were lost on average per unit of energy produced by a particular power generation technology. In this assessment, however, the entire chain – from exploration for energy resources up to the final disposal of the waste – for each of the alternative energy sources has to be compared.

It is also important to realise that some of the stages in the chain might not be applicable to some of the power technologies considered. Conca (2012) compared the worldwide fatalities per year for each unit of energy produced per power-producing technology. The results of this study are summarised in Table 1.

It should be obvious from Table 1 that the nuclear energy production, even with the inclusion of the confirmed fatalities, as well as suggested latent fatalities that may eventually result from the accidents at Chernobyl and Fukushima Daichii, is undoubtedly the safest of the various technologies considered.

Economics

If one does an economic analysis of the production of energy through a number of energy production technologies, a common metric for comparison is necessary.

→ *Table 1: Fatalities per power-producing technology*

Power technology	Fatalities per year per terawatt-hour (TWh) produced
Coal (world average)	161
Coal (China)	278
Coal (USA)	15
Oil	36
Gas	4
Wind	0.15
Hydro (world)	0.10
Hydro (world)*	1.40
Nuclear#	0.09

** The figure includes the 170 000 deaths of the Banqiao Reservoir Dam in China in 1975.*

 # The figure includes all fatalities and suggested latent fatalities that may eventually result from the accidents at Chernobyl in 1986 and Fukushima Daichii in March 2011.

Firstly, a common monetary base-line needs to be established. Internationally, the dollar is regarded as a well-recognised base for comparative purposes. Secondly, although there are a number of ways to do a financial analysis of a plant, one of the indicators developed and mostly used for comparing different systems is the levelised cost of energy (LCOE). This represents the ratio of total assumed financial lifetime expenses to the total kilowatt-hours of energy delivered at the connecting points to the grid during this lifetime. A number of factors are used in the calculation of the LCOE:

- **The capital cost of the power-generating technology:** This cost is expressed as a cost of the entire installation as if it was erected from one day to another. It is the so-called "overnight capital cost".
- **The fixed operational and maintenance expenditures in each year**
- **The variable operational expenditures in each year:** This factor includes the cost of the fuel.
- **The net electricity generated in a year:** This is a factor that includes the availability of the power expressed as a fraction of the total time available in a year for the production of power.
- **The cost for the funding that is provided for the construction of the generating plant:** This cost also implies the discount rate used in discounted cash flow analysis to determine the present value of future cash flows. This discount rate is normally calculated for a certain period over which capital cost is to be recovered and is a weighted average between debt and equity capital, called the weighted average cost of capital (WACC).
- **The availability of various country-specific incentives such as tax credits**

A selection of the results of an analysis of the average levelised cost for electricity-generating plants done in the USA for plants entering service in 2019 (US Department of Energy, 2014) is reported in Table 2.

The WACC for the study was taken as 6.5% and a common basis of 30 years was used as the cost recovery period for all the power generation technologies considered. This WACC of 6.5% consisted of two components. The first was 3.5%, which is the discount rate to analyse similar programmes in the UK (HM Treasury, 2003). The second component is a three-percentage point increase to evaluate investments in greenhouse gas-intensive technologies.

The capacity factors used for the conventional coal and advanced nuclear plants are in agreement with figures generally quoted for these two technologies worldwide. The factors for wind and solar power are both somewhat higher than those quoted for stations around the world. The introduction of wind and solar power in a network should also be analysed with caution, because of the fluctuating nature of its generating capacity, which may require reliable backup sources that will supply reliable power on demand. This will influence the cost analysis and should be included if more detailed analyses are carried out for these generating technologies.

By comparing the costs of nuclear and coal-fired power stations in Table 2, it is evident that the higher levelised capital cost and fixed operations and maintenance (O&M) cost of nuclear plants are virtually offset by its lesser expensive variable O&M cost, which includes the cost of fuel. In addition, if the analysis for nuclear plants is performed for the longer operating lifetime and therefore cost recovery period of 60 years, for which the new advanced nuclear stations are designed, an even more favourable levelised cost figure will result for nuclear power plants. Application of the WACC of 6.5% that is adjusted for the greenhouse gas-emitting technologies also disadvantages the levelised cost of electricity for nuclear plants. However, even with this artificially inflated WACC and the shorter cost recovery period of 30 years, the levelised cost of electricity still compares favourably with the cost of coal plants.

Waste

The issue of nuclear waste production has been debated for decades. Without exception, the arguments against nuclear power

→ *Table 2: Estimated levelised cost of new-generation resources in 2019*

Plant type	US average levelised cost for plants entering service in 2019 ($/MWh)				
	Capacity factor (percentage)	Levelised capital cost	Fixed O&M cost	Variable O&M cost (including fuel cost)	Total system levelised cost
Coal (conventional)	85	60.0	4.2	30.3	95.6
Gas (conventional combined cycle)	87	14.3	1.7	49.1	66.3
Wind	35	64.1	13	0.0	80.3
Hydro	53	72.0	4.1	6.4	84.5
Solar PV	25	114.5	11.4	0.0	130.0
Nuclear (advanced)	90	71.4	11.8	11.8	96.1

→ *The Koeberg nuclear power plant in South Africa.*

highlight the long half-lives of the specific isotopes produced in the reactor as the main issue of concern.

Radioactivity is the release of energy from the excited nuclei of elements that were exposed to neutrons in the core of a nuclear reactor. The release rate of this energy is inversely proportional to the half-life of the radioactive material. The shorter the half-life, the higher the energy release rate, and vice versa for long half-life radioactive nuclides. If the energy released in the decay reactions is the same for both the short half-life and long half-life radionuclides, it will be easy to understand that the energy release rate (power) of a short half-life decay reaction is more than that of the long half-life decay reaction. The radiological damage potential of the short half-life radionuclides is therefore higher than that of the long half-life radionuclides.

Since the very long half-life fission product activity has combined effective half-lives of billions of years and the short half-life fission products have combined effective half-lives of hundreds of years, one can see that the comparative radiological damage potential of the long half-life nuclides for the same energy per decay reaction can be less than a millionth of that of the short half-life nuclides.

Furthermore, nuclear energy is very concentrated because a lot of energy can be extracted from a small amount of fuel. As a result, the waste formed is also very concentrated. For example, if 1 g of nuclear material is totally consumed in nuclear reactions, it is equivalent to the consumption of 3 000 tons of excellent-quality coal. The volume of waste created by the consumption of the two types of material to generate power is then this ratio multiplied by the inverse ratio of their densities. The fissile material in current-day reactors is mostly uranium dioxide with a density of 10.7 g/cm^3, and it stays mechanically and chemically intact during its operational lifetime. Coal ash has a density of approximately 1.2 g/cm^3. With these values, it is easy to deduct that the volume ratio of the waste produced by coal compared to that produced by nuclear fission is approximately 2.7 x 10^7 for the same energy produced. In a nuclear power plant, waste is essentially managed by making sure, through mechanical and chemical means, that it is not released into the environment. Due to the large volumes, the waste handling of coal-fired power plants cannot be treated in the same way and the waste is essentially released into the environment around the power plants.

Conclusion

As of May 2014, 30 countries worldwide have been operating 435 nuclear reactors for electricity generation, and 72 new nuclear plants are under construction in 15 countries.

These countries have realised the rationality of utilising nuclear power. Let us believe that South Africa will also be unbiased and consider the foregoing arguments when it decides how to expand its power-generating capacity in the future.

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All-vanadium aqueous rechargeable lithium-ion batteries: The green macro-battery

Cor Potgieter

The lead-acid battery, which was invented in 1859 by French physicist Gaston Planté, is the oldest type of rechargeable battery. These batteries are used in a variety of applications, such as motor vehicles, boats and standby power installations. Since the technology is 155 years old, there is a need for exploring alternatives. Aside from the global movement towards greener technology, the search for new technology is driven by the need for a safer rechargeable battery. The lead in lead-acid batteries can cause lead poisoning and the battery's sulphuric acid is highly corrosive.

South Africa has abundant wind and solar energy sources, and yet the country mainly relies on coal as a power source. Renewable energy sources are cyclical. A cost-effective energy storage technology is required if these power sources are to ever significantly contribute to the country's energy needs. Due to its lower cost, the lead-acid battery is still the most widely used battery for large-scale energy storage. It is environmentally unfriendly, however, and has poor deep discharge and long-term cycling performance. The all-vanadium aqueous lithium-ion battery (VARLB) is a better alternative.

The research path leading to the VARLB started with investigations around increasing the energy density of the regular vanadium redox battery (VRB). Due to its long life span, the VRB is a promising energy storage technology for the large-scale energy storage market. The VRB is a redox flow cell.

Redox flow cells differ from commercial voltaic cells in the sense that energy is stored in charged electrolytes, not in the cell's electrodes. The reactants and products all remain dissolved throughout the charge and discharge cycle. An ion-selective membrane is required to keep the solutions from mixing. The cell short-circuits if the solutions mix, which forms heat. In the VRB, vanadium-based half-cell reactions are used in both electrodes. This eliminates the common flow cell problem of cross-contamination. The mixing of the electrolytes inevitably occurs due to the membranes leaking slightly. In VRBs, only vanadium compounds are formed when mixing occurs. These reactions can easily be reversed by recharging the cell. Therefore, the electrolyte theoretically has an infinite life span.

Unfortunately, the high cost of the VRB has hampered its commercial application. The main cost factors are the inherent low energy density and the necessity of using an ion-selective membrane. The energy density is limited by the solubility of the vanadium compounds, which are used as active materials. Water typically comprises more than half of the weight of typical electrolytes (Rychcik and Skyllas-Kazacos, 1988). The ion-selective membrane separator comprises approximately 20% of the battery cost (Prifti et al., 2012). Eliminating the water and the membrane therefore holds the key to high energy and cost-effectiveness.

Surface-supported active material tests

Initial experiments with ion exchange substrates and super capacitor substrates were conducted. The idea was to support the active ions of the VRB on a solid surface, rather than dissolving them. This immediately removed the energy density limit placed by the solubility of the active substances. This also makes an ion-selective membrane separator redundant, because the active materials are immobilised on the electrode surfaces. These initial trials led to a battery that uses the lithium-ion battery storage mechanism.

Lithium-ion batteries

Lithium-ion batteries have the highest energy density and longest life span of all the commercially available battery technologies. Organic electrolytes have classically been used to maximise the usable voltage window, and therefore the energy density of the battery. Organic electrolytes are required due to the extreme reactivity of lithium with moisture and air, but they are toxic, flammable and expensive. The production costs of traditional lithium-ion batteries are inhibiting for the large batteries required for load levelling (Wessels et al., 2012).

The costs are high because of the use of expensive organic electrolytes, safety concerns with large-scale batteries and because moisture- and air-free controlled environments are required for manufacturing.

Aqueous rechargeable lithium-ion batteries

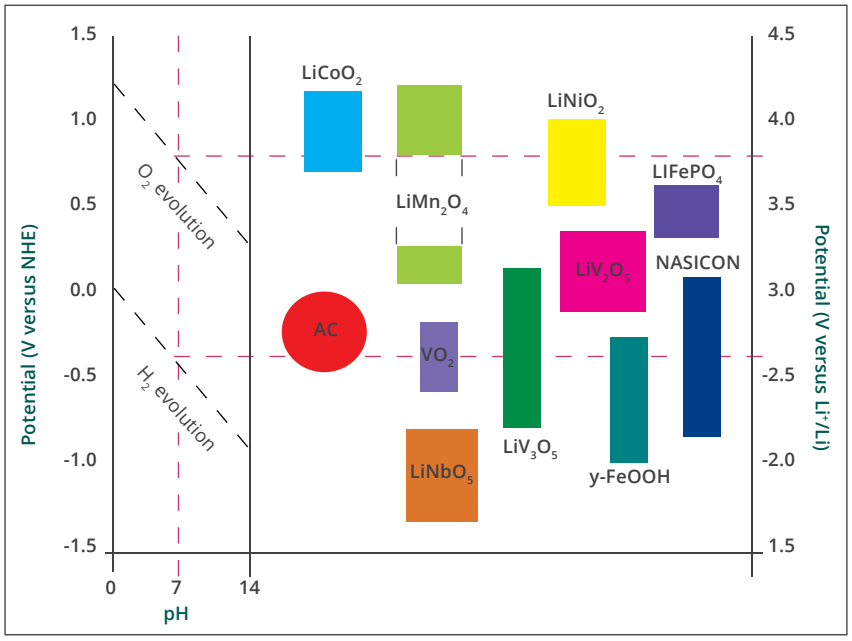
Aqueous rechargeable lithium-ion batteries (ARLBs) are less dangerous replacements for standard lithium-ion batteries and are inexpensive. The stable voltage window of aqueous electrolytes (without considering electrode overpotentials) is 1.23 V, compared to the normal hydrogen electrode (NHE), and approximately 3 V for organic electrolytes. Figure 1 pairs the stability range of water with the reaction potential of a few materials that have been tested in lithium-ion batteries. Combining a suitable half-cell pair in the stability range of water creates an ARLB.

The left side of Figure 1 shows the O_2/H_2 evolution potential versus the normal hydrogen electrode (NHE) for a different pH in 1 M Li_2SO_4 aqueous solution. The right side shows the lithium-ion intercalation potential of various electrode materials versus NHE and Li/Li^+. AC: activated carbon, NASICON: materials with NASICON structure (Luo et al., 2010).

Aqueous electrolytes generally have ion conductivities of approximately two orders of magnitude higher than those of organic electrolytes, and are non-toxic and non-flammable (Luo et al., 2010). The fabrication costs are much lower for ARLBs, because no environmental control is required during manufacturing to limit air and moisture levels. This makes the ARLB ideally suited for the large-scale energy storage market, which requires batteries with a low cost, high safety characteristics and a long life.

All-vanadium oxide ARLB

The all-vanadium oxide ARLB is a special ARLB. It is based solely on vanadium compounds, just like the VRB. A symmetrical vanadium oxide ARLB combines the strengths of the regular VRB and other non-symmetrical ARLBs. This battery requires no ion-selective membrane and has an inherently high energy density, because the solubility of the reactants does not limit the energy density. Cross-contamination of soluble vanadium compounds should not cause any irreversible side reactions. Despite the wide interest in the VRB and the extensive studies on lithium-ion intercalation compounds, no publications could be found on an ARLB based solely on vanadium compounds.



→ *Figure 1: The half-cell reduction potential map of some lithium-ion battery materials.*

Combining VO_2 and LiV_2O_5 (Figure 1), the expected cell reactions are as follows:

Cathode (reduction):

$V_2O_5 + e^- + Li^+ \rightleftharpoons LiV_2O_5$ ..... E_0= 0.33 V

Anode (oxidation):

$2Li_{0.5}VO_2 \rightleftharpoons 2VO_2 + e^- + Li^+$ ..... E_0= -0.42 V

Cell:

$V_2O_5 + 2Li_{0.5}VO_2 \rightleftharpoons LiV_2O_5 + 2VO_2$ ..... E_0= 0.75 V

The expected specific capacity of a symmetrical vanadium oxide ARLB is in the range of 120 mAhg-1. The specific energy density using a cell voltage of 0.75 V is therefore 90 Whkg-1, which is almost double that of the lead-acid battery.

Ongoing research

So far, tested experimental cells have reached about a third of the expected theoretical energy density. Cell resistance is still a problem, but the optimisation of the electrode formulation and manufacturing process is underway to improve this. The use of graphene foam as current collector is an exciting prospect, and this super-conductive material may solve the cell resistance problem. A research team led by Prof Ncholu Manyala, an associate professor in the Department of Physics at the University of Pretoria, is the world leader in graphene foam produced by chemical vapour deposition, and will collaborate on the VARLB project.

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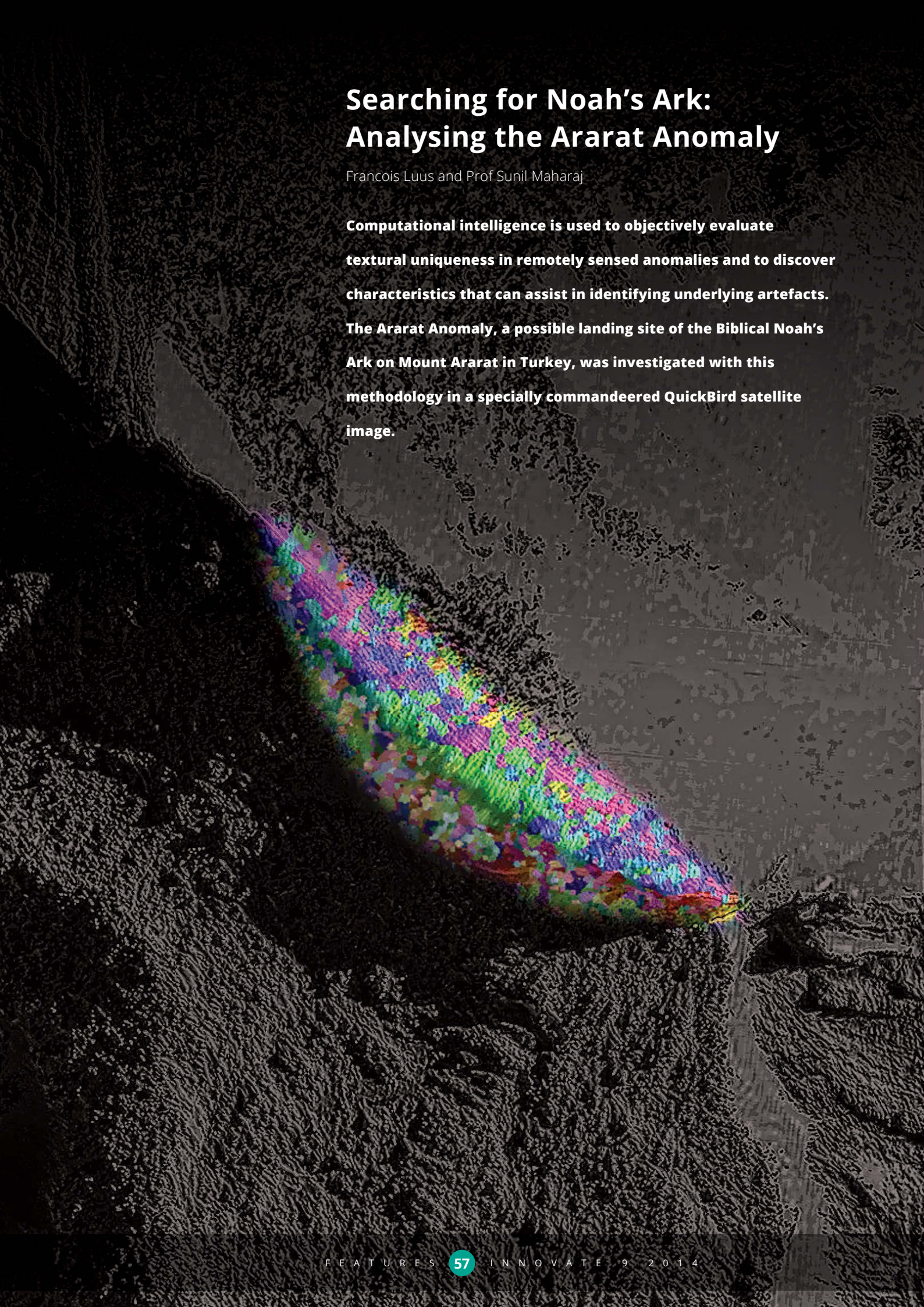
Searching for Noah's Ark: Analysing the Ararat Anomaly

Francois Luus and Prof Sunil Maharaj

Computational intelligence is used to objectively evaluate textural uniqueness in remotely sensed anomalies and to discover characteristics that can assist in identifying underlying artefacts. The Ararat Anomaly, a possible landing site of the Biblical Noah's Ark on Mount Ararat in Turkey, was investigated with this methodology in a specially commandeered QuickBird satellite image.



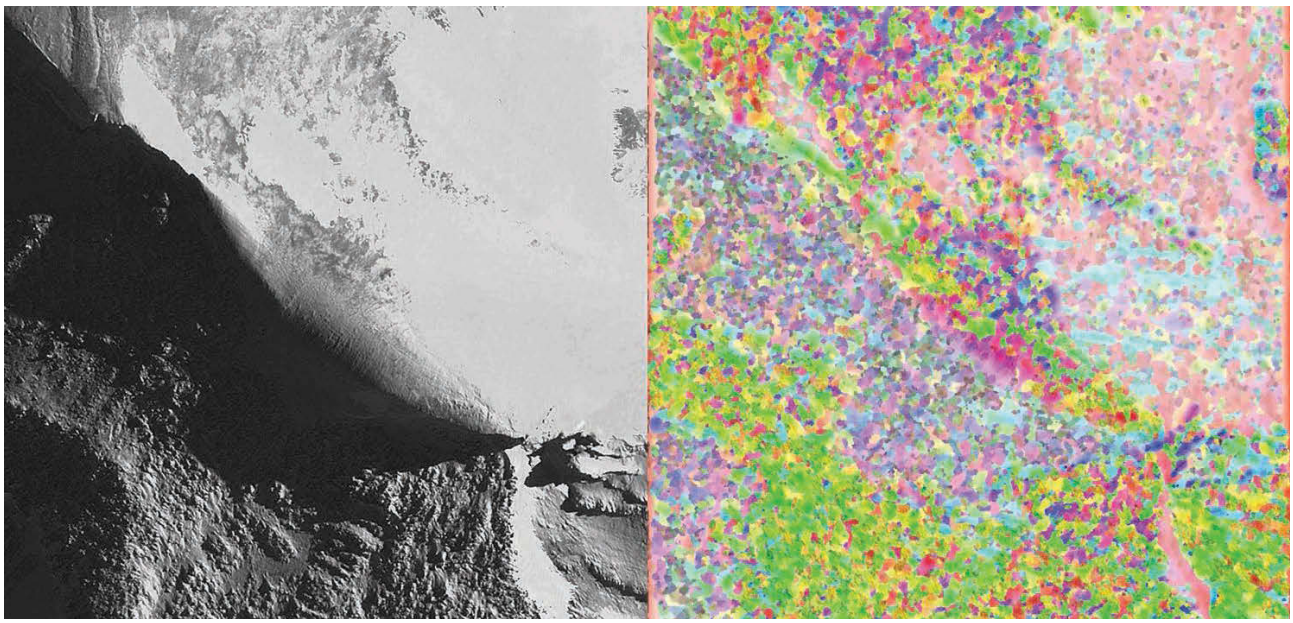


Figure 1: QuickBird February 2003 image of the Ararat Anomaly (left), © 2014 DigitalGlobe Inc., and an illustration of the dominant Gabor wavelet filter responses (right).

The data used in this study is one of the best available remote sensing images of the anomaly. This image is a panchromatic QuickBird electro-optical image that was acquired in February 2003.

The objective of this study is to quantify the novelty of textures on the anomaly, at least in terms of the textures found in the surrounding area. This data can provide a more objective starting point for further analysis of the anomaly and could possibly serve as supporting evidence of an artefact underlying the anomaly, which is covered by glacial ice.

This textural uniqueness measure is an important contribution in detailed remote sensing analysis, since it describes a low computational complexity implementation that emphasises the uniqueness of prominent and useful texture components. The original QuickBird February 2003 panchromatic acquisition of the Ararat Anomaly is shown in Figure 1.

Topaz Adjust 5 image-enhancing software was used to enhance the original with standard brightness increase and adaptive exposure maximisation with minimum region size, which balance the exposure of local regions in the image. Maximal shadow and highlight protection was used to recover all the fine detail in the shadows and highlights of the image. Maximum detail enhancement with independent detail processing was also used, without any detail boost to prevent the exaggeration of details.

Textural uniqueness

Textural uniqueness is a scalar measurement that indicates the relative scarcity or probability of a particular texture occurring relative to a set of available textures.

This measurement can be used in an unsupervised manner to detect and indicate novel textures in remote sensing imagery, such as the Ararat Anomaly images. In this way, machine intelligence can find interesting parts of the anomaly.

The uniqueness measurement is only relative and it is subject to the way in which texture and texture similarity are defined.

The similarity of two texture features can be measured by taking the Euclidean distance between the two features in the multidimensional feature space, after preprocessing each feature dimension to have a range magnitude reflecting the amount of variation accounted for by the dimension.

In unsupervised clustering, such a similarity measure is used to group very similar features together in a unique cluster, and different clusters are distinguished only as a result of the initial grouping based on the similarity measure.

To measure relative dissimilarity with an Euclidean distance measure does not guarantee that textures found to be unique will be well defined or interesting in terms of the intended application.

Gabor texture features

Gabor wavelet filter features have been used to incorporate a relative measure of texture prominence in the uniqueness search. Linear Gabor filters model the visual cortex of mammalian brains and are used for edge detection.

A filter response with a relatively large magnitude indicates a more well-defined and prominent texture and a set of filters is used to cover all edge orientations and scales. This results in a feature vector that is automatically categorised in a manner that makes sense to human visual perception.

A depiction of the dominant filter responses is given in Figure 1. The hue describes the dominant orientation, the saturation describes the response magnitude and the intensity value gives the dominant scale for each texture centred at each pixel.

A larger Euclidean distance between two Gabor texture features means that there is likely to be more prominence and novelty in one of the textures. The Gabor wavelet scales were selected by measuring the total response energy at different scales and including the appropriate scale range for the given image.

The exact wavelets that have been used for this study include seven different scales, each with 32 different orientations to obtain 224 Gabor feature dimensions. The feature dimensions are left unscaled to preserve relative response magnitudes over different scales to favour higher energy scales.

Unique textures

Locality-sensitive hashing was used to efficiently approximate the nearest neighbours, or most similar textures, for every texture descriptor vector centred at every image pixel.

By obtaining the most similar textures for every texture, the relative uniqueness of the particular texture can be measured as the average of the Euclidean distances to the nearest neighbours. Locality-sensitive hashing with eight-dot products per hash, 40 independent projections and quantisation bin widths of 0.001 is used.

The most unique textures found on the anomaly are shown in Figure 2, which includes 12 texture patches that could be considered novel in a Gabor feature sense, relative to a large range of different textures as provided by the surrounding image.

There are a number of unique texture points on the anomaly itself, which involve larger unique wavelet combinations centred at the detected points of uniqueness. If the textural uniqueness was evaluated over an even larger image, the probability of the occurrence of an overall uniqueness would be proportionally reduced, given an approximately equal textural coverage profile.

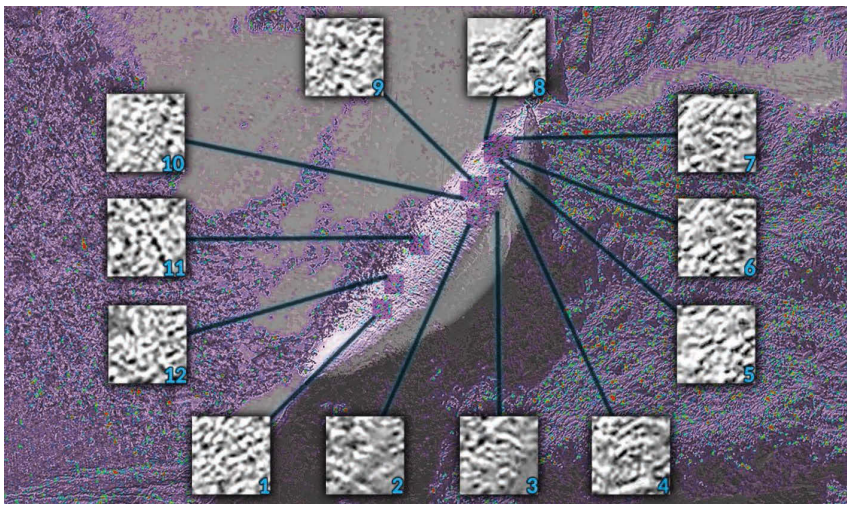


Figure 2: Twelve unique textures found in the enhanced QuickBird February 2003 image of the Ararat Anomaly.

Further study may consider the locations pinpointed by the uniqueness search to ascertain whether there might be clues that can give credence to an artefact underlying the anomaly.

Acknowledgements

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The authors also acknowledge DigitalGlobe, a leading commercial vendor of space imagery and geospatial content, as well as an operator of civilian remote sensing spacecraft. DigitalGlobe has flown numerous missions over the anomaly on Prof Taylor's request.

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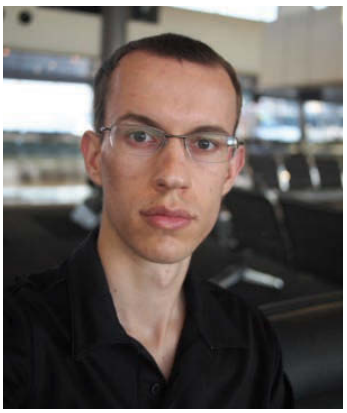

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The evolution of engineering services management

Dr Richard Weeks

Engineering and technology management is an evolving discipline globally. The increasing complexity of engineering systems and activities, the scope and sophistication of resources, and advances in technology have all been driving forces in the rapid evolution of this field.

In reaction to the complexities of engineering and technology management, the Graduate School of Technology Management (GSTM) was established at the University of Pretoria on 1 January 2007. Its technology management programmes are aimed at engineers and scientists who have recently completed bachelor's degrees. The objective is to produce engineers and scientists who not only have skills in technology, but also the ability to manage technology.

The first engineering services management (ESM) courses were launched in 2009 and evolved into a fully fledged discipline within five years. One of the first papers emanating from the author's year-long research study to determine the relevance and feasibility of establishing "service science" as a potential field of study at the GSTM was published in the *South African Journal of Management* in 2008.

The paper, entitled "The service economy: A South African perspective", reflected one of the study's key findings: although the services sector had emerged as the dominant sector of the global and South African economy, as far as could be ascertained, there were no academic institutions in sub-Saharan Africa that offered courses on services management in an engineering context. This needed to be seen in the context that many leading academic institutions in the USA, Asia and Europe had already established services science management and engineering (SSME) as a field of research and tuition.

From 2004 to 2006, the IBM Corporation's Global Innovation Outlook (GIO) brought together business and community thought leaders from four continents and 178 organisations to identify and discuss emerging trends, challenges and opportunities that affected business and society. They identified services as the sector of the economy that held the key to future sustainable growth. Considering the socio-cultural and human dimensions involved, as well as the need for innovation in competing in the services marketplace, integrating technology into new business models and processes became a recurring theme in contemporary literature.

Prof Tinus Pretorius and Dr Siebert Benade of the GSTM identified the services management trend as an area of study to be pursued. They took the initial steps to establish ESM as a field of research and tuition at the GSTM. They requested the author to develop such a curriculum, while considering international experience.

Discussions were held with staff from Portland University and academics from various international academic institutions in drafting the proposals and academic content. It soon became apparent that the scope and content of the envisaged ESM course was extensive. A lot of material had to be covered to equip students with the knowledge and skills required for the development, implementation and management of an effective services infrastructure. As a result, the first course was structured to deal with only the fundamentals of service science, and a more advanced course was to be introduced later to cover the more pertinent aspects relating to practical issues. The introduction of these courses necessitated the identification of research topics and themes for students to consider in completing the research projects required for completing their degrees.

In 2009, students could register for the ESM course for the first time. As it dealt with the fundamentals of service science, it was clear from the start that most of the students could relate the course's theory to their individual situations at work.

→ *The programmes of the GSTM are aimed at producing engineers and scientists who not only have skills in technology, but also the ability to manage technology.*

Bringing theory and practice together was an important consideration in the development of the course. Within two years, the demand for the advanced course became apparent, and it was successfully launched.

Since then, the number of students registering for the courses has increased significantly. In 2013, ten students undertook the first research project in the field of healthcare services management. The project was quite extensive and, together with Dr Louwrens Erasmus, the author worked with students to gain an understanding of technology's role in supporting healthcare service delivery. The research findings resulted in a number of papers being published and presented at local and international conferences. Servitisation was another research project that resulted in a significant number of journal articles and conference papers.

With the establishment of ESM as a domain of research and tuition at the GSTM, theory and practice converged. Insight gained from the research was integrated into the courses. One significant event was the development of a service systems framework. This framework has been adapted and used in a number of service-related fields. These include healthcare services management, and electricity generation and distribution. It now forms one of the building blocks for service systems design and management.

Over only five years, ESM has evolved from its humble beginnings into a fully fledged discipline. As they evolved, it became necessary for the ESM courses to be constantly adapted and updated. A major change was the revision of the information technology (IT) course that integrated IT and service systems theory. The IT component was consequently removed from the advanced ESM course, which had become too extensive in scope and content.

Since their inception, one of the fundamental challenges in developing and presenting the ESM courses has been determining what service science knowledge and skills need to be included in the courses. Service science theory and practice do not remain static long enough for academics and practitioners to catch up and integrate innovative new thinking and management practice into course material.

The field of healthcare service management has experienced particularly significant and innovative technology-driven progress. In recent years, there has been a significant increase in unstructured data in this field. This data emanates from diverse sources, such as medical research,

imaging, multimedia and even social networks, and needs to be analysed. The same is taking place in related service-oriented fields, such as travel and transportation, leisure and hospitality, finance, education and local government, making it extremely difficult to ensure that appropriate knowledge transfer takes place.

It is hardly surprising that no less than three editions of the textbook have been published since ESM was established at the GSTM, and the course material had to be revised in each case. Making sense of the large amount of service science data generated in these settings and this field of research is a future challenge that has to be addressed. The notion of personalised services and patient-centric healthcare will fundamentally change the way services are rendered in the future. It will no longer be a case of one size fits all.

Many of the innovative technology-driven changes are disrupting service delivery trends and processes. Personalised healthcare patient treatment is an example. Therefore, there is a need for moving from traditional incremental adaptive change strategies to embrace emergent service management practices and their technology support systems. It will necessitate the need for a culture of continuous learning and exploration, as well as the demise of traditional boundaries between technology and its application in service delivery. This will play a significant role in the evolution of future ESM course curricula and the material covered to ensure that GSTM students remain at the cutting edge of service design and management.

The importance attributed to this stems from the role that services play in both the global and South African economy. According to the World Economic Forum, services currently account for 67% of the country's gross domestic product (GDP). Servitisation strategies are also increasingly implemented in the manufacturing industry to gain a competitive advantage in global and local markets. Maintenance and repair services during the operating life of products add an additional revenue stream that, in many instances, is even greater than the cost of the original product itself. It is frequently argued that we have passed the tipping point where the knowledge-based services economy emerged as the dominant sector of the global economy.

Seen in the context of the emergence of a technology-driven services economy, it can be assumed that service science will become increasingly relevant and important in an engineering context. The need to gain a greater share of the global services market will also be given impetus by the prevailing, relatively sluggish South African economy and the more stable revenue stream generated by services.

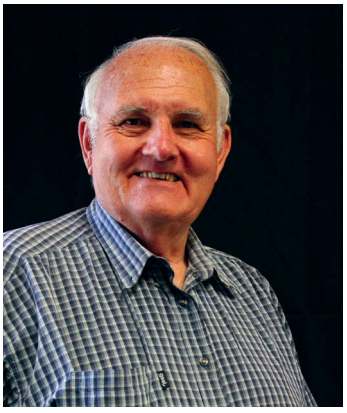
> There is a need for a culture of continuous learning and exploration.

The ESM domain will have to focus on two increasingly important aspects that will have a significant impact on the evolution of research and tuition in this field. These factors are the disruptive trend breaks in technology service support systems and the innovation in service systems in diverse sectors of the economy. Several major transitions in technology, each important in its own right, are combining to reshape the services landscape. These transitions include mobile and cloud computing, the increasing emphasis on big data analytics and the pervasive effect of the internet. Making sense of the effect of the innovative changes will in itself complicate service strategy development and implementation. Disruptive technological trends and their impact in an African context will consequently feature quite prominently in the ESM domain at the GSTM in future.

It can be expected that, with the unprecedented growth in the knowledge-based services economy, the need for technology-oriented service management skills will intensify and outstrip the availability of these skills. The use of technology to enable personalised service-based skills development is envisioned as a possible means of bridging the gap between a shortage of the required skills and the industry's demand for appropriate skills.

It is suggested that the evolution of the GSTM's ESM domain now stands at the brink of needing to find new innovative means of bridging this skills gap, which will only widen if it is not addressed. A possible solution could be the development and presentation of industry-specific service-based skills using new technology-enabled means of distance education. Industry-based data analytics can assist in identifying the essential skills required in specific spheres of service delivery, such as tourism, healthcare and the retail industry, thereby enabling personalised learning pathways.

The GSTM will accept the challenge of researching and remaining at the forefront of proactive ESM-related skills development in the South African context. In this sense, the evolution of the ESM domain appears to be on a never-ending journey of becoming more relevant in an innovative, technology-driven and dynamic services economy.



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

Optimising bulk coal delivery in South Africa

Elias Willemse, Sumarie Meintjes and Hugo van der Bijl

South Africa produces an average of 224 million tonnes of marketable coal annually, which makes it the fifth-largest coal-producing country in the world. As most of the coal used in South Africa is transported by road, a need arose to optimise coal delivery to coal stockyards.

The Department of Industrial and Systems Engineering at the University of Pretoria, in collaboration with Business Enterprises at University of Pretoria (BE at UP) and WorleyParsons South Africa, completed a series of comprehensive studies of bulk resource transport optimisation at the end of 2013. This included a coal stockyard study, a coal delivery traffic impact study and a construction traffic impact study.

Coal stockyard study

The aim of the coal stockyard study was to determine the delivery requirements of a coal stockyard based on demand requirements and variability. The study also aimed to determine the number of stockyard resources required to process the deliveries.

Key stockyard operations were simulated in a model. that considered delivery variability, planned downtimes (scheduled maintenance) and unplanned downtimes (machine failures).

The simulation model was used to verify that the stockyard's design could sustain the required capacity without any potential system failures. The simulation also highlighted all potential bottlenecks. Solutions to alleviate these bottlenecks were identified.

Conservative assumptions for the development of different scenarios were made, each with different demand requirements. For each scenario, key performance indicators, such as queue length, turnaround time and average resource utilisation, were calculated.

The number of resources required for the different scenarios were then determined.

Coal trucks or conveyor belts can deliver coal to the stockpile. The results in Figure 2 show summarised vehicle statistics and resource requirements for this scenario.

This study aimed to verify that the stockyard's design can comfortably hold the required amount of coal. A number of different scenarios were simulated, which determined that the stockyard's demand increased over time. This meant that more trucks had to deliver coal more frequently, which could result in a slower turnaround time for trucks. It could also cause bottlenecks.

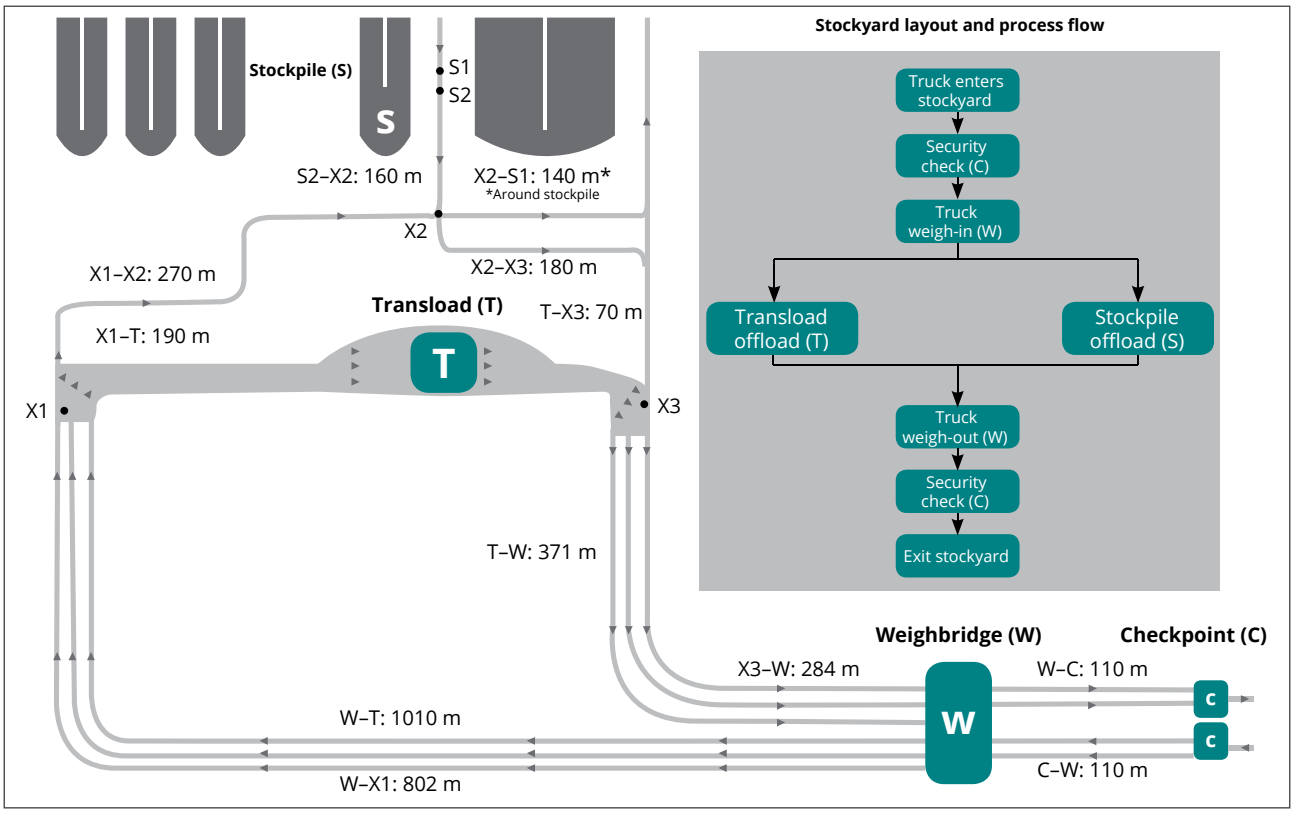
Coal delivery traffic impact study

The second project, a coal delivery traffic impact study, also commenced in August 2013. The aim of this project was to determine the feasibility of trucks for transporting coal from a colliery to a stockyard. The study considered existing and proposed new roads on and around the stockyard. Along with meeting the demand, safe and efficient coal delivery is important.

The aim of the study was to determine whether the existing road infrastructure surrounding the stockyard could support the required number of truckloads to be processed by the stockyard. It also identified risks that could constrain coal delivery via the road network.

Coal trucks entered the simulation model at key intersections surrounding the stockyard and exited the simulation model at various points of the stockyard. Only intersections that were affected by coal trucks were modelled in the simulation.

The main objective was to determine if, and under which conditions, the road network can



→ *Figure 1: The coal stockyard layout and process flow.*

supply the stockyard's maximum demand. Traffic density, truck arrival and departure profiles were considered to confirm the suitability of the road layout.

Different scenarios were tested. Construction vehicles and coal trucks were modelled to follow specific roads and to enter the coal stockyard at dedicated entry points.

The coal delivery traffic impact study succeeded in mapping the traffic patterns of trucks entering and leaving the stockyard.

These results could then be used in a further study that aimed to alleviate traffic congestion in and around the stockyard.

Construction traffic impact study

After examining the rate at which the coal stockyard needed replenishment and the peak traffic patterns around it, the team embarked on a third study, which aimed to identify and evaluate peak traffic alleviation options.

This study was conducted during October and November 2013. The high volume of construction vehicles entering and exiting the stockyard caused congestion.

The team developed a simulation model of the main intersections surrounding the stockyard. Current general traffic volumes, construction traffic volumes and projected construction volumes were used to determine the time it took for construction vehicles to enter and exit the stockyard.

Different alleviation options were identified, such as placing pointsmen at congested intersections, upgrading the road infrastructure to allow for increased traffic volumes, and changing construction shift times. The different options were simulated and each option was evaluated according to the time it takes for construction vehicles to enter and exit the stockyard.

Figure 2 shows traffic flow at the main entrance of the construction site during afternoon peak traffic.

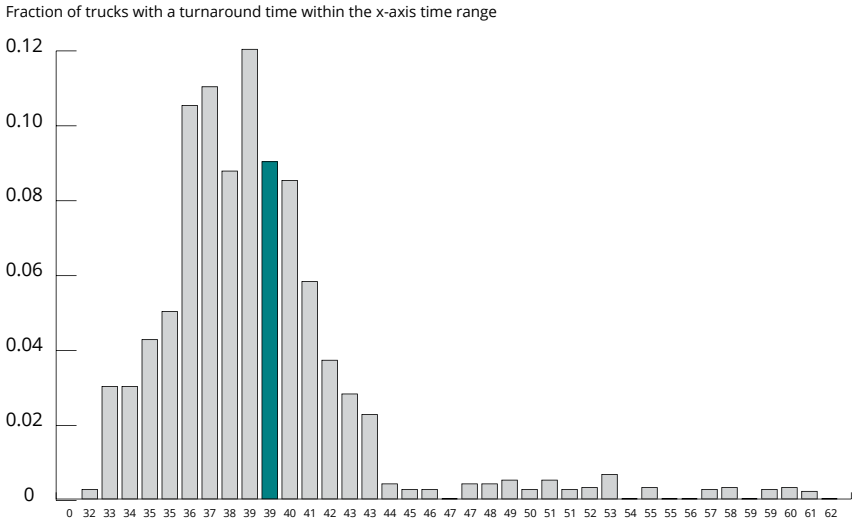
The control scenario captured the current state of traffic flow, and the scenarios on page 66 illustrate how implementing different alleviation options would affect traffic flow. Based on the results of the different scenarios, recommendations were made as to which alleviation options, if any, would alleviate congestion at the main entrance of the construction site.

The simulation model showed that the deployment of pointsmen is the most effective traffic alleviation option, eliminating the exit queue and allowing vehicles to exit the site. This reduces the time it takes to clear the intersection to one minute.

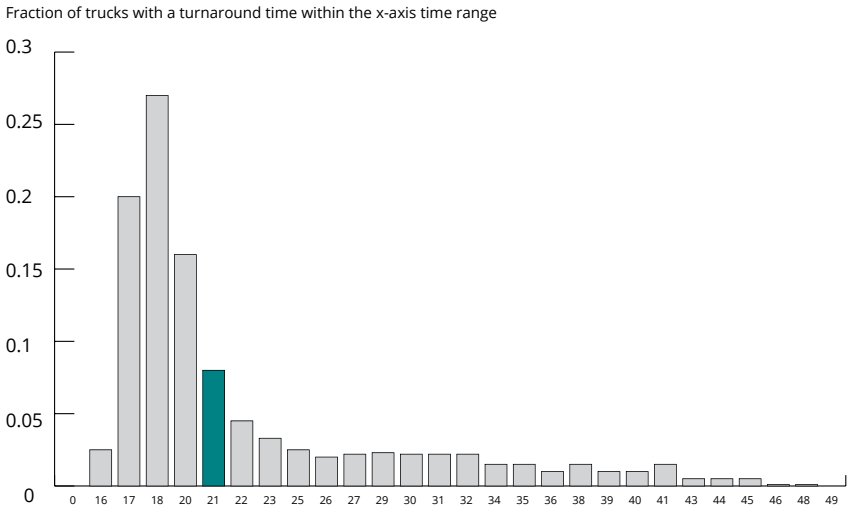
Conclusion

The three different studies investigated a coal stockyard's logistical needs in terms of coal delivery. Aspects such as stockyard delivery requirements, the viability of trucks as a mode of coal transport and the congestion these trucks cause were investigated.

VEHICLE STATISTICS	Transload offloads	Stockyard offloads
Turnaround time (TAT) (minutes)* *Calculated through simulation model	Min: 15	Min: 33
	Average: 30	Average: 49
	Max: 69	Max: 87
Stockyard entry vehicle queue length		**Number of trucks on stockyard**
	Average: 1 truck (22 m)	Average: 2
	Max: 24 trucks (528 m)	Max: 5



Scenario 3a (direct stockpile and transload offloading) – June 2016: Stockyard vehicle TAT (minutes) distribution



Scenario 3a (direct stockpile and transload offloading) – June 2016: Transload vehicle TAT (minutes) distribution

RESOURCE REQUIREMENTS

Weighbridges (W)	In	Out
Number of units required:	2	2
Average utilisation:	68%	
% of time at full usage:	78%	

Checkpoints (C)	In	Out
Number of units required:	2	2
Average utilisation:	47%	19%
% of time at full usage:	47%	10%

Coal trucks or conveyor belts can deliver coal to the stockpile.

→ *Figure 2: The simulation results for a scenario with different replenishment requirements than the control scenario.*

The simulation of various scenarios in a coal stockyard could aid the optimisation of bulk resource transport.

From these three studies, it is clear that the simulation of various scenarios in a coal stockyard could aid the optimisation of bulk resource transport.

→ *Figure 3: The control scenario at the main entrance during afternoon traffic. Vehicles are shown in yellow and blue. A queue, peaking at 17:15, formed as vehicles exited the construction site. It took the vehicles 10 minutes to exit the site.*

→ *Figure 4: Staggered working shifts for workers were implemented in the simulation model to balance vehicle departures at the construction site. A queue still forms at the construction site exit at 17:15. It took the vehicles six minutes to exit the site.*

→ *Figure 5: In this scenario, road upgrades were implemented to alleviate congestion. The exit queue still peaked at 17:15, and it took the vehicles six minutes to exit the site.*

→ *Figure 6: In this scenario, pointsmen were deployed to alleviate congestion.*

Figure 3

Figure 4

Figure 5

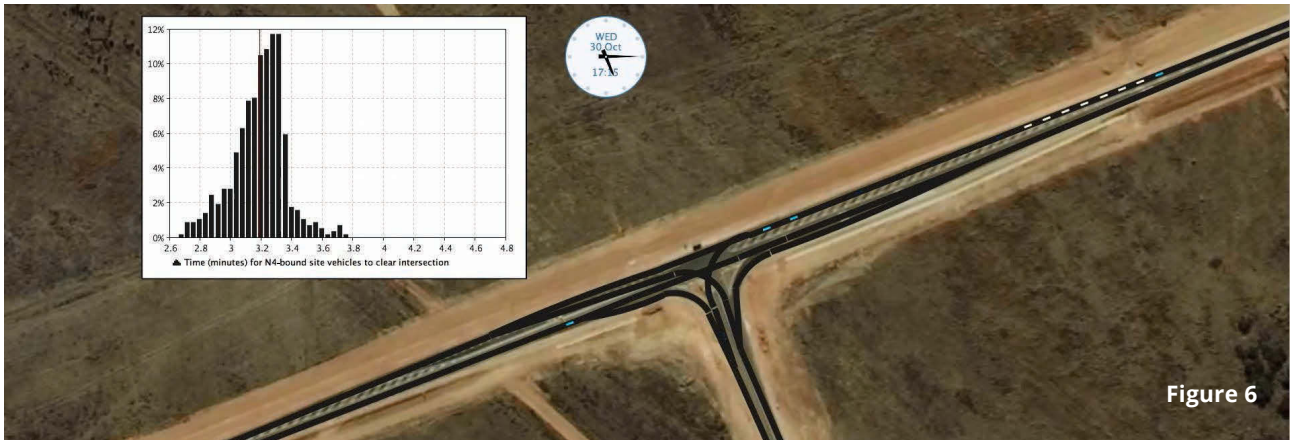


Figure 6

A look at paratransit in South Africa

Dr Susan E Woolf and Prof Johan W Joubert

Paratransit provides a valuable service offering as a flexible mode of transport between formal transit and a private car. This term collectively describes transport services such as dial-a-ride, shared taxis, community transit and subscription buses. When it evolves to compete with more formal transit modes, efforts are made to formalise it. Paratransit is a flexible mode of transport and provides mobility in a variety of settings.

Paratransit often emerges in the absence of formal transit, or in response to low-quality and intermittent services. Observing the minibus taxis – the major form of paratransit in South Africa – one may easily consider them a chaotic bunch of freelance drivers. If the mode indeed operates in a laissez-faire style, and provides all but safe transport, what is there to learn from its growth into the dominant urban mode of transport?

In Gauteng, the economic nucleus of the country that includes Johannesburg, Tshwane and Ekurhuleni, as much as 70% of all transit trips are made using paratransit, so it is by no means a small illegal operation anymore.

To appreciate the role of paratransit, South Africa's taxi industry is used as an example and shows why a better understanding of the mode opens up opportunities and establishes its potential niche. The terms "taxis" and "taxi industry" are used to describe the paratransit mode in South Africa that uses minibuses. The terms do not imply metered taxis as is often the case internationally.

The South African paratransit industry

Minibus taxi transport and the associated vernacular emerged as a consequence of the system of segregation in South Africa from 1948 to1994. During the apartheid struggle, public transport services became sporadic and unpredictable.

In earlier years, the Motor Carrier Transportation Act of 1930 prohibited the transportation of passengers by road without a permit, essentially making transport a state monopoly held by South African Transport Service (SATS). The Act was also an attempt to protect the state-owned railways from competition by road transport. Taxis were restricted to carrying no more than four passengers.

Train stations had become centres of frustration for would-be commuters. On arrival, there would be no knowing how long it would be before the next train left or if there would be place on the train to accommodate even half the passengers waiting to board. As a result, many taxis started operating illegally, especially in rural areas that were not serviced.

In the late 1970s, legislation did not define taxis per se, but implied a bus to be a vehicle carrying more than nine people (including the driver). This loophole in legislation resulted in the legal use of minibus vehicles to carry eight passengers without having to conform to strict public transport vehicle regulations. The first taxi permits were area-based, and authorised taxi drivers to operate in regions within a radius of 100 km around a central point. Competition for passengers was fierce and drivers argued over ownership of routes.

Hendrik Schoeman, who was the Minister of Transport from 1980 to 1984, recommended that taxis go back to using the four-passenger sedan vehicles. The taxi owners were concerned that this arrangement was going to kill their industry.

The South African Black Taxi Association (SABTA), the only recognised body by the end of 1989, warned that deregulation such as this would lead to too many operators entering the market too soon and would result in chaos and violence.

→ *Minibus taxis in Klein Street in the city centre of Johannesburg. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*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The minibus taxi industry developed from a need for more efficient public transport to the city centres. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)

Local taxi liaison committees (later referred to as local taxi councils) had to be set up in all major centres and local authorities would then be responsible for regulating the industry.

Dynamics in the paratransit structure

The taxi industry is often referred to as a single entity, but in itself, the industry remains dynamic. This complicated matters, because the industry did not have one unified entity to represent it, and government recognised SABTA as the main taxi organisation.

There was animosity between SABTA and the South African Long Distance Taxi Association (SALDTA). Government's solution was to split the taxi ranks: half for SALDTA and half for SABTA. By that time, many associations apart from SABTA had been formed. SABTA then mobilised to form the South African Taxi Council (SANTACO). A second group also assembled and called itself the National Taxi Alliance (NTA).

As a result of the deregulation, the taxi industry remained largely overtraded. Ambiguous permits, associations claiming taxi ranks and subsequent conflicts between local and long-distance taxi associations at the ranks often resulted in violent clashes.

Grassroots taxi operations

Despite the industry's growth, taxi operators are faced with daily frustrations. They receive no formal training and enjoy no employment protection, despite the existence of progressive labour laws.

Millions of young individuals endeavour to become part of the taxi transport industry at entry level. Many others who belong to the larger taxi associations have other commitments to face.

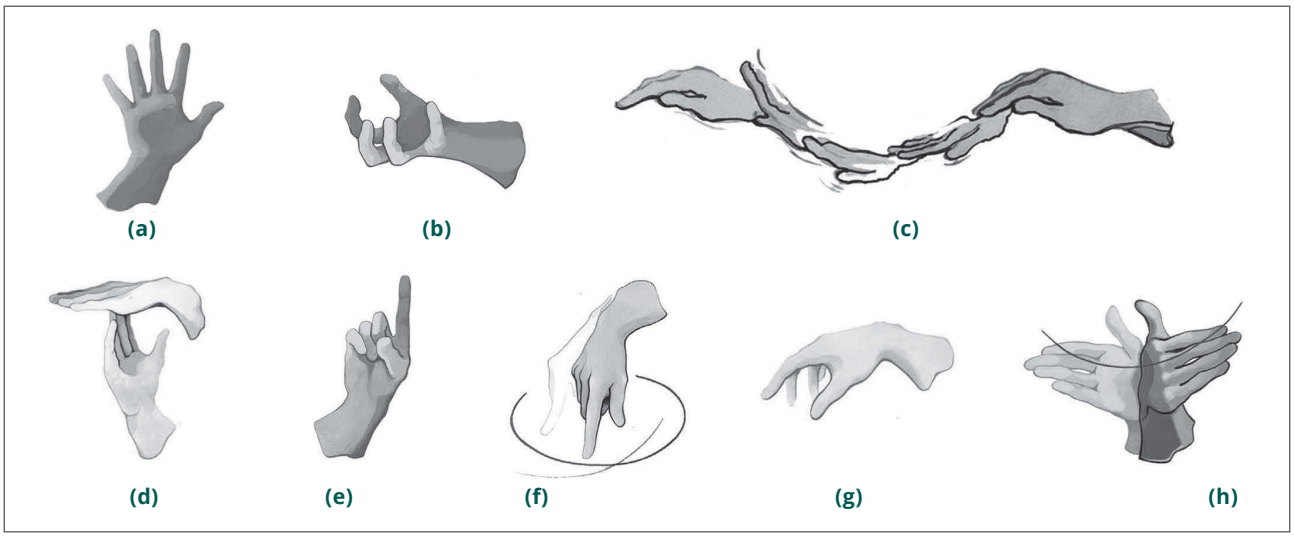
Salary structures and agreements differ among the owners, but two main models seem to emerge. In the first and most common, an owner specifies the daily check-in amount that is based on the distance of the vehicle's specific operating licence route. From the total weekly check-in earnings, the owner would then pay the driver a basic salary, typically 30% of the earnings. Tracking the exact earnings is daunting. Whatever earnings a driver makes in excess of the agreed check-in amount, after fuel expenses have been covered, are for his own pocket.

In the second model, an owner will price the check-in amount higher, closer to the total turnover, and establish a weekly contract price. The driver will then spend the first portion of the week trying to accumulate the week's contract price without having claim to any portion of the turnover. Once the contract price has been reached and paid over, the driver has the remainder of the week to drive for his own income. Financial survival, frequency of routes travelled, time, passenger capacity and number of passengers become more important than traffic etiquette, consideration, safety and rule of law.

The development and evolution of hand signals and other taxi lingo is important, since it influences the dynamic taxi commuter interaction. It is possibly a contributing factor to the widespread use of taxis and it allows taxi drivers to instantly identify commuters.

Communities often decide on hand gestures in conjunction with the taxi drivers in the area. The gestures are also used to communicate with potential passengers.

The taxi hand signal to the township settlement Orange Farm (Figure 1b) describes the name, as commuters



→ *Figure 1: A selection of taxi hand signals.*

use a cupped hand to indicate an absent orange. Many taxi hand signals are geographically descriptive of a place. The forward movement of a hand rising and falling (Figure 1c) describes the uneven ground in the area of Diepsloot. Commuters who want to catch a taxi to the nearest T-junction, simply make a T-junction with their hands (Figure 1d).

Some taxi hand signals are so commonly used that they have become established for particular destinations. For instance, the taxi hand signal to town, in most main cities in South Africa, is one index finger pointing upwards (Figure 1e). Similarly, the sign to any nearby location is a downward point using the index finger to trace an imaginary circle (Figure 1f). A cupped, downward-facing hand indicates a shopping mall (Figure 1g). The waving hand signal used for a trip from Tembisa to Sebenza (Figure 1h) indicates the direction of Sebenza, although, like many hand signals, the exact meaning may yet be established.

Interventions aimed at formalisation

In South Africa, two seemingly parallel economic systems developed (Development Policy Research Unit, 2008). The first, popularised by former President Thabo Mbeki in 2003 as the first economy, is a modern economy similar to that found in developed countries.

The first economy is formal and is well documented with receipts, records, a credit system and legally enforceable rights and remedies. The second economy lacks all these elements. It is informal and mostly regulated by community norms or self-appointed regulators, and is based on small taxless cash transactions. As the taxi industry is probably the largest single contributor to the second economy, government has made a number of efforts to formalise the industry and migrate it to the first economy.

Taxi owners feel that, instead of appreciating their contribution to mobility, government is out to punish them through formalisation. It is not formalisation per se that the taxi industry is opposing, but rather government's general approach. In engaging the industry as a single homogeneous body (at national level) with large-scale nationwide initiatives, many aspects of the essential nature of the industry, such as its grassroots communal structure, are disregarded.

One of the attempts to formalise the taxi industry was the Taxi Recapitalisation Programme. This was a multibillion rand effort from government to provide a R50 000 incentive to taxi owners to exchange their old, unroadworthy minibus taxis with newer, safety-standardised vehicles. Another formalisation attempt was Bus Rapid Transit (BRT).

With the success of BRT in other developing countries (Deng and Nelson, 2010), most notably Bogota in Columbia and Curitiba in Brazil, the South African government envisaged BRT to be a viable instrument to formalise the minibus taxi industry.

SANTACO was opposed to BRT, and the first phase of the rapid transport system was launched without agreements being reached with the taxi industry. Instead, an intermediate operating company was formed. Eventually, the City of Johannesburg secured the removal of taxi competition from the BRT routes. In return, the City agreed to pay the 313 shareholders – former owners of the 585 affected taxis – direct monthly payments, as opposed to yearly dividends, for the first four years of operation.

The current cash check-in amount required by owners has long been identified as a significant factor contributing to the generally unacceptable driving behaviour of minibus taxi drivers. Speeding and skipping traffic signals are unintended consequences of the way in which the drivers are remunerated.

The government has been using a top-down approach to influence the taxi industry for too long. It was critical to understand and appreciate the taxi industry as essentially a bottom-up entity: taxi drivers make a living by driving for taxi owners, who require decent returns on their investments. The owners make up the local associations and these associations

→ *Traders and minibus taxis in Bree Street in the city centre of Johannesburg. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*

make up regional, provincial and national bodies. A bottom-up approach enables decision-makers and change agents to successfully engage with the taxi industry.

The way forward

Changing the view of paratransit is both valuable and necessary. It should not be considered a problem that has to be solved by forced formalisation. It should be considered an essential part of the economy, both as a mobility service provider and as an employer, even if it remains completely informal or semi-informal.

The culture surrounding the taxi industry is already changing. Holland (2011) urges other road-users to consider the inherent value provided by taxis. In South Africa, decision-makers need to change their attitudes towards paratransit. Many low-income earners remain on the periphery of large metropolitan areas and require low-cost transport services. It is not economically viable for government to consider providing fixed and costly transport infrastructure.

Little fixed infrastructure is required for the taxi industry to operate, especially when compared to rail infrastructure or the expensive pavement structures for heavy BRT vehicles. A proactive approach can see a subsidy structure that outlines and benefits the responsive and agile nature of the taxi industry.

Promoting the taxi industry holds a number of scientific, social and political opportunities. Scientific, state-of-the-art research already attempts to incorporate the behaviour of paratransit operators in agent-based transport planning models (Neumann and Nagel, 2011). Social and political awareness and appreciation needs to be created to increase the accessibility of the minibus taxi industry and lower the barrier to entry.

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Inferring commercial vehicle activities in Gauteng

Prof Johan W Joubert and Prof Kay W Axhausen

People and organisations pursue their goals through participating in a variety of activities. Since the chosen activities are usually separated by space and time, some form of transport is implied, which typically requires network infrastructure such as roads, and vehicles such as cars, buses and trains. In areas where there is a limited network infrastructure for the number of vehicles, traffic congestion occurs.

Studies show that well-constructed road infrastructure, which makes up the largest category of "core" public infrastructure, decreases transport cost. In turn, lower transport cost allows companies to be more profitable. Freight and commercial services are key users of network infrastructure, and the efficient movement of freight is critical to economic vitality.

The purpose of a study conducted at the University of Pretoria was to present novel results and characteristics about transport geography in Gauteng, the economic centre of South Africa. The study aimed to introduce new metrics to evaluate a geographical area's economic productivity based on commercial activity. In this study, an activity is the loading, offloading or service activities freight vehicles perform, and not necessarily the routes they travel.

The study distinguished between vehicles that performed the majority of their activities in the study area (within-traffic) and those that performed their activities in larger geographical areas (through-traffic). Over a six-month period, the study collected the Global Positioning System (GPS) data of 31 053 commercial vehicles through on-board fleet management tracking devices.

The choice of Gauteng as the study area is useful, as it has some unique characteristics. Although it occupies less than 2% of South Africa's land surface, it accounts for more than 30% of the country's gross domestic product (GDP). The province is also a porously bound economic space that acts as a gateway into the rest of southern Africa with omnidirectional through-traffic often originating from the two main ports in South Africa: Durban and Cape Town.

South African transport policy

In a paper presented at the 21st Annual South African Transport Conference in Pretoria, Stander and Pienaar (2002) reviewed the early South African permit system, which favoured government-owned railways and has restricted the carriage of goods by road since 1930. A gradual deregulation of freight towards free competition started in 1977 and concluded in 1989. The substantial increase in road freight haulage since the economic deregulation was only governed by the technical and safety regulation of operators and vehicles. In essence, government lost control of where freight moved, and to a large extent, of what was being moved.

In the past, the freight system was configured to support the movement of the products of inward industrialisation and provided cheap transport to a very limited number of economic participants, most of which were government-owned and -regulated (Fourie, 2001). The system was characterised by uneven flows of goods, and had dramatic peaks in specific areas. The Department of Transport implemented a project called Moving South Africa to address the challenges of the transport sector in 1999. The project outlines the strategic framework for the South African transport sector up to 2020. It addresses urban, rural, freight and special transport needs, analyses the sustainability of the present transport system, and presents possible solutions to the problems the industry faces.

Extracting activities from GPS data

DigiCore Fleet Management, which offers vehicle tracking and fleet management services, made its Ctrack system data available for the purposes of this study.

The detailed GPS log of commercial vehicles from 1 January 2008 to 30 June 2008 was recorded during the study. A total of 31 053 vehicles were identified, which represent approximately 1.5% of the national heavy and light delivery vehicle population. The vehicles represented in the GPS data are from customers subscribing to DigiCore's vehicle tracking and fleet management services.

In this study, ignition triggers were used to identify activity start and stop times. The start of an activity was identified as the point when an ignition is turned off, and an activity stops when the ignition is turned on again. Figure 1 shows the duration of all activities before chains of activity were identified. There are no clear breaks in the histogram, suggesting a definite, logical distinction between minor activities that make up the links of the activity chains and major activities that signal the start and end of an activity chain. The total number of activities exceeded 10.5 million. Although 31 053 vehicles represent a sizable sample, only the density of commercial vehicle activities could be estimated. This was achieved through kernel density estimation. The density maps of the minor and major activities are very similar.

An interesting observation was the near-continuous activity along the major route connecting Gauteng to Cape Town via Bloemfontein, as well as along the route from Gauteng to Durban (Figure 2). There is limited development along the majority of these routes, especially between Bloemfontein and Cape Town.

Activity and chain characteristics

The first analysis of the GPS data aimed to distinguish between through-traffic vehicles and within-traffic vehicles. Through-traffic vehicles perform activities in more than one geographical area, while within-traffic vehicles perform activities in one specific geographical area.

The 60% of vehicles that are considered through-traffic in Gauteng is considerably higher than the 6% reported by Hunt and Stefan (2007), who also conducted a study of the modelling of freight transportation and distribution systems in Calgary, Canada. This difference is attributed to the fact that Gauteng is a gateway into southern Africa. On average, 97% of the vehicles were active in Gauteng.

The time-of-day analysis of activities in South Africa confirms the survey results of Hunt and Stefan that commercial activities take place throughout the business day and not necessarily during the morning

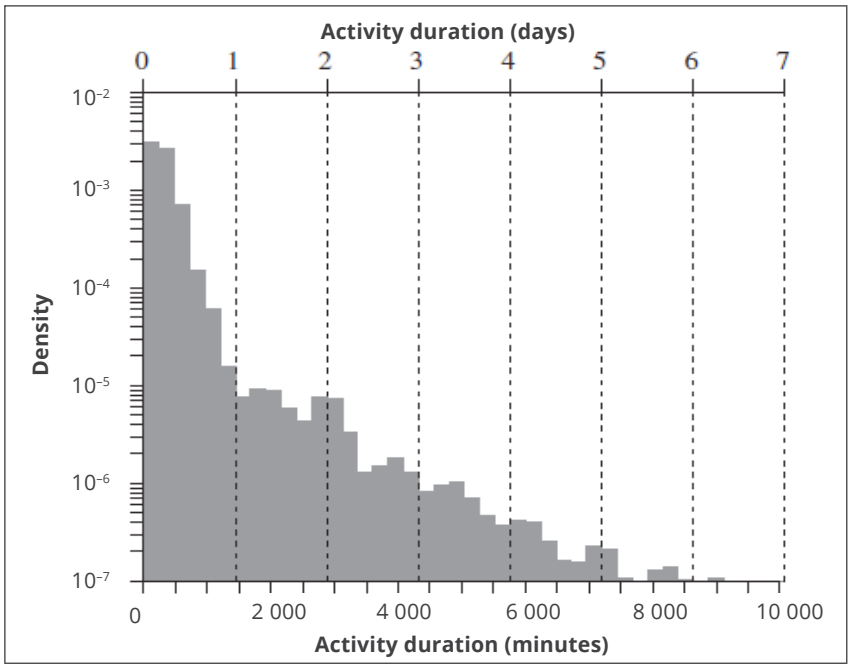


Figure 1: Histogram of all activity durations.

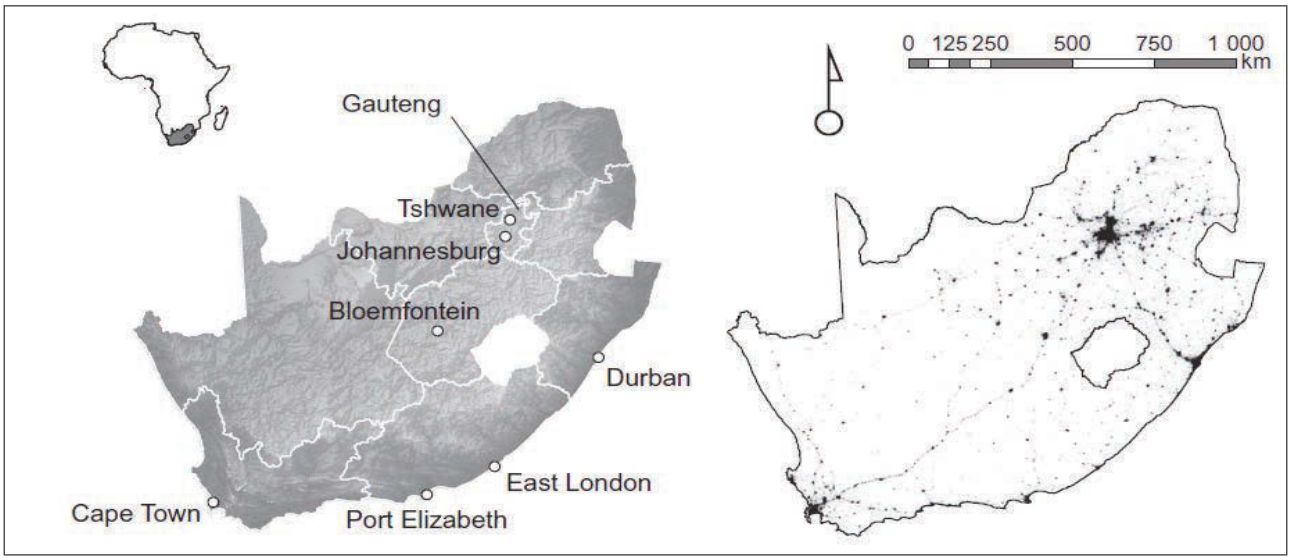


Figure 2: The extent and density of activities throughout South Africa, indicating Gauteng as the province of interest.

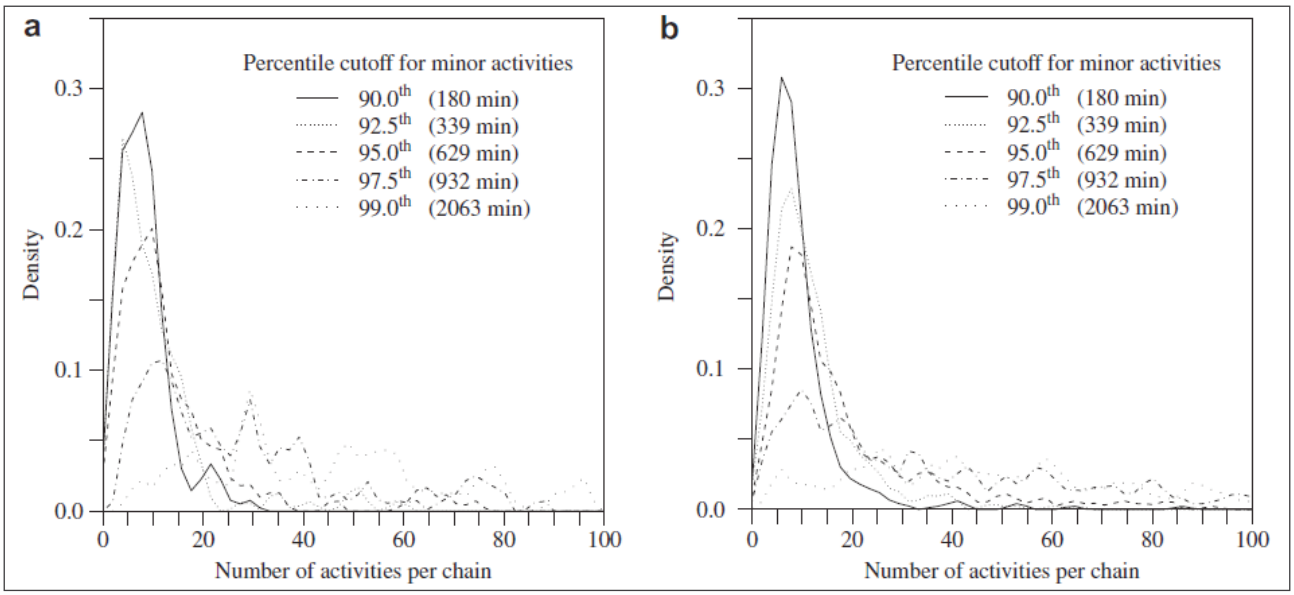


Figure 3: Comparison of the number of activities per chain for the different minor activity thresholds: (a) within-traffic and (b) through-traffic.

and afternoon peaks. Approximately 75% of all activities start between 08:00 and 17:00. The disaggregate description of commercial activities makes a significant contribution to understanding the spatial impact of commercial vehicles.

The number of activities per chain change with different minor activity threshold values was analysed. The comparison in Figure 3 distinguishes between within-traffic (Figure 3a) and through-traffic (Figure 3b). As expected, the higher the threshold value for both within- and through-vehicles, the more activities are included in each chain. The similarity of the distributions of the two vehicle types was not anticipated. It seemed plausible that within-vehicles would perform more activities during a business day than their through-traffic counterparts that are (typically) associated with long-haul trips where fewer, but larger deliveries per chain are concerned. On the contrary, the study shows that within-traffic has slightly fewer activities per chain.

Although the activity chain characteristics were much clearer at this point, the study attempted to find a way to link the spatial density of activities in Gauteng to productivity. Government funds the development and maintenance of transport infrastructure from taxes and levies. Fuel and road levies (tolling) also contribute to the development and maintenance of transport infrastructure. In return, people and companies need good transport infrastructure to competitively pursue their goals and be profitable.

In an article that refers to the richness and diversity of freight transport geography, Rodrigue (2006) notes that the transport and logistics corporations are generally more profitable than their (mostly) government-owned counterparts. Freight, being spatially more challenging and diverse than public transit, provides a means to measure the productive use of the infrastructure of a province.

Productivity metrics

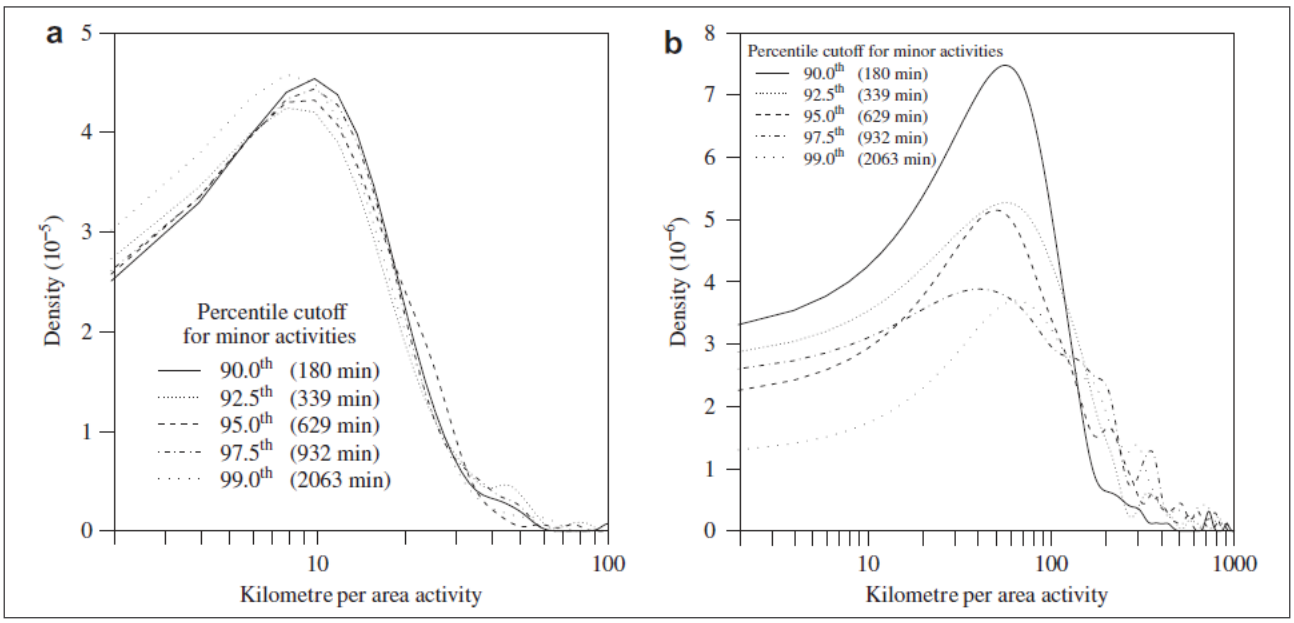
The premise of the metrics that evaluate a geographical area's economic productivity based on commercial activity is that commercial vehicle activities contribute to the profitability of companies and to the GDP.

The first metric is fiscal and calculates the amount of GDP generated by the province with each activity conducted in the province. The higher the metric value, the more productive an area, contributing more to GDP per commercial vehicle activity. Gauteng makes the highest fiscal contribution at R151 700 per activity, followed by the Western Cape at R106 200 and KwaZulu-Natal at R73 100.

Another metric that could be used to determine the freight productivity of a province is distance per activity. For each vehicle, the total distance of chains that had one or more activities in Gauteng was divided by the total number of activities the vehicle performed in the province. The fewer kilometres travelled on the road per activity, the more spendable GDP could be invested in the development and maintenance of infrastructure. The results are visualised in Figure 4, which again distinguishes between within-traffic and through-traffic.

Within-traffic is more productive than through-traffic. As within-traffic performs the majority of its activities within the province, its use of the road infrastructure is much higher. The contribution is also higher with more activities and the combination results in a more productive use of the road infrastructure, and a lower metric value.

Since traffic congestion is notoriously unproductive, it is interesting to note that between 60 and 87% of chains have ended before the afternoon peak starts at 16:00. This further fuels the debate that commercial vehicles are lesser contributors to peak-hour congestion.



→ *Figure 4: Comparison of the chain distance per activity metric for the different minor activity thresholds: (a) within-traffic and (b) through-traffic.*

Density comparisons

There is a significant overlap between activity densities and population densities. In a paper published in *Journal of Transport Geography*, Hesse and Rodrigue (2004) observe that distribution centres are concentrated on the fringes of urban areas and beyond. In South Africa, logistic activities are concentrated in the urban areas, especially in Gauteng.

To be an effective economic hub and gateway into southern Africa, Gauteng should consider a strategic urban development plan. This plan should consider the activities and movement of both people and freight. As a result, the richness of the transport geography cannot be fully exploited with only the observed characteristics of commercial vehicles, for example, the number of activities per chain, the chain duration and the temporal distribution of activities. The interaction of commercial vehicles with their environment needs to be considered in an appropriate context.

Conclusion

Although Rodrigue (2006) praised the profitability of the freight transport sectors, such praises may be somewhat dampened if the work of Stander and Pienaar (2002, 2005), which notes that freight does not cover the full social and political cost for its road use, is considered. Knowing where business and freight stakeholders are located and what the interactivity distances are will allow researchers to evaluate and compare the activities against underlying land-use data in the future. In turn, land-use analysis may provide guidelines in predicting future freight activities based on strategic land-use master plans.

Using a large-scale agent-based transport simulator such as the Multi-agent Transport Simulation (MATSim) toolkit makes it possible to incorporate freight movement in dynamic traffic simulations.

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Designing energy-efficient mineshaft systems

William Kempson

The mining industry in South Africa faces many challenges, primarily in the area of electrical energy consumption. In 2007, South Africans faced increasingly stringent load shedding of the electricity supply. In January 2008, Eskom took the unprecedented step of informing its key industrial consumers (KICs), including mines, that it could no longer guarantee its electricity supply to them. This announcement resulted in the temporary closure of all deep-level mines associated with large mining houses, such as Anglo American and Gold Fields, because of safety concerns in the event of power failures.

As the mining industry is one of the mainstays of the South African economy, it was decided to evaluate the design of mineshafts to determine whether their total energy consumption could be reduced. The Department of Mining Engineering at the University of Pretoria was approached to discuss potential opportunities for the reduction of energy requirements in mines, thus emphasising the impact of future mine design.

Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering, and William Kempson, a postgraduate student, concluded that there was potential for optimising the design of vertical shafts, specifically with regard to reducing the pressure losses that occur in deep-level vertical shafts. The initial calculations showed that more than 50% of the pressure generated by a mineshaft's main ventilation fans is dissipated as the ventilation air is forced through these shafts. The contribution of Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering, is acknowledged in this research.

Impala Platinum was approached to conduct the necessary research, and a few mineshafts were tested to obtain the data needed to verify the assumption. The actual pressure losses on the Impala 14 Shaft were measured. These measurements for the main downcast shaft were obtained by installing a pitot tube manometer 15 m above the main cage, stopping at various points in the vertical shaft to take pressure, temperature and velocity measurements.

The results were compared to calculations that were made by using the current theory. They showed good agreement. This confirmed that the vertical shafts consume a significant amount of energy to allow the ventilation air to move through them. The complication of the shaft conveyances that provide additional obstructions past which the ventilation air would have to move was also a cause of concern. A method needed to be found to include these variables while the shaft evaluations were being conducted.

It became clear that results acquired from this study would be thorough and directly applicable to industry. Consequently, the researchers set about the work in the following four phases:

- **Phase 1:** A detailed evaluation of the current body of knowledge associated with the design of shaft systems and the flow of ventilation air through them.
- **Phase 2:** A detailed testing of actual shafts to understand the flow of ventilation air through them. This would need to include the movement of the conveyances to measure the pressure differences against time in conjunction with the movement of the shaft conveyances. These measurements were then compared to the current theory.
- **Phase 3:** A computational fluid dynamic (CFD) model would be completed for each of the measured shafts to allow for the calibration of these models against the measured data.
- **Phase 4:** Once a CFD model had been calibrated and proved, the researchers would be able to make a careful modification to this model to try and reduce the shaft system's energy consumption.

Building and calibrating the CFD model

As the CFD model was being built (using Star CCM+), various versions of the same model were run,

The current theory does not provide sufficient accuracy to design new shafts, as it does not account for the effect that the shaft equipment has on the ventilation flow.

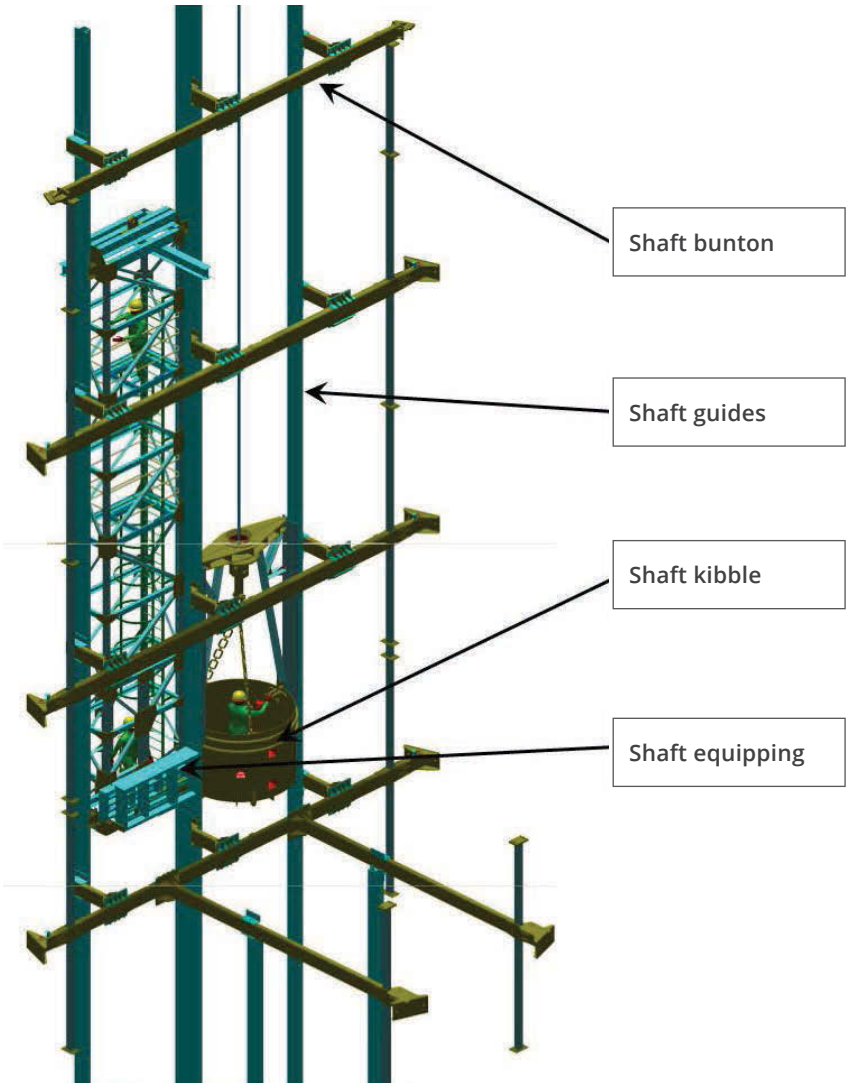


Figure 1: The various components of a mineshaft.

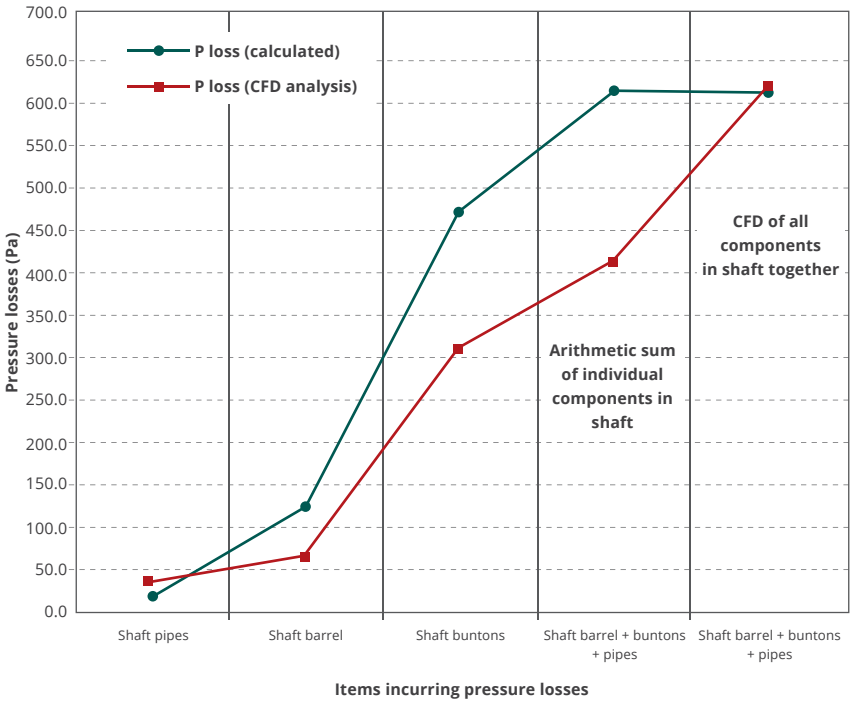


Figure 2: Calculated and CFD-analysed pressure loss in a shaft.

while pieces of shaft equipment (for example, shaft buntons and shaft guides) were added. This approach allowed the researchers to understand the contribution of each individual obstruction to the overall shaft pressure loss. The current theory also allowed the evaluation of these individual obstructions, and was used for comparison as the models were constructed. The current theory already proved accurate according to the physical shaft measurements obtained in Phase 2.

At first, there was very little agreement between the CFD model results and the values calculated from the current theory. The differences in the pressure losses between these two calculations exceeded 30%. However, as the researchers continued to build the model and the complexity of the model increased, so did the agreement between the measured data and the CFD data. When the entire shaft was modelled, there was almost complete agreement between the two models.

Figure 2 illustrates the differences between the various obstructions in the shaft and the shaft pressure loss calculations. When the items in the shaft are considered in the CFD model, the individual and cumulative pressure losses of the items in the CFD analysis are not equal to the calculated data. However, when the shaft equipment is considered as a whole and the model is run, there is close agreement between the results.

This means that the current theory does not provide sufficient accuracy to design new shafts, as it does not account for the effect that the shaft equipment has on the ventilation flow. Furthermore, the assumption made for the pressure losses associated with the pipes and the shaft conveyance was calculated incorrectly.

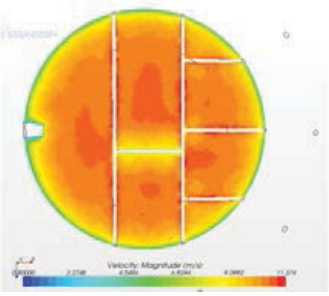
The illustrations in Figure 3 show the pressure losses and velocity distribution over the shaft at various cross-sections. This shows that the separate items have markedly different velocity profiles when

compared to the profile of the equipment as a whole.

This particular result demonstrates the dangers of measuring systems and then adjusting the known theory to fit the results. While this allows some prediction of pressure losses in similar systems, significant errors can be made when different systems are evaluated using the same theory.

With this new knowledge, a typical shaft system was modelled. In an effort to reduce the pressure loss over the shaft length, changes were made to the shaft buntons and the placement of pipes around the shaft. Table 1 and Table 2 demonstrate that significant savings can be accrued if this technique is used to analyse shaft systems.

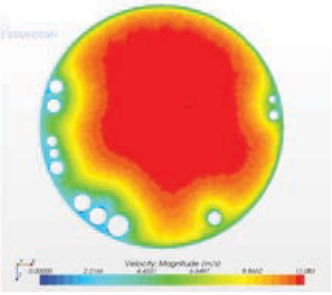
This research demonstrates that the use of modern analysis techniques, together with good engineering, can yield results that are beneficial in situations where researchers think they already understand the theory. This has resulted in an analysis technique that will help with the design of future mines and has the potential of saving significant sums of money at no additional capital costs.



Calculated pressure loss (Pa/m) – 0.65

CFD-derived pressure loss (Pa/m) = 0.44

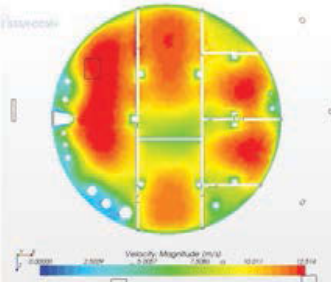
Red: 11.3 m/s
Blue: 0.0 m/s



Calculated pressure loss (Pa/m) – 0.15

CFD-derived pressure loss (Pa/m) = 0.11

Red: 11.1 m/s
Blue: 0.0 m/s



Calculated pressure loss (Pa/m) – 0.71

CFD-derived pressure loss (Pa/m) = 0.71

Red: 12.5 m/s
Blue: 0.0 m/s

Figure 3: Pressure losses and velocity distribution over the shaft at various cross-sections.

Table 1: Difference associated with bunton shapes

Item	Description	Shaft P_{Loss} (Pa)	Ratio differences	Life of mine (20 years) (potential savings)
1.01	Airflow buntons	822	1.00 (baseline)	–
1.02	Streamlined buntons	774	0.94	-R5 738 460
1.03	Square buntons	1 608	1.95	R94 046 991
1.04	I-beam buntons	1 324	1.61	R60 413 237

Table 2: Difference associated with piping placements

Item	Description	Shaft P_{Loss} (Pa)	Ratio differences	Life of mine (20 years) (potential savings)
2.01	Piping along shaft edge (no flanges)	857	1.13	R12 114 528
2.02	Piping away from shaft edge (no flanges)	819	1.08	R7 651 281
2.03	Piping distributed around shaft (no flanges)	755	1.00 (baseline)	R -
2.04	Distributed piping with flange	867	1.14	R13 310 040

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Finding digital forensic evidence in document counterfeiting

Enos Mabuto and Prof Hein Venter

Counterfeit documents created in graphic design programs often enable serious crimes, such as terrorism, fraud, money laundering and theft. Therefore, it is very important that law enforcement entities are able to identify counterfeit documents by acquiring an accurate understanding of how these documents are created. A study in the Department of Computer Science investigated ways in which these documents can be traced in order to be used as evidence.

Many graphic design applications can be used to create counterfeit documents, such as identity documents (IDs), driver's licences and passports. Adobe Systems Incorporated is regarded as the largest software manufacturer of graphic design software (Kell, 2011). The Adobe suite consists of applications such as Adobe Photoshop, Adobe InDesign and Adobe Illustrator. Adobe Photoshop is a professional industry standard application for digital image editing and creation. Adobe InDesign is a professional layout and design application that delivers production workflows, complex graphics and typography. Adobe Illustrator is an application used for vector artwork in planning projects.

These three graphic design applications were used to create approximately 300 dummy counterfeit documents. These documents were created by editing the following four personal identifying insertions: barcodes, fingerprints, signatures and photographs of human faces.

Because the counterfeit documents are generated electronically, digital evidence can be collected to trace the source of fraud. Digital evidence is defined as any hardware, software or data that can be used to prove the occurrence of a breach of security (Barret et al., 2005).

Computer evidence further consists of digital files and their contents left behind after an incident. Traces that are left behind from the use of an application or from an operating system can be referred to as digital forensic artefacts. There are three methods of gathering digital evidence: system-generated, user-generated and timeline-associated digital evidence.

System-generated digital evidence

System-generated digital forensic evidence refers to evidence that is automatically produced by the application without any specific user intervention. These digital forensic artefacts show that a document has been scanned, edited, saved and printed.

Generally, when one attempts to create a fraudulent document, it is necessary to first acquire an original document so that one can use it to create a new and fraudulent identity. When a criminal does this, the first action is to scan the original document to make it available for digital editing on a computer.

The study focused on the digital artefacts that are created from executing the scan commands in the graphic design application. These scan commands need to be executed in the same graphic design application that subsequently edited the scanned document.

In the course of the study, 20 documents for each application were scanned. When a document has been scanned, the application automatically records the digital artefact (the forensic evidence that scanning has taken place) into one of its log files. After scanning has taken place, the criminal may inevitably follow it up by editing the acquired document in order to falsify some of its content.

Document editing is one of the most important stages in the creation of a counterfeit document, because it allows the criminal to insert objects of interest into the scanned document. These may include the image of a human face, a barcode or a fingerprint.

Editing actions include typing, colouring or drawing. The study focused on the kind of editing that results in the insertion of an image or object, because these can later be used by an investigator to determine whether the document that was created was counterfeit or not. During the analysis of the inserted objects, the researchers tried to establish what could be inferred from a computer system that would indicate to a digital forensic examiner what had been inserted and the location from which it was inserted.

Once a document has been edited, the user usually needs to save it in order to print it, or to edit it further.

An Adobe Photoshop log file records the digital artefacts that indicate entries saved. Adobe Photoshop records the location where the files were originally saved, as well as the original file size. Entries with the actual names of the saved documents are located at about six tenths of the log file. This entry consists of the full file name. It includes the location and the file extension in which the document was saved.

The log file InDesign SavedData contains information about the name and type of the file that was saved, as well as the location where the file was saved. This information is recorded at various locations in the log. The digital artefacts for saved entries are recorded consecutively in the log file, with the latest saved document appearing first.

Printing is one of the last stages of counterfeit document creation. A user might need to create a hard copy of the edited document so that it can be used in a physical environment. Unlike what happens in scanning actions, printing actions can be performed in all the graphic design applications under consideration.

In order to locate the place from which printer(s) were used to print a document, one makes use of one of a number of registry entries to establish a printer connection. After establishing the installed printers, the actual physical existence of the printers can be verified. This can be a great help to an investigator in cases where actual printers have been removed. Physical printers are necessary in an investigation, because they are needed to match the digital evidence to the actual printer so that the case against the criminal can be supported in court proceedings.

User-generated digital evidence

In order to conduct a comprehensive investigation into any crime that has been committed with the use of a graphic design application, the digital forensic examiner must first acquire a thorough understanding of the nature of the files that are generated from the particular graphic design applications that are being used by the criminal.

When examining counterfeit documents, the digital forensic examiner initially examines all changes that have been made to files in a systematic way. The investigator will thus make a careful study of all the fingerprints, barcodes and human faces that are embedded in the graphic design application file types. The three graphic design applications that have been described and utilised in this study are associated with more than 39 file types. In this study, however, the researcher has only focused on file types that are specific to the three graphic design applications, and has excluded other well-known file types.

Before an investigator examines a file intensively, he or she needs to first establish its identity or file extension. Content identification is the process that an investigator uses for determining or verifying particular types of specific files. Counterfeiting criminals have the capacity to alter the file extension of a particular file to confuse potential investigators and conceal the trail that might lead to their conviction. It is therefore essential to confirm the integrity of files by conducting a file signature analysis. In this particular case, a digital forensic examiner must be able to recognise a file type. The real file identity can be found in the content of the file, and is usually known as the file signature. This kind of signature is uniform for all files with an identical file extension. It is normal practice to identify a file signature by examining its first bytes (Carvey, 2009).

Content examination refers to the retrieval of any embedded metadata that may be present in any given file. Content examination necessitates the identification of the metadata of files, which are graphic design application file types. Metadata means “data about data”. Metadata is an indispensable component of any forensic digital investigation, because it contains evidential information about what might be extracted from a particular file. Such information may include the name of the tool that was used for criminal purposes or the name of the perpetrator who used the application.

Timeline-associated digital evidence

The timeline of activities refers to the kind of digital evidence that is based on the interpretation of the time stamps that are automatically generated in graphic design applications. Time stamps are a vital and indispensable part of any forensic digital investigation because they provide incontrovertible digital evidence of when alleged criminal activities occurred.

In any digital forensic investigation, it is necessary to establish a timeline so that the chain of criminal actions can be linked and explained in such a way that they are comprehensible to anyone connected with the case who is not familiar with the technicalities of a digital forensic investigation. This kind of explanation is indispensable for obtaining a successful outcome in a criminal case. For example, the suspect will sometimes deny that a particular application was installed and used for creating counterfeit documents. Under such circumstances, it becomes necessary to prove that a particular application was installed and that it was actually

used for criminal purposes. The time stamps that are associated with the installation and the application's subsequent uses are interpreted.

The timeline indicates the sequence of a series of events between the installation and the execution of an application. At this point, the digital forensic examiner will know when the application was installed and when it was last run. The investigator will then be able to make use of the actual files, the time stamps, and the modifying dates obtained from user-generated digital evidence to establish whether these files were created between the time of installation and the last date of execution of the application.

Timelines of this kind can be used to determine whether the actions taken during the editing of the document occurred between the installation of the application and its last use. All of this is vital information to support a case in court against someone who is suspected of counterfeit activities. It is, of course, possible to construct a timeline for other applications if one takes their unique circumstances and settings into account.

Investigating counterfeiting

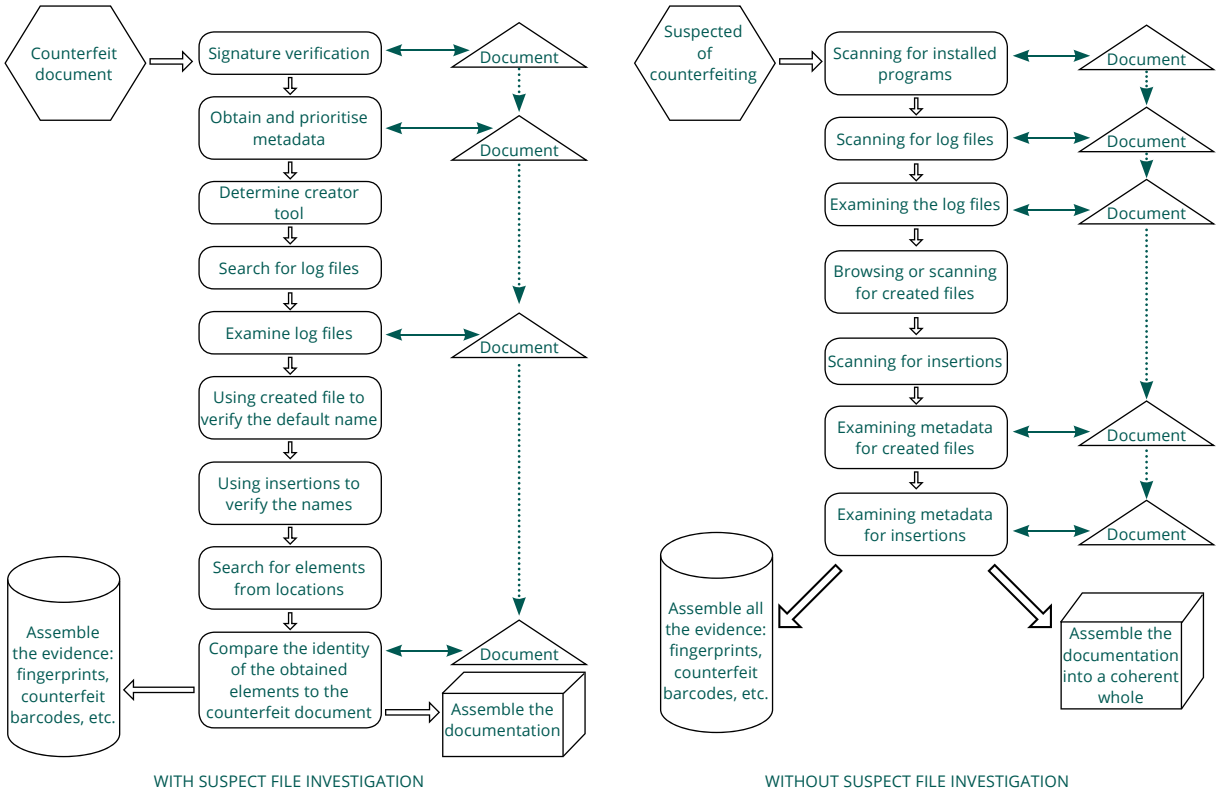
Investigating counterfeiting is a two-pronged process, which is both application- and platform-independent. This means that, with the necessary adjustments, it can be applied to any graphic design application or operating system.

This two-pronged approach is based on two hypotheses. The first, referred to as "without suspect file" (also known as the blue route), is based on a computer system that might have been used for counterfeiting purposes, even though there is no suspicious digital evidence. The system might be questioned because hard-copy counterfeited documents were found in the vicinity of the system. The investigator's task is to establish whether or not the system was actually used for counterfeiting. The second is concerned with investigating a file for which there is *prima facie* evidence of counterfeiting. This is referred to as "with suspect file" (also known as the green route). This approach is based on the existence of a digital file that is assumed to be implicated in the creation of a counterfeit document.

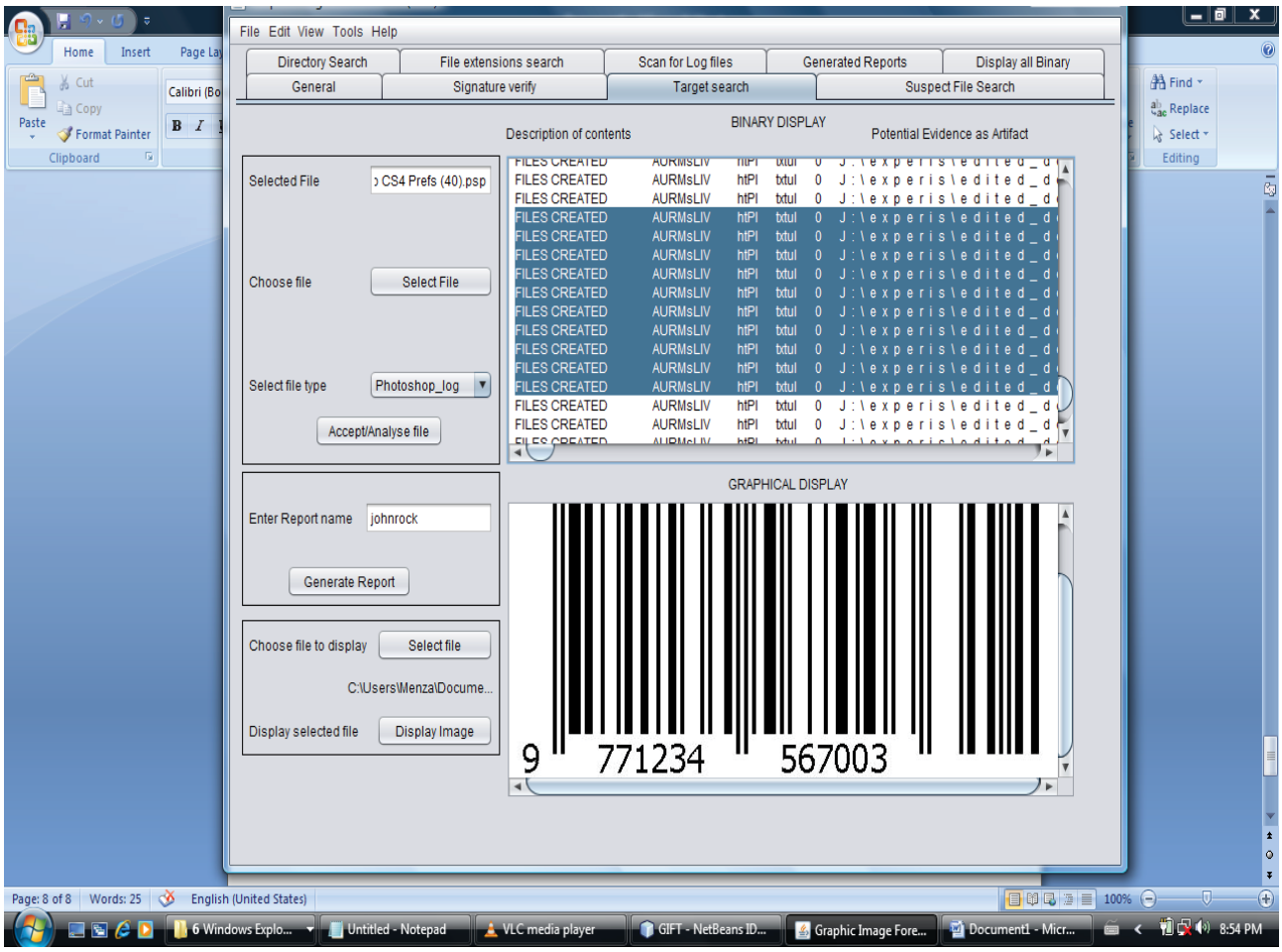
The investigator who uses the green route assumes that an acquired digital document is counterfeit. An investigator can identify a document saved in a graphic design file type and open it using any pre-installed application. This may result in an assumption that it is a counterfeit document. One may arrive at the same assumption by examining the naming of a document. For example, a document that is named Jacob_Meyer_passport is likely to arouse suspicion. When there are reasonable grounds for suspicion, an investigator will accumulate sufficient digital evidence to support the suspicion that the document is counterfeit.

In the counterfeit investigation, the investigator undertakes a number of logical steps to obtain digital evidence that can be used to establish whether the document is counterfeit.

Once a suspect document has been obtained, the first step is to verify its file type (file format). By verifying a file's signature, an investigation is initialised on the identity of that file. It is then necessary to document the file signature from analysis.



→ *Figure 1: Two-pronged counterfeiting investigation process.*



→ *Figure 2: Graphic representation of the tool.*

Graphic Image Forensic Tool

A tool was developed to assist investigators to accumulate digital evidence that indicates how counterfeiting activities were carried out. Graphic Image Forensic Tool (GIFT) was developed in Java programming language on a Net-beans platform. GIFT enables an investigator to examine and perform digital forensic tasks on the basis of the graphic design applications that were selected for this research. This tool can determine whether a suspect file is counterfeit by extracting essential forensic evidence. GIFT can identify the author's name, the time stamps, the copying of the original document and the names of the printed documents. It can also recognise the identities of the inserted objects by displaying the actual barcode and the image of the human face that were inserted during editing, as indicated in Figure 2. As it works on the principle of extracting essential forensic evidence from documents, GIFT may prove to be an indispensable tool for catching perpetrators, particularly as it can successfully reveal actions by criminals to conceal their actions, such as the renaming of files, file deletion and disc wiping.

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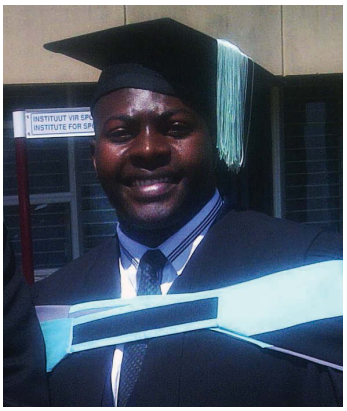

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The causality and determinants of energy and electricity demand in South Africa

Dr Roula Inglesi-Lotz and Prof Anastassios Pouris

The current energy crisis has many people asking questions related to the factors that influence electricity demand and prices. A study by Dr Roula Inglesi-Lotz of the Department of Economics in the Faculty of Economic and Management Sciences and Prof Anastassios Pouris of the Institute for Technological Innovation focused on existing energy research to investigate the causal relationship between energy consumption and growth or the determinants of energy demand in South Africa from 2007, and to outline recent forecasts for electricity demand. Their findings have the potential to inform the relevant stakeholders to make appropriate interventions to improve operations in the energy sector.

The South African energy crisis of 2007/08 had such negative consequences – not only on the sector itself, but also on the economy – that research in the field has increased substantially, as indicated in Figure 1. This research has been increasing over the last three decades, with the curve becoming steeper from 2007 onwards.

As a result of the crisis, Eskom applied for further electricity price increases in the future. This has sparked debates on whether it is indeed necessary and how increases will affect the energy sector and the economy. The discussions among policy-makers, researchers, industrialists and various stakeholders in the country revolve, firstly, around the relationship between energy demand and economic growth (which one affects which), and secondly, the determinants of energy demand. Both topics are of particular importance for the forecasting of energy demand through the policy decisions made.

Appreciating the importance of these issues, the researchers reviewed, summarised and critically assessed the studies from 2007. The results of this review aimed to identify gaps in existing research on the causality and determinants of energy and electricity.

This research is significant because it is the first primarily econometric study on energy in South African literature. Previous investigations were conducted purely from an engineering perspective.

The causality of energy and electricity demand

The question of whether a relationship exists between energy (electricity) demand and economic growth has attracted massive attention in international literature. The existence of this relationship is of great importance, especially for energy policy-makers. In a global environment where energy conservation is a target for many governments, but where growth, development and sustainability are also high on the political and economic agenda, energy conservation policies should not become obstacles to a country's growth. Apart from the existence of the relationship, the direction of the

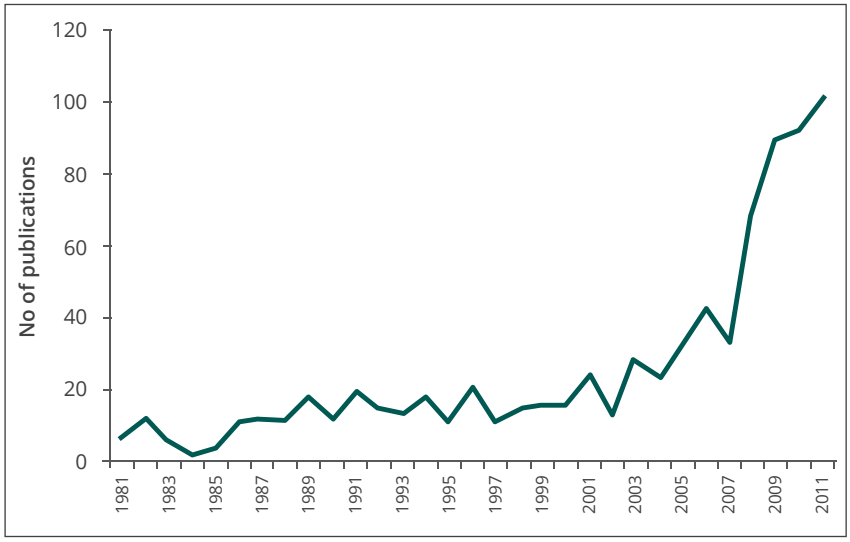

Figure 1: The number of publications in the field of energy and fuels in South Africa from 1981 to 2011 (Source: ISI, 2010).

causality also has significant policy implications. Four possible scenarios of the causal direction have been identified in research by Prof John Asafu-Asjaye (2000), James E Payne (2010a and 2010b) and Dr Jay J Squalli (2007):

- **Growth hypothesis:** According to this hypothesis, there is a unidirectional causality from energy consumption to economic growth. The implementation of policies aimed at the reduction of energy demand/consumption will affect the economic growth of the country.

- **Conservation hypothesis:** This hypothesis assumes that energy consumption is dependent on economic growth. If this hypothesis holds, energy conservation policies, such as phasing out energy subsidies, will have no effect on economic growth (Mehrara, 2007; Kahsai et al., 2012). On the contrary, it is confirmed that the higher the economic growth of a country, the more energy is used.

- **Neutrality hypothesis:** According to this hypothesis, there is no causality between the two variables. Energy conservation policies will have no effect on economic growth, and improving economic growth will not influence energy consumption.

- **Feedback hypothesis:** This hypothesis assumes that the causality between the two variables runs in both directions (they are complementary) (Kahsai et al., 2012). Decreases in energy consumption will affect economic growth, which will subsequently affect energy demand.

The studies have, however, failed to reach a consensus on the direction of the causality. Payne (2010b) surveyed studies that examined the direction of the causality between energy consumption and income, and found that in the individual country studies surveyed, 29.2% of the results supported the neutrality hypothesis, 28.2% the feedback hypothesis, 23.1% the growth hypothesis and 19.5% the conservation hypothesis (Kahsai et al., 2012). Another survey of the studies by Payne (2010a), which investigated the causal relationship between electricity consumption and economic growth, showed approximately the same results: 31.5% supported the neutrality hypothesis, 27.87% the conservation hypothesis, 22.95% the growth hypothesis and 18.03% the feedback hypothesis (Kahsai et al., 2012).

Studies have failed to reach a consensus on the direction of the causality.

Since 2007, nine studies have dealt with the South African case. They have examined the relationship between the country's energy or electricity consumption and economic growth, either individually in a time-series context or in a panel data framework together with other countries, usually from the African continent. Based on the discussion of the findings in the international literature, the fact that the studies' conclusions vary for the South African case is not surprising. For example, Al-Mulali and Sab (2012) and Eggoh et al. (2011) confirm that energy consumption causes economic growth, while Esso (2010) concluded exactly the opposite. Interestingly, Kahsai et al. (2012) found that there is no relationship in the short run (neutrality hypothesis), but a bidirectional causality exists in the long run (feedback hypothesis).

The majority of these studies employed a traditional Granger causality test by estimating vector autoregressive (VAR) models. Interestingly, various studies that use the Granger test differ in the technique they use to identify cointegration: for example, Esso (2010) uses the Gregory and Hansen testing approach, Odhiambo (2010) uses the autoregressive distributed lag (ARDL) bounds testing procedure, while Kahsai et al. (2012) use the cointegration test established by Pedroni in 1999. To improve on the Granger causality test, some studies have used a modified version of this test proposed by Toda and Yamamoto (1995). The advantage of this test is that it avoids potential bias linked with unit root and cointegration tests.

Although a bivariate analysis of the relationship between energy consumption and economic growth is not unusual in the international literature, the majority of the studies concerning South Africa operate within a multivariate framework. Wolde-Rufael (2009) argues that the relationship should be examined from a complete production function view where energy is an input to economic growth, together with capital and labour. Continuing with this argument, he agrees with Lutkepohl (1982) that the exclusion of relevant variables might affect the accuracy of the causality tests. Except for the rest of the factors of production employed as additional variables, such as employment, and labour and capital employment, other studies used prices, financial development or pollutant emissions.

The drawback of the multivariate analysis is the inability to properly compare different studies' conclusions. The variation of the results with regard to the direction of the causality can be attributed to factors such as different econometric techniques, variable selection, the time period examined and specific testing procedures. Balcilar et al. (2010) also argue that the reason behind the variability is partially due to the relatively small data span of the sample periods covered, especially for studies that include the 1980s, and, secondly, due to the structural or regime changes. When omitted, these structural breaks can lead to misspecifications and false results (Eggoh et al., 2011).

→ *Rainbow over Eskom electricity pylons. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*

Determinants of energy and electricity demand

In accordance with basic economic theory, the international literature assumes the demand for goods or services is usually dependent on factors such as their own price, the income of the consumers, the price of substitute goods and other exogenous variables related to the nature of the goods. The majority of international studies include the income of the consumers (or economic growth) and the price of energy (electricity) as main explanatory variables. Other studies include the prices of possible substitutes, such as natural gas, heating oil and others.

As studies such as those of Esso (2010), Kahsai et al. (2012) and Odhiambo (2010) have found that economic growth causes energy (electricity) consumption in South Africa, it is considered one of the main determinants. The majority of the studies that examined the determinants of energy or electricity demand in South Africa has included income or economic growth among the significant factors.

Another key determinant is the price of electricity. The first attempt to estimate the influence of electricity prices on electricity consumption was made by Pouris (1987). Since then, different econometric approaches have been used to assess the impact of price.

Ziramba (2008) examined the residential electricity demand and found that, for the period 1978 to 2005, the price of electricity was insignificant in the long run. Amusa et al. (2009) also found that electricity prices had an insignificant effect on aggregate electricity demand for the period 1960 to 2007. On the contrary, Inglesi (2010) found that price was a significant explanatory variable for electricity consumption between 1980 and 2005. The conflicting results are explained by Inglesi-Lotz (2011). She found that price elasticity was becoming lower through the years in absolute terms, and price was thus becoming an insignificant factor, while the real prices of electricity were generally declining. The insignificance indicated by Amusa et al. (2009) can be linked to the almost zero elasticity values; with a focus on short-run dynamics, price was found to be insignificant. Indeed, Inglesi (2010) also concluded that, in the short run, price was not a determinant of electricity consumption. Inglesi and Pouris (2010) used the same approach to forecast electricity consumption and to critically assess Eskom's estimations.

The majority of the studies on the determinants of energy and electricity demand employed time-series econometric analysis. Cointegration techniques were most commonly used, but two studies attempted to identify the factors affecting changes in energy and electricity consumption by using decomposition methods (Inglesi-Lotz and Pouris, 2011; Inglesi-Lotz and Blignaut, 2011). The overall results showed that changes in the structure of the economy and changes in the efficiency with which the country uses energy (electricity) play an important role in the trend of energy usage.

These studies also investigated the behaviour of different sectors of the economy. Inglesi-Lotz and Blignaut (2011) looked at electricity consumption factors for five sectors of the economy. Their results showed that only for the industrial sector, both output and price were significant variables, while for the industrial and commercial sectors, only economic output was a positive factor. For the agricultural, transport and mining sectors, electricity consumption was neither affected by price nor by production between 1993 and 2006.

For residential demand in particular, variables representing micro-behaviour, such as household size or number of appliances, have also been used in the literature, along with variance in weather conditions. For the South African case, Louw et al. (2008) examined the determinants of electricity demand for newly electrified low-income African households. Their results showed that income, wood fuel usage, iron ownership and credit obtained were the main determinants of electricity consumption in the two examined areas, Antioch and Garagapola. For the specific case of Gauteng, Senatla (2011) looked at the energy demand projections and income dynamics of the residential sector. The assumed drivers included the number of households, population, electrification growth rate and the households' mobility among various income categories.

Electricity demand forecasts

Not many studies have dealt with the direct forecasting of electricity demand after estimating its driving forces. Forecasting can be considered an art in the sense that its correctness and accuracy are highly dependent on the choice of variables and the assumptions made for the future.

As part of the Integrated Resource Plan 2010 (IRP2010) formulation process, the System Operations and Planning Division (SO) (2010) and the Council for Scientific and Industrial Research (CSIR) (2010) forecast electricity demand using primarily statistical modelling and expansion of historical trends, while Inglesi (2010), and Inglesi and Pouris (2010) make use of econometric forecasting methods. The main difference between their results may not stem from the employed methodology, though, but rather from the choice of variables to predict the future electricity demand values.

SO (2010) and CSIR (2010) do not use price as a driving force for electricity consumption. SO (2010) suggests that the price sensitivity of consumers should rather be incorporated into the gross domestic product (GDP) growth values than be included as a separate factor. The CSIR (2010) model omits the price impact on electricity demand for two reasons. Firstly, it believes that it is impossible to model price elasticity successfully at the national level and there is a need for sectoral price elasticities. Secondly, due to the fact that such high electricity price increases have not occurred in the past, there is no precedent set for further analysis.

→ *Electricity pylons in Beaufort West in the Western Cape. (Photograph: Chris Kirchhoff, MediaClubSouthAfrica.com.)*

On the other hand, Inglesi (2010), and Inglesi and Pouris (2010) employ econometric methods to estimate the price elasticity, and, based on specific assumptions, show that the inclusion of prices (and their high increases lately) can even overturn the path of electricity consumption from upwards to downwards. It is important to mention that the 1986 review identified that all forecasts for 2000 predicted a demand of 300 000 GWh. No study took the effects of prices, technology-based efficiencies and similar factors into consideration. The actual demand for electricity during 2000 was approximately half of the projected demand.

It should be noted that the recent efforts were made before the effects of the global economic crisis of 2009 were visible. All the studies assumed high economic growth rates and production; a fact that was not confirmed in the recent economic data. As a result, recurring forecasting exercises using the latest available data are needed in the country. As stated by the CSIR (2010), the existence of numerous forecasting studies is beneficial for the country and their aim should not be to replace one another, but rather to provide additional support to each other's methods and results.

Conclusion

Dr Inglesi-Lotz and Prof Pouris found that studies examining the causality direction between energy (electricity) consumption and economic growth failed to reach a consensus. The main differences were the time periods examined, the econometric approaches and the variables included in the estimations. On the other hand, the studies on the factors affecting energy (electricity) demand agreed that economic growth, income and output are considered significant factors. There were a few differences in the results regarding the role of prices, but these can be attributed to the different econometric methods used, as indicated by Inglesi-Lotz (2011). Reaching a consensus on the nature of these relationships is imperative for the proposal and implementation of appropriate policies to conserve energy and promote economic growth.

Along with the diversity of methodological approaches, another potential reason for the results is the availability or lack of data specific to the country. One would expect studies on South Africa to use detailed and exact data from local sources. This is the case for a number of studies, where data is derived from the energy balances of the Department of Energy.

Earlier studies used data from Eskom's annual reports and the electricity supply statistics of the National Energy Regulator of South Africa (Nersa), because the energy balances of the Department of Energy were not up to date.

This fact indicates that because of the increasing econometric modelling of South Africa's energy issues, local stakeholders should focus more on the collection, reporting and publication of reliable and usable energy information. A sectoral analysis of the energy sector is imperative due to the sectoral policies that are needed in South Africa.

The review of the forecasting studies showed a lack of such activity for the South African case, lately. Individual studies that employ different methodologies and assumptions offer policy-makers a range of possible forecasting values that will assist in the appropriate interventions. Critically reviewing the success or failure of past forecasts could also assist in developing more accurate forecasts.

→ *Prof Anastassios Pouris (left) and Dr Roula Inglesi-Lotz.*

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Research emphasis and collaboration in Africa

Anastassios Pouris and Yuh-Shan Ho

Researchers contributing to recent scientometric literature regarding scientific co-authorship among African researchers are increasingly investigating the effects, modes and dynamics of, and motives for collaboration. Prof Anastassios Pouris and Prof Yuh-Shan Ho conducted a study to identify co-authorship patterns of research on the African continent through an examination of both the patterns of collaboration at country and continental levels and the scientific disciplines that are emphasised.

Governments utilise research collaboration as a policy instrument for knowledge transfer from abroad and as a means to improve diplomatic relations with other countries by creating goodwill in order to gain political capital (Wagner et al., 2001). Governments allocate substantial resources in support of this objective. Russell (1995) and Wagner et al. (2001) suggest that international collaboration is replacing other models as the preferred method of building scientific capacity in developing countries.

Prof Pouris and Prof Ho approached their research from a policy perspective regarding the importance of assessing the benefits (or otherwise) of international collaboration to the African continent.

Researchers collaborate with each other for various reasons. However, the practice of collaboration is not without debate in terms of its risks and benefits. Arguments against collaboration include the concern that spending on international cooperation is not always beneficial to the paying country and that critical technologies and key knowledge for competitiveness are given away to competitors. An additional concern is the notion that collaborative agreements advocate strategic or political ends rather than the interests of science and technology.

An issue of specific importance in the African context is the dependency on the size of collaboration and the size of the scientific community. Narin et al. (1991) found that the number of international co-authorship projects of scientifically small countries is higher than that of larger scientific countries. Melin (1999) concludes that researchers from scientifically large countries collaborate less internationally than researchers from scientifically small countries, because the first group easily finds partners within its national borders.

Historically, studies on research collaboration focused on data from industrialised countries. More recently, such studies have included developing countries in general and African countries in particular. For this project, co-authorship analyses were used to identify the state of research collaboration on the African continent. The researchers attempted to answer the following questions:

- Which scientific disciplines are emphasised in Africa?
- How did research collaboration evolve in Africa between 2007 and 2011?
- Who are the main research partners of African countries?
- Are the patterns of collaboration (extended and disciplinary) in Africa similar to those in the rest of the world?
- How do the various African countries perform in terms of collaboration?
- Which are the main African institutions that are actively engaged in collaboration?

Data sources and methodology

The data used in this study was retrieved from the Science Citation Index Expanded (SCI-Expanded) of the Thomson Reuters Web of Science. All journal articles that were published in this index by authors on the African continent were selected and analysed to identify publishing institutions and countries, and to classify articles as collaborative or single-authored publications. The researchers limited the analysis to publications between 2007 and 2011, and articles were the only document type considered.

The collaboration type was determined by the affiliation of the authors and is presented in the following way:

- Internationally collaborative publication (ICP) – articles that were co-authored by researchers from at least two countries
- Inter-institutional collaborative publication – articles that were co-authored by researchers from at least two institutions
- Institution-independent article – articles where the researchers' affiliation was from the same institution
- African collaborative publication (ACP) – articles whose authors' affiliations were from different countries on the African continent
- Outside-African continent collaborative publication (OCP) – articles that were co-authored by authors from Africa and from countries outside the African continent

The identified articles were further allocated according to the Web of Science subject categories. The journal citation reports of 2011 indexes 8 336 journals, classified across 176 Web of Science categories. A total of 111 877 articles published by authors in African countries between 2007 and 2011 were analysed.

Output in research areas

The number of world publications in particular fields was compared with the number of African publications in these fields, and the African share and its activity indices in the different fields were determined. The activity index indicates the relative research effort a country or region devotes to a given field. It is defined as the country's share in the world's publication output in that field, divided by the share of the country or region in the world's publication output in all science fields.

It was found that the most emphasised research fields are those of tropical medicine (12.5 times bigger than that expected from the scientific size of Africa), parasitology (6.5 times bigger than that expected from the scientific size of Africa) and infectious diseases (4.6 times bigger than that expected from the scientific size of Africa). The list of emphasised research areas is dominated by medical and natural resources fields (for example, biodiversity, water resources, entomology and mining).

The research areas that are under-emphasised in Africa include those underpinning modern technologies and economies (for example, engineering, physics, chemistry and materials science). This is in contrast to a country like China, which emphasises engineering, physics and chemistry. This raises the following questions: Why does Africa not follow international examples? Are the needs of the African continent served best by its current research emphasis?

These findings lead to arguments that the small research community and research activities on the continent will not be able to resolve current scientific challenges, such as the HIV/AIDS pandemic. If the regional capacity is unable to provide a scientific or technological solution to a challenge, overemphasis on particular disciplines will not be fruitful. Similarly, while international efforts to develop high-technology industries based on brain power are emphasised, these trends are ignored by African countries. For this reason, it may be advisable for African researchers to move away from expensive fields like medicine and focus on wealth-creating disciplines that generally require less investment and may be more easily diffused in African economies and societies.

Characteristics of collaborative publication outputs

During the five-year period studied, the number of articles from Africa increased by 50%. Single-country articles increased by 35%, while the internationally collaborative articles grew by 66% – almost twice the growth of the single-country articles. It is interesting to compare the share of internationally collaborative articles from Africa (54% of 111 877 articles) with those in other countries between 2007 and 2011.

In the same period, the number of publications and collaborations by the top 20 prolific countries in the world amounted to 5 114 346, as indicated in SCI-Expanded. The Brazil, Russia, India and China (BRIC) members had relatively similar percentages of internationally collaborative articles (26% for Brazil, 33% for Russia, 20% for India and 23% for China). Higher percentages could be found in the Group of Seven (G7) countries (33% for the USA, 51% for Germany, 26% for Japan, 54% for the UK, 52% for France, 44% for Italy and 49% for Canada).

With regard to the collaboration of individual African countries, it was found that these countries exhibit substantially high patterns. Nigeria was the only country with a collaboration rate lower than 50%. Twenty-nine countries published more than 90% of their articles in collaboration with other countries. Although it is possible that the division of the continent into 54 countries may contribute to the

This research was approached from a policy perspective regarding the importance of assessing the benefits of international collaboration to the African continent.

substantial number of collaborative articles, other factors may also affect the apparent pattern.

Internationally collaborative articles grew from 52 to 58% on the African continent between 2007 and 2011. Internationally, articles that list institutions from more than one country (internationally co-authored articles) also grew dramatically, but only from 10 to 24% between 1990 and 2010 (National Science Board, 2012).

From a policy perspective, it is important to identify the benefits or otherwise of international collaboration on the African continent. Does the African agenda direct the collaborative research agenda or is collaboration directed by international imperatives?

Africa's main collaborating partners are the USA, France and the UK. It is important to note that these countries are not only the most collaborative countries in the world (National Science Board, 2012), but also the largest funders of research in the biosciences, with a specific emphasis on medicine and agricultural sciences in Africa.

Single-authored articles in Africa are a matter of concern. The share of single-authored articles in Africa is very small (a single-digit number for most countries). This may raise questions as to whether there is a scarcity of researchers on the continent who are able to undertake research on their own. With the exception of Nigeria (29%) and Egypt (43%), all African countries produce more collaborative articles with co-authors from other countries than with local co-authors.

It is also important to note that the number of OCP articles is much bigger than the number of ACP articles. What drives researchers in Botswana and Zimbabwe, for example, to produce more than 74% of their collaborative publications outside Africa? South African universities are a few hours away by road, while Europe and the USA are a number of hours away by plane.

Similarly, why does Egypt collaborate almost exclusively with non-African countries? Conclusions derived from these examples may argue that African collaboration is not driven by local researchers searching for collaborators, but by the availability of resources and interests outside the continent.

Egyptian (9) and South African (7) institutions dominate the list of the most prolific institutions on the African continent. Ethiopia, Nigeria, Tunisia and Uganda also appear on the list. All institutions have a larger number of inter-institutional collaborative articles than single-institution articles.

An angle to be emphasised in this regard is that South African universities are subsidised by the government according to the number of publications produced by their members of staff (Pouris, 1991). This is a disincentive to inter-institutional collaboration, because collaborating institutions have to share the government subsidy. However, the high share of inter-institutional collaborative articles from South African universities indicates that the forces promoting inter-institutional collaboration are stronger than the adverse impact of the funding mode.

Conclusion

Small scientific countries, because of their scientific limitations, have to be particularly attentive to their research priorities in order to optimise their developmental goals.

The above argument is supported by the identified disciplinary emphasis of Africa's research on natural resources and the medical fields. While it can be argued that this emphasis is underlined by the resources available on the continent and the diseases present, it may be that these priorities are not necessarily the best options for the continent's developmental objectives. It should be mentioned that African

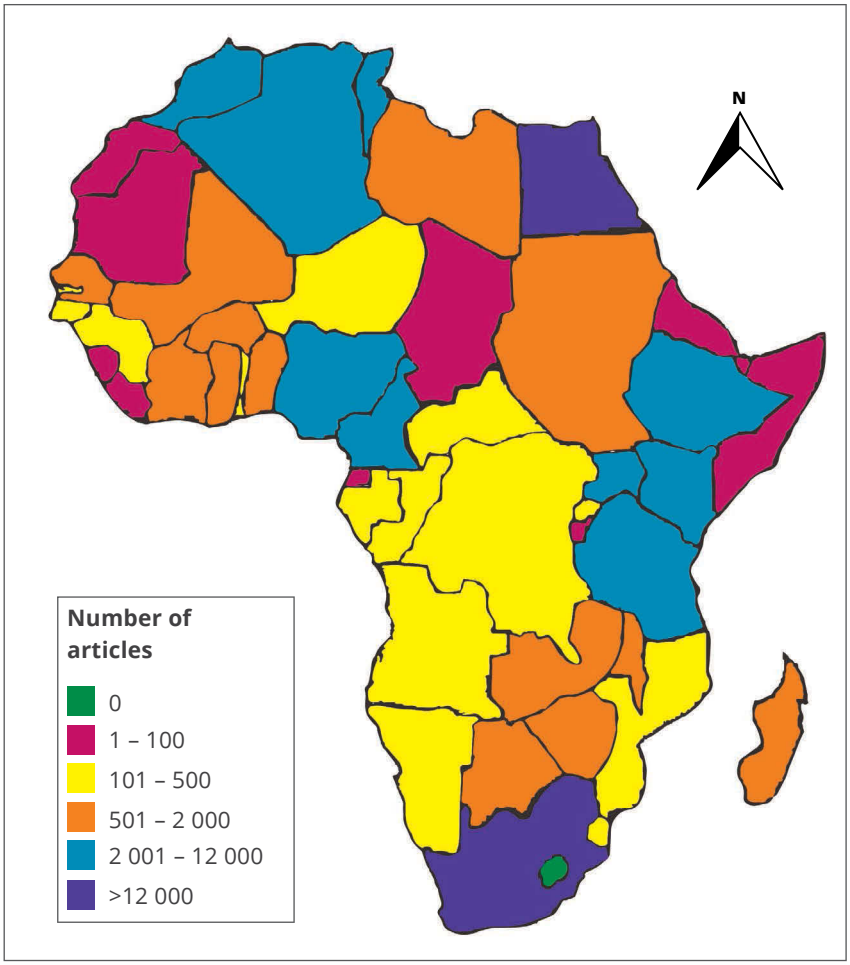

Figure 1: Distribution of articles in African countries.

prioritisation mechanisms, and any embryonic efforts in this domain are based on the immediate needs of the existing activities, and not on the most achievable and beneficial efforts for the future when the research outputs will materialise.

In the African context, South Africa, for example, spends considerably more research efforts in the field of HIV/AIDS than what is expected from its relative scientific size. It is doubtful that the HIV/AIDS epidemic can be resolved by South African research alone, without the support of the rest of the world. This emphasis may need further assessment (Pouris and Pouris, 2011).

The identification of the research outputs of the African countries and their related collaborative patterns show that the continent suffers from subcritical research systems and collaboration dominance. Single-author articles on the continent appear to be on the verge of extinction. This could be the effect of foreign funding sources that favour groups of researchers and not individual researchers.

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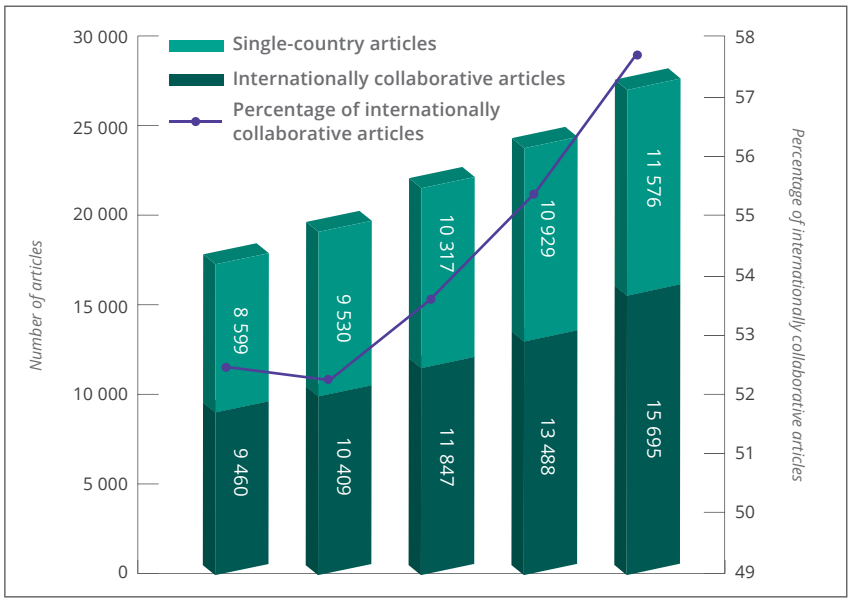


Figure 2: Growth in African collaboration: 2007–2011.

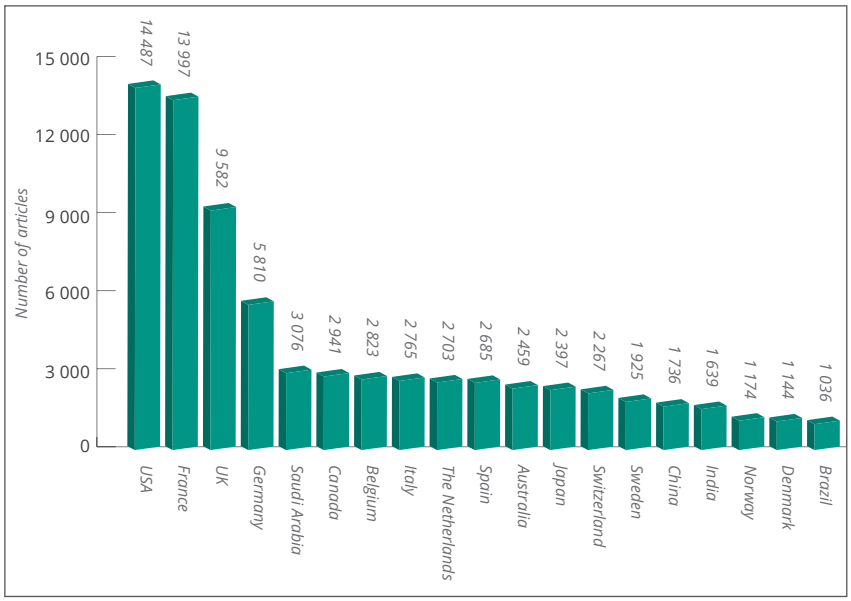
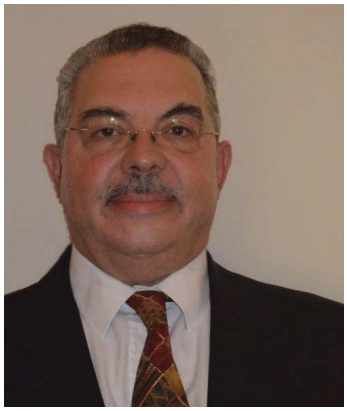


Figure 3: The main collaborating countries with Africa: 2007–2011.



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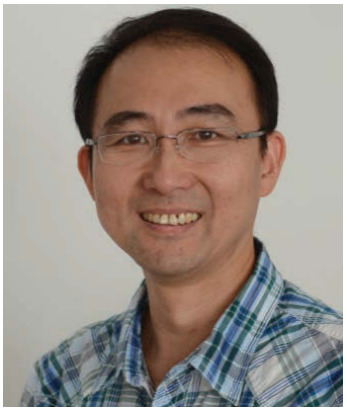

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The effect of digital publishing on the traditional publishing environment

Susan Gaigher, Dr Elizabeth le Roux and Prof Theo Bothma

Digital technologies, such as e-books, are predicted to have a profound effect on publishing, but are yet to have a serious impact on the industry. Research conducted in the Department of Information Science at the University of Pretoria considered the implications of digitisation and digital publishing for the trade book publishing industry in South Africa by evaluating the current state of the industry using the context and predictive value of disruptive technology theory.

Digital technology is seen as a disruptive technology in the traditional print publishing environment. The principles of disruptive technology can therefore be applied to develop recommendations and suggest strategies for publishers who are planning to venture into digital publishing. Although the research focuses on South African trade publishers, the results and recommendations can be applied to different sectors of publishing, as well as to the wider international publishing industry.

The hype surrounding e-books and digital publishing has come, gone, and returned with renewed vigour since the first e-book was published in 1971. Today, the industry faces a high level of e-book optimism again. In July 2010, Amazon revealed that it was selling 180 e-books for every printed book (Teather, 2010).

Not long after that, the publishing industry was shocked at the news that the e-book market had exceeded expectations and had reached the $1 billion mark (Gobry, 2010). Even before these figures were released, publishers like Simon & Schuster and Penguin Books USA, and the bookseller Waterstones, had reported significant growth in their e-book sales (Wyatt, 2008).

Despite these promising reports, the future of digital publishing is still highly speculative: It is not clear when and to what extent publishers will move into digital publishing or if and when the market will truly embrace e-books.

But whether or not e-books will eventually usurp printed books in the marketplace, publishers cannot afford to ignore the vast opportunities created by digital technology. Guenette et al. (2010) believe that, for publishers, and their technology and service partners, the challenge over the next few years will be to invest wisely in technology and process improvement, while simultaneously being aggressive about pursuing new business models. In such a speculative environment, research is needed to provide direction in the transitional phase between traditional and digital publishing.

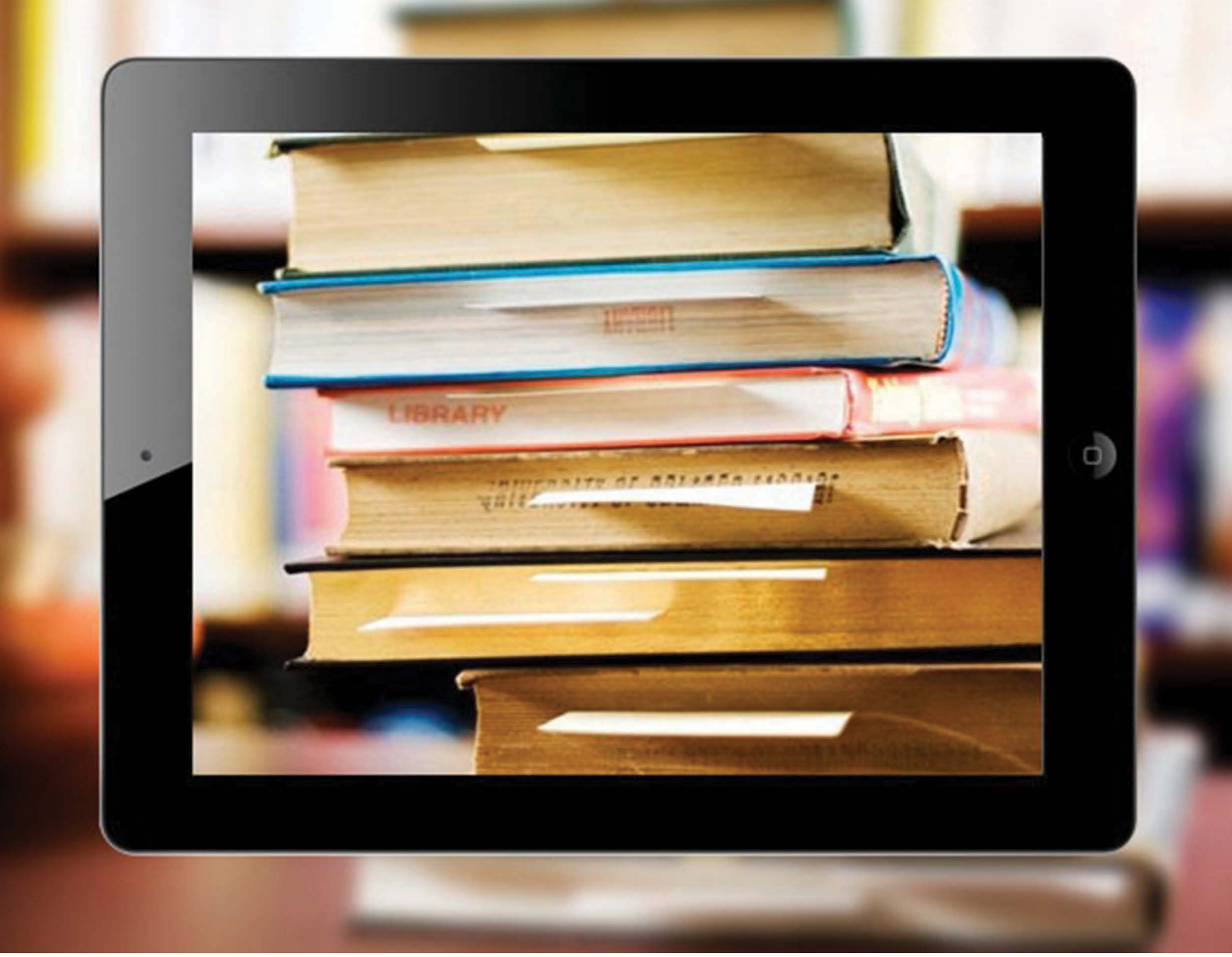
Selecting a suitable business model

There are no clear guidelines for the selection or implementation of the significant new technologies that are available to publishers. Moreover, although business models will need to be revised to encompass new value-adding processes as supply chains and value chains change, there is still no consensus on the most suitable business model or framework for publishers.

This is even more true of the publishing industries in small countries. In South Africa, there has been very little research in the field of digital publishing, and no standards for implementation exist. To fill this gap, research was undertaken to investigate the current state of digital publishing in the South African trade publishing industry in 2010 and 2011 (Gaigher, 2013).

Research

The focus of the research was on the digital publishing strategies of South African trade publishers, as well as the ways in which publishers are using internet communication channels, such as social networks, in their businesses. The empirical research employed a mixed-methodology approach that



→ *The future of digital publishing in South Africa is highly speculative. It is not clear to what extent publishers will move into digital publishing or if and when the market will truly embrace e-books.*

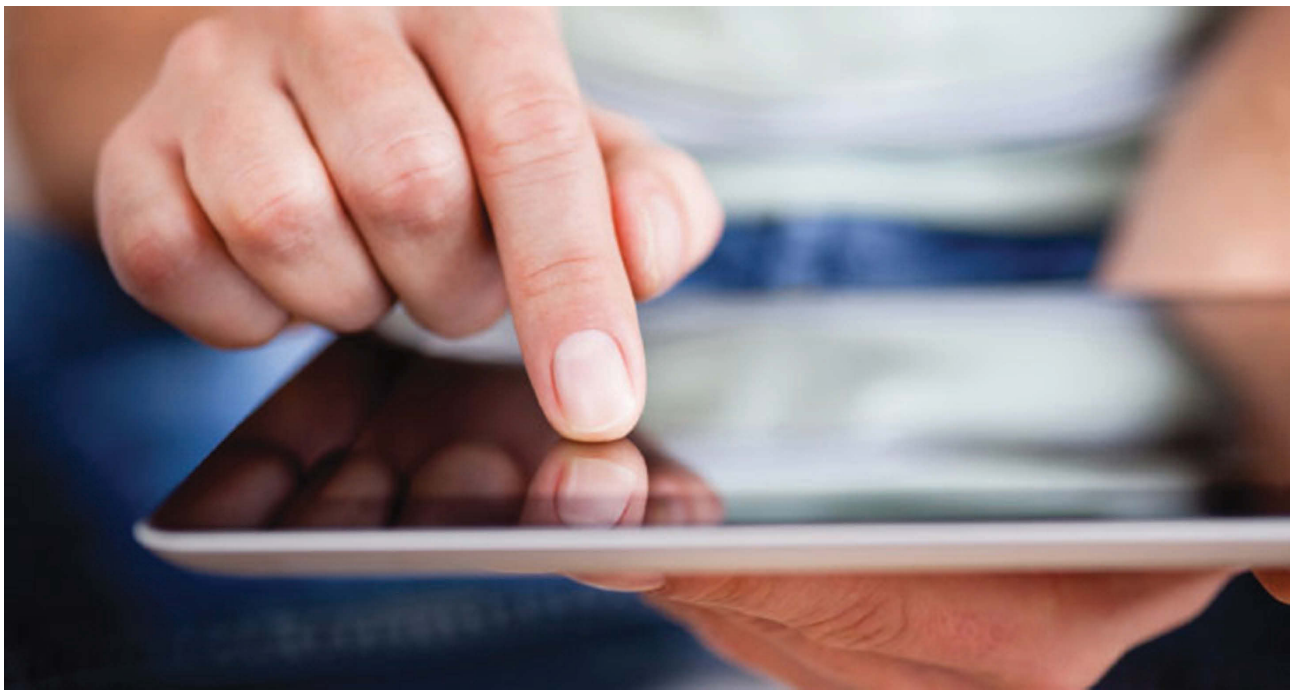
included an online survey of trade book publishers, reinforced by follow-up interviews with selected participants. The principles of disruptive technology theory served as a theoretical framework for the study.

Disruptive technology

When one considers the changes necessitated by digital developments in the publishing industry, one can consider digital publishing to be a potential disruptive technology. Harvard Business School professor Clayton Christensen first coined the term "disruptive technology" in 1997 (Christensen, 1997).

A disruptive technology is a technology that initially serves only a niche market, but eventually displaces the current technology in the mainstream market (Christensen, 1997). Disruptive technologies initially underperform in comparison with established ones in serving the mainstream market, as they do not satisfy the minimum requirements that are most valued by mainstream customers (Danneels, 2004). Over time, as research and development investments are made and technology matures, the performance of the disruptive technology improves to the point that it can also satisfy the requirements of the mainstream market. During this process, those firms that supported the disruptive technology – often new entrants – tend to displace incumbent firms that only supported the traditional technology. Therefore, disruptive technology often goes hand in hand with the displacement of established firms by new entrants. If one follows the logic of disruptive technology, one can theorise that digital publishing could prove so successful that traditional publishing houses lose their market dominance and even disappear (Burk, 2001). Mierzejewska (2008) proposes that disruptive technology theory can provide a valuable tool to evaluate the potential threat of new technologies to the publishing industry.

Two factors that have been identified as pivotal to a company's ability to survive disruptive technology are the resource allocation process and the organisational resources, processes and values (RPV) framework (Danneels, 2004). Using these parameters as a basis,



→ *Disruptive technology theory can provide a valuable tool to evaluate the potential threat of new technologies in the traditional publishing industry.*

this research sought to reconcile publishers' digital publishing approaches with the predictions of disruptive technology theory.

The state of digital publishing in South Africa

In South Africa, e-book markets are in a very early stage of development. This makes it difficult to compare this emerging segment with the overall publishing industry. In 2011, the Publishers' Association of South Africa (PASA) included data on the sales of electronic books in its annual statistical survey of the publishing industry for the first time (PASA, 2011).

This data was based on the number of titles made available, the number of paid downloads, and the revenue generated by these sales. The total net turnover of the general trade e-book industry in South Africa was found to be only R102 000 in 2011. In 2012, this figure grew to R1 036 000 (PASA, 2012).

To place these very small figures in perspective, the total net turnover for general print books in 2011 was more than R400 million and in 2012 it was nearly R480 million. The report also showed that only 111 locally produced e-books were available for downloading and that 896 paid downloads had been recorded for 2011, which suggests an average of eight downloads per title (PASA, 2011). This shows that the South African e-book market is in an embryonic stage when compared to the international e-book market.[1]

Empirical research in the form of a survey conducted among trade publishers confirmed that digital publishing in the South African trade publishing industry is in its infancy. The survey respondents consisted of a sample of 13 trade publishers who were already engaged in, or planning to venture into digital publishing soon after 2010. The sample included incumbent firms (well-established, traditional print publishers) and new firms (small publishing startups), and represented at least two-thirds of the trade publishing industry in South Africa.

The data revealed that 62% of respondents were small- to medium-sized publishers with between one and 20 full-time employees. The average number of e-books published annually by publishers was 39, but this figure is disproportionately influenced by three large, established publishers that each publish close to 100 electronic titles annually. Disregarding these large publishers leaves an average of 15 e-books annually for each of the seven remaining publishers. This gives a total of 105 titles, wich correlates closely with PASA's figures of 111 local e-books available for download. PASA's 2011 report found that this number had grown exponentially to 860 titles available for download, and the report speculated that the conversion of backlist titles to electronic form accounted for this increase (PASA, 2012). Improved awareness and reporting may also have accounted for a part of the increase.

The fact that the majority of publishers that currently publish e-books are small- to medium-sized companies confirms the finding in the general literature that the size of a company may be negatively related to disruptive innovation (Christensen, 1997; Dan and Chieh, 2008; DeTienne and Koberg, 2002).

1 *At this stage, the US market is unequivocally dominant, with an e-book market worth $6 billion, but a high rate of growth is expected in the EMEA areas (Europe, the Middle East and Africa): forecasts of 51% compound annual growth have been made (Guenette et al., 2010).*

This is to be expected, as the size of a publisher is inherently linked to the company's processes, resources and strategies. Larger companies are hampered by their more conservative and less flexible operating procedures, as well as the expectations of their stakeholders and existing customers. Their resource flow is controlled by current customers and investors (Dhillon et al., 2001). To adopt a new technology or to venture into a new market, they first have to navigate a complex corporate structure and hierarchy in order to start publishing for a new market. Small- to medium-sized publishers do not experience these problems, as they have the flexibility to make business decisions more intuitively, unhampered by organisational inertia or bureaucracy.

Another key finding was that the majority of South African publishers tend to outsource e-book-specific processes such as production and electronic distribution. This shows that, although smaller publishers have started publishing digitally, they are still not investing in establishing in-house resources to perform the new processes. There is a clear lack of knowledge and skills.

In light of the transition from traditional to digital-based processes, traditional publishing business models need to be revised to encompass new value-adding processes as supply chains and value chains change (Tian, 2008). The transition to a digital publishing business model can potentially disrupt marketing, production and distribution processes – in both a positive and a negative sense. Since there is limited information available on trends and digital implementation strategies in the publishing industry, there are no clear guidelines for publishers to adapt their businesses to digital processes. It is vital that publishers have a clear understanding of the opportunities and threats inherent in such a transition before they attempt to develop a digital publishing strategy.

→ *Table 1: Opportunities and barriers with regard to digital publishing in South Africa*

Opportunities
▪ Streamlined publishing processes ▪ Lower cost due to a shorter and simpler supply chain and the elimination of printing costs ▪ Greater savings on costs tied to the physical product (warehousing and physical distribution) ▪ The potential for greater profit ▪ The elimination of risk related to the damage to and depreciation of printed books ▪ The potential for greater flexibility and interactivity of content ▪ The potential for new levels of creativity in the production of new and interesting products and features ▪ Simplified searching, annotation and bookmarking for easy navigation ▪ New marketing and distribution opportunities ▪ Direct channels to target markets via social media ▪ The possibility of tracking, monitoring and predicting online consumer habits and buying patterns
Barriers
▪ Costly transitions to digital publishing strategies and operational models (new systems for e-book production, archiving and distribution) ▪ The necessity for extensive consultation and experimentation following the replacement of the printing process ▪ Expenses related to electronic archiving and the development of systems ▪ Preservation concerns ▪ The acquisition of new resources (including training staff in digital processes) ▪ The problematic alignment of digital and traditional intellectual property rights, and the accompanying digital rights management (DRM) restrictions and expenses ▪ The plethora of different e-book formats and reading devices, and confusion about which one to choose ▪ The confusion around pricing models, as there is a lack of standards in pricing, and the complication of users expecting e-books to be cheap or even free ▪ Readers' reluctance to move away from the printed book ▪ Low internet access rates among the majority of the population ▪ Slow and expensive broadband internet

The survey of South African trade publishers tested to what extent respondents were experiencing and reacting to opportunities and barriers to digital publishing, and how their processes were changing. It became apparent that South African publishers had not made significant adjustments to their business models to accommodate the changes necessitated by digital processes. Although publishers have digitised many of their processes, they have invested very little in e-books and have not taken advantage of opportunities to make changes to each step in the publishing value chain.

Managing disruptive technology in the publishing industry

The recommendations and lessons learned from disruptive technology theory were used to develop a set of objectives to serve as guidelines for publishers venturing into digital publishing. All recommendations and actions should take place against the backdrop of publishers' resources, values and processes.

→ *Table 2: Objectives to serve as guidelines for publishers venturing into digital publishing*

Autonomous spin-offs or divisions
Create a separate, autonomous division responsible for digital activities in traditional publishing companies. Such a division should be small enough so that smaller revenues and profits are acceptable, and so that it remains unhindered by the demands of existing customers and investors.
Create a core team to collect disruptive ideas and mould them into a proposition
Appoint a fresh team (either new staff members with specific skill sets suitable for the job at hand or flexible, free-thinking team members already in the company) to collect digital publishing ideas and draw up proposals and implementation plans. Team members should be innovative risk-takers with digital publishing expertise and optimistic attitudes towards the e-book industry.
Employ an informal management style
Allow managers in charge of digital publishing teams to proceed intuitively rather than having to be backed up by careful research and analysis. There is no definitive market research to rely on when making decisions regarding digital publishing at this stage. Digital publishing teams need the freedom to make decisions based on instinct and conjecture in an experimental fashion.
Design long-term plans
Develop long-term digital strategies that are not dependent on immediate or short-term returns on investment. Strategies should not be formulaic, but rather experimental and daring. Publishers should strive to reach new markets and investigate several different avenues of digital publishing to find what works best for the company. Publishers will also need to ensure that the company and its employees understand that digital publishing is a real part of their business in the long term and not just a sideline project in order to incentivise employees to change their attitudes, to learn new skills to keep up with technology and to make a success of digital publishing activities.
Keep resources in reserve
Invest enough time, money and resources in digital publishing to sustain digital publishing activities until the market breaks even, when e-books meet the requirements of the mainstream market and become a lucrative source of revenue.
Prepare for organisational change
Unlearn deeply entrenched values and habits, while preserving and valuing some integral parts of the culture, such as entrepreneurship, risk taking, flexibility and creativity. Senior management must initiate a transformation of culture within the book publishing industry.
Cater to existing and new customers equally
Do not ignore customers, current or potential. Identify the drivers of the future that emerge when the customers' environment changes. A mainstream customer orientation and an emerging customer orientation can co-exist. Publishers should develop techniques to understand new customers' needs. These needs and expectations will usually relate to technical issues such as the hardware and software used, but they could also relate to the content that readers prefer to read in a digital format. With internet communication channels, publishers have the opportunity to access new niche markets that they were unable to monitor before. Publishers need to engage in extensive research and development, making full use of social media and other communication channels that now enable them to monitor and understand the needs of customers, both existing and emerging.
Analyse trends in customer behavior
Take heed of the challenges and issues facing market acceptance of e-books, which will ultimately determine when e-books are accepted in the mainstream market. Publishers should keep a close eye on the progress of e-reading devices, formats, and DRM and pricing issues to judge accurately when the outstanding requirements have been met.
Exploit the technology's unique attributes
Exploit the interactive, innovative possibilities that the digital medium offers. E-books have the potential to include features such as search and cross-reference functions, hypertext links, bookmarks, annotations, highlights, multimedia objects and interactive tools (Vasileiou and Rowley, 2008).
Engage in open innovation
Explore shared-stake ventures, joint ventures and joint acquisitions of resources that would be well placed and suited to enrich them in the face of digital publishing. In the case of digital publishing, a traditional publisher would benefit from acquiring a partner with a strong foothold in the digital market.
Assume an international perspective
Creating disruptive innovations nearly always requires an international perspective (Dan and Chieh, 2008). One of the most significant advantages of digital publishing and e-books is the portability, ease of access and boundless distribution possibilities that naturally follow when a product exists in cyberspace. The internet offers an international ocean of e-book vendors that have no restrictions on shelf space. It also allows access to an endless pool of consumers in the international sphere that can be directly accessed through e-marketing and distribution strategies.

Recommendations

The literature provides recommendations and guidance for companies implementing disruptive technology in their businesses. Christensen (1997) highlights the importance of "customer competence" – knowing the market intimately and being proactive enough to sense when the needs of the market are changing as a result of a new technology. Dan and Chieh (2008) identify the challenges of leadership, organisational structure and culture, the new product development process, employees, and spin-off or ambidextrous organisations as being particularly relevant to the publishing industry.

The opportunities and advantages inherent in a move to a digital publishing process relate mainly to the shortened supply chain that would result from digitisation.

The following areas have been identified as likely to be the most affected by the move to a digital publishing value chain (Carreiro, 2010; Du Sautoy, 2010; Hyatt, 2002; Tian, 2008):

- Production and distribution processes are potentially much cheaper, as digital publishing eliminates warehousing and shipping, resulting in a shortened supply chain. These changes will necessitate major changes to production and distribution processes and workflows, and will require investment and resources.
- Marketing, research and development, and commissioning processes will see significant changes as new opportunities for sales channels, intermediaries and direct contact with customers abound. Investment and resources are essential to develop new systems in these areas.

The survey suggests that publishers have not invested in restructuring production and distribution processes. Although publishers have digitised many of their processes, they have invested very little in e-books and have not taken advantage of opportunities to make changes to each step in the publishing value chain.

Although they have started experimenting with digitisation in marketing, research and development, and commissioning, they have not made significant changes to their business processes in the production and distribution stages, which are the stages that need to undergo the most structural change in the move to digital publishing. They have not upgraded the skills of their current staff, nor have they acquired specialists to deal with digital aspects in-house. This not only refers to digital production skills, but also to digital marketing skills. Traditional marketing experts in publishing houses are probably not schooled in e-marketing to the degree necessary to remain competitive in the digital marketplace. In the case of e-books, the scenario is even more complicated, as market uptake is still small. Christensen (1997) advises companies to engage in "agnostic marketing": Market under the explicit assumption that no one can know whether, how or in what quantities a disruptive product can or will be used before they have experienced using it. Thus, in order to foster a digital reading culture, publishers should actively promote the use of e-books in addition to specific titles.

Dhillon et al. (2001) state that success in the face of disruptive technology will be defined by the ability of a company to allocate and manage resources successfully. In order to successfully implement digital publishing processes, publishers have to understand what resources they need (and lack) and how to allocate them efficiently.

Conclusion

Implementing digital publishing and digitising processes could result in a shorter publishing value chain. This would afford publishers tighter control over projects and budgets. Adjusting their business models to keep these processes in-house would be highly advantageous to publishers if the e-book market grows significantly, as most publishers believe it will. Not only would they save on production, distribution and technical costs, but being involved in the entire digital publishing process would enable publishers to know their products and the market on a much more intimate level than at present – leading to Christensen's "customer competence".

Most South African e-book publishers are not yet reaping the benefits of a shorter publishing value chain. The initial cost of acquiring new resources to shorten the supply chain would be very high, as it would entail much training, new staff and implementing a new business model. Understandably, most publishers are hesitant to do this until the future market share of e-books becomes less of a gamble. The majority of South African e-book publishers continue to outsource most production and distribution processes, and are not profiting from the marketing opportunities as they could be.

Despite the tentative and experimental nature of current digital publishing initiatives, 50% of publishers that ventured into the digital realm intend to dual-publish all titles in future: in other words, publish new titles in both print and electronic format. The remaining publishers will only publish a selection of their front-lists digitally, and they take a number of factors into consideration when deciding which titles to publish in digital form. The genre and market of the book are the most important of these considerations. These criteria reinforce the belief that digital publishing decisions are economy-driven. Publishers make decisions based on costs versus revenue (Meadows, 2010). Whether there is a significant market – which goes hand

→ *The future of traditional publishers is dependent on them being proactive enough to sense when the needs of the market are changing as a result of new technology.*

in hand with genre – is the most important factor in a publisher's decision to publish an e-book. Issues related to digital rights management, printing costs and shelf life are secondary considerations to the main question: Will the book sell, regardless of format?

Due to the current lack of a defined market, not to mention budgetary restrictions as book sales in general are down, publishers are clearly hesitant to invest heavily in digital publishing. As Attwell (2009) points out, the technical costs of setting up a digital publishing system might currently outweigh the potential sales of e-books. Similarly, Gordon et al. (2008) note that a traditional publishing company's change to an electronic publisher demands a huge reorganisation effort and much investment. As long as digital publishing remains a niche market, the costs involved do not justify overturning publishers' existing business models entirely. Publishers are only likely to invest enthusiastically in e-books once the market grows to a significant size and scope.

However, disruptive technology theory provides us with many cautionary tales of businesses that did not invest in new technology for these very reasons. When the tipping point is reached and the digital publishing market becomes profitable, traditional publishers that did not invest in digital technologies will face the risk of being left behind. The recommendations formulated from disruptive technology theory can provide a useful "how-to" guide for publishers implementing and managing digital publishing in their business processes.

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TuksBaja rocks

TuksBaja is certainly the project at the University of Pretoria that most benefits the professional (and personal) development of mechanical engineering students, in particular.

The students attest to this, saying that they not only gain practical experience of engineering principles, but also of aspects such as finance and logistics, which are just as important in the world of work. This is especially true when TuksBaja competes overseas, which it managed to do for the third consecutive year in 2014.

In April 2014, the current TuksBaja team showed that it can hold its own against the best in the world. The Tuks team, which consisted of Reyn Kapp, Matthew Perry, Ruan van der Merwe, Kraig Wright, and Carl Becker as faculty advisor for the trip, performed extremely well, and ended in 20th place overall. This is an enormous feat if one takes into account that 100 universities from the USA (which constituted 90% of the competitors), Canada, India, Mexico, Venezuela, Iran and Egypt competed and only approximately a third of the field finished the endurance race, where TuksBaja ended in 16th place.

This international event took place in El Paso, USA, and was hosted by the University of Texas at El Paso. It was one of a number of annual international Baja SAE events.

Three of the competitions are hosted by the USA. The others take place in Brazil and Korea. South Africa hosts its own local competition in October every year.

This was the fourth time that TuksBaja competed in an international event, and the team members were excited not only to represent their university, but also their country. The team from the University of Pretoria is the only South African Baja team that has managed to raise the funds in the last three years to compete internationally.

For the Baja SAE competition, all teams are provided with a 10 hp Intek Model 20 engine donated by the Briggs & Stratton Corporation. The innovation and manufacture of the rest of the car is up to the different teams. It is remarkable that no Baja car is exactly the same as any other.

The students literally build their own off-road vehicles – constantly tweaking and improving different parts to give them the edge in the endurance race and earn them maximum marks in the static design event.

→ *The TuksBaja team with their sturdy car (from left): Matthew Perry, Reyn Kapp, Ruan van der Merwe and Kraig Wright.*

In addition to the usual work that goes into preparing the car for an event – the students say their academics suffer a bit, as they have tight deadlines for work on the car – they have to arrange for the shipping of the vehicle when they compete overseas. They also have less time to work on the car, as the car needs to be shipped one month before the race.

Once their car is delivered – in the hotel's parking lot – they start working on it immediately to complete the final tweaks. Most of the work in assembly is done right there in the parking lot. Then the car is taken to the work area that the event managers provide for the duration of the competition. However, these work areas close at nine in the evening, and any additional adjustments have to be made quite quickly. (If a team is not finished by the time the work area closes, they need to find another working area.)

The competition consists of four sections. It starts off with the teams giving sales and design presentations. After that, there is a technical evaluation, where the judges verify that the vehicles meet the requirements stipulated in the hefty rules book. Once the technical inspection has been passed, teams can progress to the dynamic events, which generally include a hill climb, acceleration, suspension and traction, and manoeuvrability. After all these sections have been completed, the teams compete in the four-hour endurance race. This is the true and ultimate test to see if the cars can handle the harsh conditions.

Apart from the endurance race, teams can be sure that they will encounter a few problems. At El Paso, the judges found that the way the University's team mounted its engine was not according to regulations. The Tuks students had to go back to the work area to get the car up to standard overnight. Fortunately for them, they had a good relationship with the team of the Virginia Polytechnic Institute and State University (Virginia Tech), who assisted them.

International collaboration: Virginia Tech helped out the South Africans in a big way.

The engine had to be encased within the framework of the car – it required a "minor adaptation" in the sense that they only had to weld a tube around it, so that it did not protrude from the back of the car. This was to make sure that the engine – which, of course, uses fuel – would not make contact with the ground in the event of the car rolling.

Eventually the team passed the technical inspection (in time), but the fact that they had to work on the car for so long put them at a disadvantage in the dynamic events. They had little time left for these and scored naught in most of these events.

On to the four-hour endurance race – the determining factor in this competition. The event managers always ensure that the track conditions adhere to the definition of "harsh". This year, the conditions were desert-like, with a lot of dust and rocks on the track.

The team says the worst thing was that the rocks moved when the cars went over them, so the driver could never get familiar with the track and could not anticipate any obstacles.

All the teams that finished could be proud of themselves. Reyn says: "It was not so much about driving, but more about surviving." It is indeed a case of the driver's (and the car's) endurance on a near-impossible course over four hours.

How TuksBaja compares

The TuksBaja team's achievement in the American Baja SAE competition is remarkable on a couple of different levels. Apart from the fact that Tuks is the only South African team that competes overseas, it would be fair to say that it has more obstacles to overcome than the American teams.

The budgets of most of the other teams are much bigger than the one of Tuks. The University of Pretoria provides some funding, but the team members have to obtain sponsorships to be able to compete at the level they do. Their budget amounts to approximately R300 000 a year – that includes sponsorships. As the economy is in a recession, it has become increasingly difficult to obtain this kind of funding.

Because of the limited budget, TuksBaja's car is larger and heavier than those of the other competitors, because they don't have the money to use more sophisticated materials – but it is absolutely reliable. Furthermore, they build their car from scratch and manufacture the parts for the car themselves. The Tukkies are quite proud of the fact that they cut their own gears, write their own code and build their own shocks. They also take great pride in the excellent quality of work they do, and this is why the car is so reliable. This adds an extra dimension to the students' understanding and experience of real-life mechanical engineering. Although some teams mock South Africa for building "tanks", many of them are quite amazed by the team's innovations, as most of the others simply purchase state-of-the-art parts. "Ours was definitely the cheapest of all the cars that placed before us in the endurance race," says Reyn.

TuksBaja

Although it sounds quite simple, the Baja SAE project has to be run like a business for the team to be successful. It is an opportunity for would-be engineers to experience a simulated work situation during which they learn about aspects other than

→ *The team about to unload the precious cargo (from left): Carl Becker (Faculty advisor), Matthew Perry, Reyn Kapp, Ruan van der Merwe and Kraig Wright.*

engineering that influence projects and in which they develop additional skills.

Apart from building the car, the team is responsible for administration (such as submitting the entries for competitions), financial matters (they have to raise all the funds by themselves and rely on sponsorships), project management and logistics. Other skills relevant to the professional world they gain are people skills – they simply have to learn to work as an effective, cohesive team and each member has to respect and accommodate the views and ideas of the others. Generally speaking, this is not known to be a strong competency in engineers.

A slightly different skill set is developed when the team goes overseas. Being out of their comfort zone, the students quickly have to determine where they can source parts and other necessities they did not take along. They describe it as a steep learning curve and having to grow up quickly – not only on a professional level, but also on a personal one.

On international level, these students are also building relationships with teams from other universities, especially Virginia Tech, with which they have close ties. Apart from socialising, a strong relationship for potential future cooperation is established.

This ties in with the University of Pretoria's strategy to strengthen and enhance its international academic collaboration and, consequently, its international profile.

The TuksBaja team is busy for the entire year. At the start of the project each year, engineering students across all disciplines are invited to apply to become a part of the team if they are interested. They work with the team for a while, and if they show the required commitment, they are accepted.

The University usually ends up with quite a diverse team in the sense of strengths and personalities, which is essential for a project of this nature.

TuksBaja's current strategy is to use the South African competition as a kind of test run for new innovations, and then to send a refined car to compete overseas.

Sometimes this strategy can end in disaster. Last year, for example, the team entered its "old, reliable" car and a prototype for the South African Baja SAE. However, they were so confident that the reliable car would perform that they concentrated on the prototype and neglected to replace a vital part in the old one – and they did not get anywhere in the race.

One can see this as gaining experience, and this is what the Baja SAE is all about: gaining experience in a diverse range of skills, learning from good and bad experiences, and learning from other teams.

Kraig Wright, the TuksBaja captain, states: "For me, the most important thing about Baja SAE is not the final position at the end of the event, but rather how the team has learnt and grown from the experience. Our ability to not give up after having failed technical inspection the first time is what Baja SAE is all about."

"If you have done the Baja SAE, you are basically a plug-and-play engineer," says Reyn.

The following sponsors made it possible for the TuksBaja team to once again compete internationally:

- Sasol
- Kühne + Nagel
- Bearing Man Group
- Investmech
- Faculty of Engineering, Built Environment and Information Technology, University of Pretoria

The material for this article was provided by Reyn Kapp (final-year mechanical engineering student, member of this year's international team and driver of the car in the USA), Odette Scholtz (third-year mechanical engineering student, member of last year's international team) and Matthew Perry (third-year mechanical engineering student, member of this year's international team).

To follow TuksBaja's work, please visit its website, www.tuksbaja.co.za, or like the Facebook profile "TuksBaja".

New Dean for Engineering, Built Environment and Information Technology

The University is pleased to announce the appointment of Prof Sunil Maharaj as Dean of the Faculty of Engineering, Built Environment and Information Technology.

Prof Maharaj obtained his BSc and MSc degrees in Electronic Engineering at the University of Natal, after which he completed an MSc in Operational Telecommunications at Coventry in the United Kingdom. He completed his PhD in Electronic Engineering at the University of Pretoria.

Prof Maharaj began his career at Electromagnetic Laboratories and then moved to academia where he worked as a part-time lecturer at the ML Sultan Technikon in Durban and a senior lecturer at the Transkei Technikon. He then accepted a position as Vice-Rector: Academic at the Eastern Cape Technikon.

He joined the University of Pretoria as a senior lecturer in 2000, where he progressed to Head of the Department of Electrical, Electronic and Computer Engineering. Prior to his appointment as Dean, he was the Chairholder of the Sentech Chair in Broad-band Wireless Multimedia Communications (BWMC).

Prof Maharaj has published widely in several accredited journals in his field, and has received a number of awards, including the Technology and Human Resources for Industry (THRIP) Award of the Department of Trade and Industry (the dti) in the Advanced Hi-tech Category for his research in broadband wireless communications in 2013.

Innovate would like to congratulate Prof Maharaj on his appointment and wishes him well in his future career as Dean of the Faculty of Engineering, Built Environment and Information Technology.

Michelle Bosch receives the Gold Medal award as the best final-year student in Quantity Surveying in South Africa in 2013 from Onie Dhliwayo, President of the ASAQS. Larry Feinberg, Director of the ASAQS, looks on.

Department of Construction Economics receives awards

The Department of Construction Economics at the University of Pretoria endeavours to be locally relevant, and to compete with the best internationally.

As a testimony to the Department's success, the Head of the Department, Prof Tinus Maritz, and alumna, Michelle Bosch, received awards at the 7th Annual Quantity Surveying Conference, hosted by the Association of South African Quantity Surveyors (ASAQS) and the South African Council for the Quantity Surveying Profession (SACQSP) from 21 to 23 September 2014.

Prof Maritz was awarded a medal of honour for his lifelong dedication to the profession. He has been active in the industry since 1975. Michelle, who completed her BSc Hons (Quantity Surveying) (cum laude) degree at the end of 2013, received the gold medal for the best final-year student in Quantity Surveying in South Africa in 2013. She now works as a quantity surveyor at Matla Quantity Surveyors in Pretoria.

The conference aimed to bring together academics, researchers, postgraduate students and industry practitioners so that they could share thoughts on how the profession presently influences the dynamic socioeconomic environment and how it will influence the future.

The ever-changing socioeconomic, technological and environmental spheres cause various obstacles in the profession. Clients are constantly demanding better services and quantity surveyors are under pressure to deliver.

These awards are proof that the Department of Construction Economics has succeeded in its objective of delivering the best graduates to address this need.

Prof Roelf Sandenbergh (far left) receives the donated BMW on behalf of the Department of Mechanical and Aeronautical Engineering from Edward Makwana, Manager: Group Automotive Communications at BMW (front).

Vehicle Dynamics Group shifts gears

The Department of Mechanical and Aeronautical Engineering welcomed BMW South Africa's donation of a preproduction BMW 3 Series sedan on 23 July 2014. The vehicle will play an integral part in the Department's research on different aspects of vehicle dynamics and mobility.

According to Prof Schalk Els, Head of the Vehicle Dynamics Group (VDG), the Department will be using the vehicle to research aspects such as safety, comfort and efficiency. Research in the field of vehicle dynamics and mobility at the University of Pretoria began in the 1970s and gained renewed momentum with the establishment of the VDG as a formal research group in the Department of Mechanical and Aeronautical Engineering in 2011.

The VDG needed a research vehicle that has newer technology than the Land Rover Defender it has been using for its research up to now. The Defender will still be used, but the VDG can now conduct research on electronic driving aids, such as the parking assist and lane departure warning systems. Although it was part of the preproduction stage of BMW's Rosslyn Plant in Pretoria in 2012, the vehicle is ideal for the VDG's innovative research. Brett Kent, a member of the VDG who is studying towards a BEngHons (Mechanical Engineering), said: "We don't have to test new technology in simulations and hope the simulations are accurate. We can just validate it on the platform the BMW provides."

Prof Roelf Sandenbergh, former Dean of the Faculty of Engineering, Built Environment and Information Technology, received the vehicle from Edward Makwana, Manager: Group Automotive Communications at BMW South Africa, on behalf of the University. In his keynote address at the handover function, Prof Sandenbergh highlighted the fact that UP needs to collaborate with industry to address the shortage of engineers in South Africa. The Faculty has shown strong growth in research activities over the last few years, but collaborations like the one with BMW can pave the way for further growth.

A local platform for international participation

Coetzee Bester and Rachel Fischer

The African Centre of Excellence for information Ethics (ACEIE), housed by the Department of Information Science at the University of Pretoria, was officially established in May 2012. Its purpose is to formally reflect on the activities relating to, 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. Since its establishment, the Centre has made good progress in meeting its objectives.

When the memorandum of agreement (MoA) was signed between the Department of Communications (DoC) and the University of Pretoria on 15 December 2011, six objectives were agreed upon. Each activity has to answer to one or more of the six objectives. Apart from the general office duties and research projects that have to be an ongoing endeavour of the ACEIE, it also has to contribute to the body of knowledge of information ethics on local and international levels. Two of the objectives are of specific relevance in this regard:

- **Objective 1: Development of information societies:** To create an awareness of the importance of information in different communities and among responsible persons and information practitioners, in terms of where to access information and how to overcome inequalities in access to information, how to integrate it, and to create an awareness of society's dependence on information.

- **Objective 6: International-isation of information ethics policies and practices:** To promote key proposals and research, as agreed, concerning the research on information ethics and its application, for consideration within African and international intergovernmental organisations, such as the African Union (AU), African regional communities and the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

Based on these two objectives, the ACEIE has proceeded to engage with international role players on four levels:

- The design and rollout of an information ethics curriculum across universities in Africa
- Meetings with relevant stakeholders
- Interaction with the UNESCO National Commission offices in the southern African region
- Workshops and conferences at universities across Africa

Good progress has been made with the development of the information ethics curriculum. The first workshop in this regard took place at the University of Pretoria in July 2011, and hosted participants from Germany, the USA, Uganda, Kenya and South Africa. The framework for the curriculum was created at this workshop, and the first draft was made available to the universities concerned by November 2011 to allow them to start implementing the curriculum.

The second workshop took place in Nairobi, Kenya, in July 2012 and specifically addressed the information ethics issues concerning social media. By raising their concerns, the participants could address the content requirements of the curriculum to make it even more relevant for universities and individuals already experiencing problems and opportunities with social media. This workshop experience was further developed into a conference theme – "The cheetah generation's fast track to social media" – for the third International African Network for Information Ethics (ANIE) conference on information ethics. At this conference, held in South Africa in September 2012, the participants of the Kenyan workshop presented their research on the information ethics concerns of social media. The pre-conference workshop further elaborated on the curriculum content.

The ANIE Pre-conference Workshop was held at the LAICO Regency Hotel in Kenya on 3 June 2012.

On request of UNESCO, the ACEIE conducted workshops in Lesotho, Mozambique, Namibia (above) and Swaziland (below).

In July 2013, the ACEIE team visited Kampala, Uganda, where a fourth workshop was hosted together with Makerere University. This workshop predominantly involved academia from universities across Uganda, but participants from Tanzania and Kenya were also present. This workshop further extended participation to include the African Centre of Cyber Law and Cyber Crime Prevention (ACCP) and the United Nations African Institute for the Prevention of Crime and Treatment of Offenders (UNAFRI). The next African workshop took place in Zanzibar, Tanzania, in October 2013. This involved academia from both the mainland and the island. The Minister of Trade, Industry and Marketing provided further support for this event, as well as for the process of raising awareness on the topic of information ethics. One of the results of this workshop was the second draft of the information ethics curriculum, which was subsequently distributed.

After extensive research and revision by the curriculum specialist, Dr Beverley Malan, and the Director of the ACEIE, Coetzee Bester, the third draft of the information ethics curriculum was presented at the fifth information ethics workshop in Kampala, Uganda, in January 2014. Makerere University hosted this event and included academia from across Uganda. The final product of all the information ethics curriculum research was formally launched at the fourth international ANIE conference in July 2014, which was once again hosted in Kampala, Uganda.

The ACEIE collaborated with UNESCO and other organisations in a number of meetings. It was invited by UNESCO to address and participate in the World Summit on the Information Society (WSIS) session that addressed the current and emerging ethical and societal challenges of the information society, which took place on 26 February 2013 as part of the WSIS+10 review meeting in Paris. The theme of the event was “Knowledge societies for peace and sustainable development”.

The African workshop in Tanzania (above and below) resulted in the second draft of the Information Ethics curriculum.

The ACEIE team visited Kampala, Uganda, in July 2013. (Photograph: Maxwekk Omwenga.)

Following the event in February 2013, the ACEIE also attended the 37th UNESCO General Conference in Paris, France, in November 2013, where the Centre participated in interpreting the draft resolution for Major Programme V – sustaining peace and development through freedom of expression and access to knowledge. Activities focused on Strategic Objective 9 (promoting freedom of expression, media development and access to information and knowledge). The ACEIE worked on Strategic Objective 9 (UNESCO Document 37 C/5 – Volume 1 – Draft Resolutions), particularly 13 focus areas and two main lines of action that will guide activities and reports for the period 2014 to 2017. The aim of this was to analyse the content of the documents on Strategic Objective 9 and to explore the content in terms of the African milieu, traditions and background. The ACEIE presented practical details for implementation project proposals to the UNESCO Director-General in achieving Strategic Objective 9 in Africa.

During 2013, the ACEIE actively participated in the activities of SA Natcom, the communication and information sector and other Africa-based UNESCO structures to achieve the related UNESCO and WSIS objectives. The Africa-based activities included a number of projects of the UNESCO southern African region. On 28 and 29 April 2014, the ACEIE addressed the UNESCO Multisectoral Regional Office in southern Africa in Harare, Zimbabwe, during a joint consultative meeting of UNESCO national commissions in southern Africa. It led to a UNESCO request to the ACEIE to conduct further workshops in Lesotho, Mozambique, Namibia and Swaziland.

International cooperation is important for achieving the aims of the Centre. The conferences that have been held and the projects that have been initiated have led to the ACEIE collaborating on various issues with local, African and overseas universities. This has resulted in research projects and publications in accredited journals.

Heidi van Eeden with the model of her winning entry.

Alumna is Corobrik's Architectural Student of the Year

Heidi van Eeden (above), a UP alumna, has taken first place in Corobrik's 27th annual Architectural Student of the Year Award. This award is presented to the top master's degree graduate of the 2013 studio. It recognises the creative and technical talent of South Africa's top architecture students and serves to promote the advancement of design excellence nationally.

Heidi's master's dissertation was entitled "Machinarium: Architecture as a living machine, a 21st-century textile mill". It presents new ways of architectural place-making in a fast-changing world. The project explores the potential of the industry as urban catalyst with which to revive urban environments and reintegrate fragmented socio-ecological systems.

In an attempt to redefine the modern concepts of waste and combat the flood of pollution stemming from 20th-century industrialisation, the investigation is focused on restructuring the textile industry and is based in an "urban wasteland" – the Daspoort Wastewater and Sewage Treatment Works.

According to Heidi's dissertation, the site is reprogrammed as part of a new industrial ecology, an architectural system that reuses wastewater and other untapped resources on site to produce textiles and algae-based dyes. By integrating local urban communities and natural ecosystems with this industrial space, a 21st-century textile mill is designed as a holistic environment that blurs distinctions between social, productive and natural space, and proves that there is productive value in the resources that are discarded as waste.

Edna Perez, one of Heidi's supervisors, pointed out that, in a world where architecture's ability to navigate an uncertain future is being questioned, Heidi explored one of the biggest challenges of our time – how to transform wasted sites, wasted structures and wasted land into places where life can flourish and evolve.

Innovation comes in all shapes and sizes

This year, four Bachelor of Information Science (BIS) Multimedia students from the University of Pretoria won the South African leg of the annual global student technology competition, the Microsoft Imagine Cup. The Super Sea Dragons also won the sought-after Skype Award for innovation and collaboration in the online Microsoft Imagine Cup world semifinals.

The Microsoft Imagine Cup is a prestigious competition in which teams from 190 countries are afforded the opportunity to participate in a challenge of innovation in three categories: games, innovation and world citizenship. The competition inspires creative thought in young students in an attempt to cultivate a passion for innovation and progress. Students from all over the world enter their inventions into the competition in an attempt to win the grand prize at the Microsoft Imagine Cup world final hosted in Microsoft's hometown, Seattle. This prize comprises $50 000 for each of the winning team members, as well as a private chat with Bill Gates.

The UP team, the Super Sea Dragons, comprising Daniel Esterhuizen, Eleanor Harding, Emile Hay and Gerhard Janse van Rensburg, developed a 2D action adventure circular platform game set in space as part of their final-year project. The game is called Orbit and the gameplay is focused on navigating and exploring small planets as the character, Atlas, an astronaut who travels through space and encounters hostiles to earn meaningful rewards. Atlas is Earth's last hope for finding a new habitat for survival.

Orbit ties together the genres of action, adventure and puzzle with core mechanics focused on using gravity and momentum to navigate and explore systems of tiny planets. The game is built in unity with a focus on crafted artwork and exploratory adventure gameplay. All the music and artwork were originally created by members of the team. Orbit is set apart by its replayability, its circular

perspective and its distinct art style. The students were inspired by the South African animator, Mike Scott, a YouTube video by PJ Ligouri, "PJ, Tiny Planet Explorer", and the games Angry Birds Space, Super Mario Galaxy, Aether and Capsized. The Super Sea Dragons won the South African national finals of the Microsoft Imagine Cup after beating more than 50 teams from South African universities.

The top three local teams went on to compete against teams from all over the southern hemisphere in the Microsoft Imagine Cup world semifinals. There, the Super Sea Dragons won the Skype Award for innovation and collaboration – a $5 000 cash prize aimed at helping the young game designers to improve their product. The Skype Award aims to tap into the innovative and creative spirit among the Microsoft Imagine Cup participants to deliver new ideas on how to leverage Skype to have a positive social impact. Three world semifinalist teams each received this prize for recording the best Skype video message explaining how to use Skype to do great things in the world. The Super Sea Dragons will use their prize money as a contribution towards promoting Orbit and getting the game onto the Windows phone store.

The students described their experience of this large-scale collaborative innovation as follows: "If you put enough brilliant minds into one room, the atmosphere becomes electric." The experience is an important driver of future innovation for these talented students and they hope for it to be a stepping stone for their careers. Three of the four students have already secured contracts with Microsoft.

They report that the most important lessons that they have learned pertain to their product's leap from innovation to a real-world business. The students have integrated extensive testing and version and quality control into their business model and plan to sell Orbit when it is finished. Orbit is already available online as a demo version, the first step in the game's five-step business plan.

Technology to enhance gold recovery

The University of Pretoria has been collaborating with the gold processing solutions company, BIOMIN South Africa (Pty) Ltd, on the development of new technology to improve gold recovery in the processing of double refractory ores.

Gold recovery often results in native carbon competing with activated carbon, which limits gold recovery (commonly called preg-robbing). BIOMIN's process manager, Craig van Buuren, announced that the new technology is now available for commercial use. BIOMIN is a biological oxidation (biox) solutions provider, which acquired the patent for the BIOX® (biological oxidation) refractory processing technology in 2013.

The process, called high-temperature caustic conditioning (HiTeCC), is a conditioning stage introduced after conventional carbon-in-leach (CIL) processing to recover preg-robbed gold from native carbonaceous materials. Preg-robbing of gold during cyanide leaching occurs when the leached gold is adsorbed by certain components of the ore.

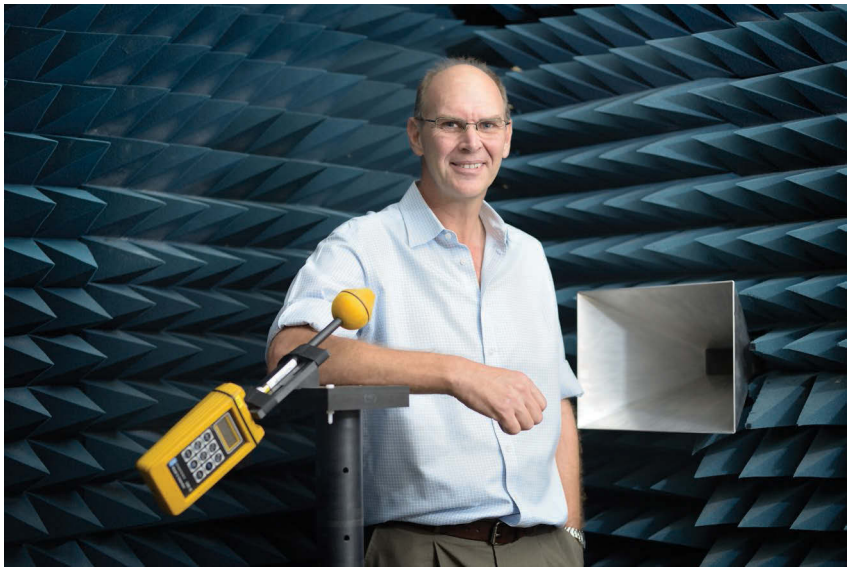
HiTeCC was reliably proven to improve gold recovery by 5 to 10%. "BIOMIN is working with the University of Pretoria to further the fundamental understanding of the HiTeCC process, which will allow it to be extensively modelled," Van Buuren added.

"In our tests on double refractory concentrates with high native carbon content, normal gold recoveries were severely impacted without the HiTeCC process," he explained. After conventional CIL processing, the process involved conditioning slurry with heat, carbon and caustic reagents to reverse the preg-robbing effect. Gold was stripped from the native carbon and recaptured onto activated carbon through a two-stage temperature swing. This "innovative" slurry heat exchanging process meant that HiTeCC could easily be tied into conventional leach circuits.

BIOMIN noted that it had done significant work to improve the efficiency of the process for plants processing double refractory ores and would continue to develop the modelling to enable tailored solutions for specific preg-robbing materials.

Faculty congratulates its exceptional achievers

In 2014, the Faculty of Engineering, Built Environment and Information Technology saw two of its researchers receive an Exceptional Achiever Award. This award is based on outstanding achievement in research, teaching and learning, and community service, and is presented annually to senior academics who have already achieved the status of professor and are highly regarded by their peers. Furthermore, five of the Faculty's researchers were newly rated by the National Research Foundation (NRF). These ratings are based on a researcher's recent research outputs and impact as perceived by international peer reviewers.



Exceptional Achiever Awards

Prof Johan Joubert

Prof Joubert is a professor in the Department of Electrical, Electronic and Computer Engineering, where he heads the Electromagnetism Research Group. His research is in the field of microwave antennae, inter alia on the size reduction of antennae as a result of communication devices becoming smaller. The miniaturisation of an antenna has a significant impact on its performance, and designing small antennae of satisfactory performance in terms of power handling, radiation pattern and bandwidth has become a challenging task. As integration increases, a single antenna is often used to support two or more wireless services across a broad frequency range, in which case an antenna with multiband or wideband characteristics is required. The concept of a novel reactive impedance surface as substrate for planar antennae, which can miniaturise size and significantly enhance both the bandwidth and radiation characteristics of an antenna, has been demonstrated.

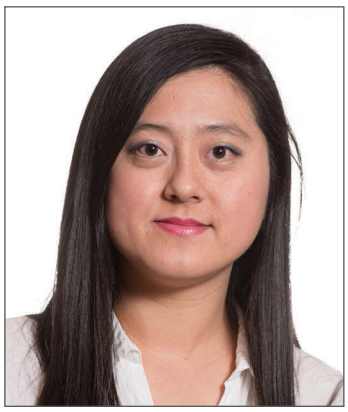
Prof Wimpie Odendaal

Prof Odendaal is a professor in the Department of Electrical, Electronic and Computer Engineering and the Director of the Centre for Electromagnetism. His research effort is focused on achieving a high level of excellence in electromagnetic technology, particularly in the design, development and evaluation of microwave antennae, radar backscatter and antenna measurements. He has developed various novel antenna-radiating elements, as well as feeding and matching techniques with specific application in wireless and array technology. He has contributed to the practical implementation of polarisation optimisation for conformal antenna arrays.

NRF-rated researchers

The following researchers have been newly rated by the NRF:

Dr Kai-Ying (Alice) Chan



Dr Chan received a Y2-rating from the NRF. She is a senior lecturer in the Graduate School of Technology Management. Her research is focused mainly on theory-based empirical studies of knowledge networks and innovative behaviour of organisations. Her most significant recent publication was an article entitled "Knowledge exchange behaviours of science park firms: the innovation hub case", which was published in *Technology Analysis & Strategic Management* in 2010.

Dr Loek Cleophas

Dr Cleophas received a Y2-rating from the NRF. He is a research fellow in the Department of Computer Science. His main research interests are algorithms and automata for text- and tree-structured data processing, model-driven engineering (MDE), code generation, software language engineering, and software correctness-by-construction. He obtained a PhD in Computer Science and Engineering from Eindhoven University of Technology in the Netherlands in 2008.

Prof Helene Gelderblom

Prof Gelderblom received a C3-rating from the NRF. She is an associate professor in the Department of Informatics. She works mainly in the field of human-computer interaction, with the emphasis on the design of technology for special user groups such as children, the elderly and computer-illiterate persons. She has a special interest in the evaluation of mobile and computer interfaces through eye tracking and in the application of technology in education.

Prof Gerhard Hancke

Prof Hancke received a B2-rating from the NRF. He is an emeritus professor in the Department of Electrical, Electronic and Computer Engineering, as well as the Programme Coordinator for Computer Engineering. He heads the Group for Advanced Sensor Networks (GSN) and enjoys international recognition for his work in the GSN, especially with regard to industrial applications. He collaborates and publishes with researchers from all over the world.

Dr Nixon Ochara

Dr Ochara received a C3-rating from the NRF. He is a senior lecturer in the Department of Informatics. His educational background is in business, specifically in management science, with its emphasis on the application of scientific and mathematical approaches of operations research to managerial decision-making. His current research focuses on the disciplines of operations and information systems, and he is establishing himself as a professional and interdisciplinary researcher.

Prof Herman Steyn

Prof Steyn received a C3-rating from the NRF. He is a professor in the Graduate School of Technology Management, and has been researching various areas related to project management. His most recent work has involved the use of computer-mediated communication by project teams, and project management maturity.

Research in rock mechanics receives a boost

In 2013, Harmony Gold Mining Company Limited announced a donation of R4.7 million to the Department of Mining Engineering at the University of Pretoria over three years. This has allowed the Department to establish a Chair in Rock Engineering and Numerical Modelling.

Research on a safer working environment in the hard-rock mining industry is a very specific focus area of the Department of Mining Engineering. The aim of the Chair is to advance research in the field of rock mechanics and numerical modelling in the mining industry. It presents opportunities for the development of products such as software to support numerical modelling.

Another important function of the Harmony Gold Chair is to arrange much-needed liaison between academic institutions and the industry in general, but specifically between Harmony Gold and the University of Pretoria.

Harmony Gold, one of the world's leading gold mining companies, will benefit from this donation through its interaction with international leaders in the field of rock mechanics and numerical modelling research. Another benefit is the interaction with undergraduate and postgraduate students through projects at the University.

Graham Briggs, Chief Executive Officer of Harmony, said: "Ensuring the safety of each of our mineworkers is Harmony's top priority. Therefore, further research and development to ensure even safer underground conditions are of the utmost importance to us. It is a privilege to have the University of Pretoria as a partner in the pursuit of even safer mining activities."

Johann Hanekom has just been appointed to the position of Chairholder. He is a well-acclaimed rock engineering practitioner, and is currently registered for his PhD in rock engineering in the Department of Mining Engineering at the University of Pretoria. His vast experience in the field makes him ideally suited to head this Chair. He is well known in the industry, and has taught the Rock Engineering module in the Department of Mining Engineering before.

Sound scientific research informs asset management decisions

Globally, there is a rapidly growing need to manage physical assets optimally over their entire life cycles, from the design phase to the operational and decommissioning phases. To address this need, the University of Pretoria formally established the Centre for Asset Integrity Management (C-AIM) during 2014. This centre functions in the Department of Mechanical and Aeronautical Engineering.

Prof Stephan Heyns, Director of C-AIM, explains that the management of physical assets, such as plant equipment, buildings, aeronautical structures, machinery and vehicles, focuses on establishing, operating and maintaining an asset portfolio that is aligned with the organisation's strategic objectives. This necessitates the need for an in-depth understanding of asset management principles and processes at an operational management and technical level.

During the mid-1980s, the Department of Mechanical and Aeronautical Engineering commenced with research in various fields related to physical asset integrity. This included structural fatigue testing, experimental modal analysis and vibration monitoring. Maintenance initiatives were subsequently launched. In 2008, these initiatives culminated in the establishment of a Centre of Excellence for Maintenance Engineering, with industry support from Sasol, Eskom, Exxaro and Anglo American.

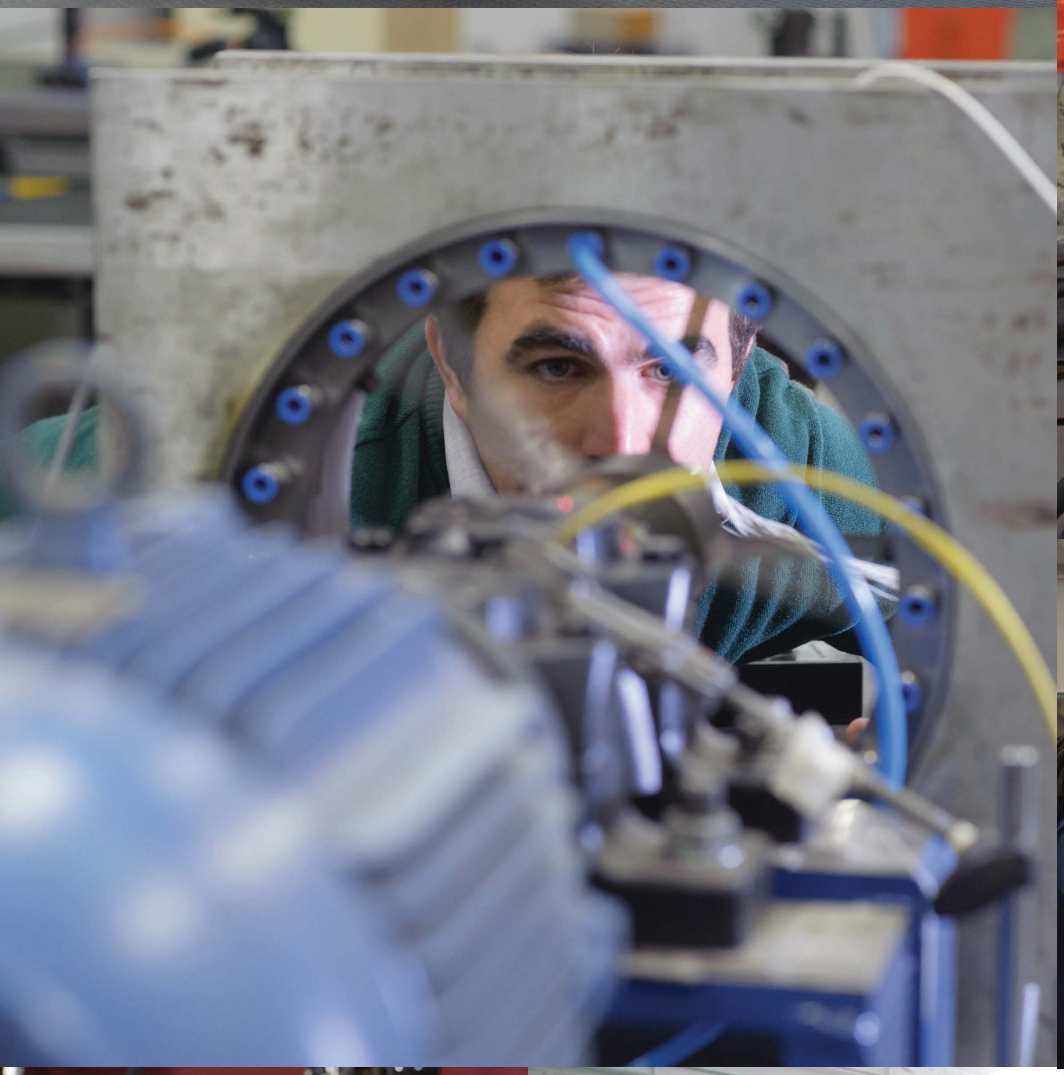
In 2012, Eskom established a Chair for Plant Asset Management as part of the University's Eskom Power Plant Engineering Institute (EPPEI). This was followed by the establishment of the Rand Water Chair in Mechanical Engineering, as well as a collaboration agreement with Weir Minerals to establish a research focus on machine condition monitoring.

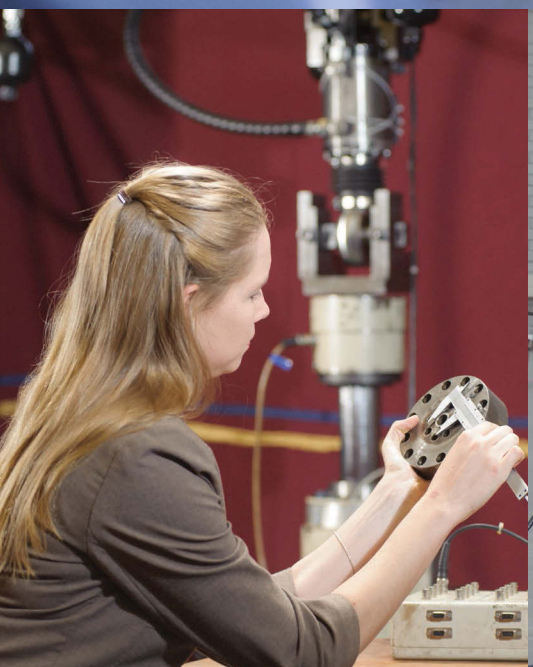
Following the growth of knowledge and expertise in this field, C-AIM was eventually established to function as the hub of all asset integrity management activities in the Department of Mechanical and Aeronautical Engineering.

Research focus

C-AIM has identified a number of research focus areas, aimed at setting the standard for asset integrity management in South Africa.

- **The identification of critical assets:** Research in this field concentrates on the assets that may have the most significant and immediate impact. Identifying these assets is important in developing an asset integrity management plan, as companies manage many assets with very diverse attributes.
- **Designing for reliability and performance:** It is essential that sophisticated techniques are used to ensure that asset design is optimal during the manufacturing and operational phases of an asset's life cycle. Techniques that can be utilised include the finite element modelling of complex structures, scanning laser vibrometry and digital imaging.
- **Data acquisition:** The measurement of system parameters, such as solids, liquid and gas flow rates, pressure, temperature, oil condition or vibration, are important. This necessitates detailed data of the operating conditions. Research on data acquisition includes the utilisation of non-contact sensors for condition monitoring, as well as acoustic emissions in specialist applications.
- **Condition monitoring:** There are significant research challenges related to condition monitoring in industry. These challenges include fluctuating operating and process conditions in systems, as well as optimising online condition monitoring and inspection





Prof Stephan Heyns (centre) with some of the staff and students of the Centre for Asset Integrity Management in the Department of Mechanical and Aeronautical Engineering.

techniques for a variety of equipment.

- **Diagnostics:** Research focuses on understanding failure modes and criticality, which is crucial in identifying approaches to optimal condition monitoring. Detailed models to link features extracted from system response and performance measurements are indispensable to diagnose system faults.
- **Prognostics:** Maintenance decisions based on the outcomes of time-to-failure estimates often contain a strong element of uncertainty. This suggests a need to integrate traditional condition assessment and statistical reliability models. This research requires one to move away from intuitive decisions and adopt more sophisticated prognostic models capable of dealing with complex equipment that has many interrelated failure modes.
- **Life cycle decision support:** When considering life cycle management decisions, research extends beyond immediate failure. It also focuses on understanding the long-term operational and maintenance implications. Therefore, the current research on life cycle decision support entails the integration of condition information with an improved understanding of the degradation mechanisms that manage maintenance interventions, risk, inventory and end-of-life decisions.
- **Standards and databases:** The optimal utilisation and life cycle management of expensive physical assets is becoming more important in a competitive cost-sensitive society. As a result, new asset management standards, such as PAS55 and ISO 55000, have been implemented. Research conducted on standards and databases aims to understand the implications of such standards.

Industry collaboration

In addition to its research activities, C-AIM strives to achieve scientific excellence and industry relevance by working closely with industry partners. The approach utilises the establishment of industry-sponsored chairs in specific research areas.

- **The EPPEI Chair in Plant Asset Management** was established in 2012 and will be active until 2017. At the end of this period, C-AIM would have supervised 20 to 30 Eskom staff members who will have studied towards a master's degree. High-impact research projects that deal with issues ranging from mill maintenance optimisation to fatigue life prediction of steam turbine blades are underway.
- **The Chair in Maintenance Engineering** was established in 2009 in collaboration with Anglo American, Sasol, Exxaro and Weir Minerals. This Chair has enabled C-AIM to considerably expand its capacity in the area of maintenance engineering.
- **The Rand Water Chair in Mechanical Engineering** was established in 2014 and strongly focuses on the development of asset integrity analysis and management techniques for water distribution.

These collaborations not only play a vital part in the improvement of asset management, but may also afford postgraduate students the opportunity to join collaborators once they have completed their studies.

Postgraduate programme offering

Two unique postgraduate programmes are offered in asset management to provide the mining and engineering industry with sufficiently qualified individuals.

The Multidisciplinary Postgraduate Programme in Physical Asset Management (PAM) is managed in collaboration with the Graduate School of Technology Management (GSTM) and is ideal for candidates who prefer a stronger management focus. The Mechanical Engineering Postgraduate Programme in Asset Integrity Management is managed through the Department of Mechanical and Aeronautical Engineering, and is preferred by candidates with a stronger technical focus.

Both these programmes are course-based honours degree programmes, followed by a research dissertation for master's degree purposes, designed to achieve specific objectives. They allow students to choose modules from different departments within the School of Engineering, including the departments of Civil Engineering, Industrial and Systems Engineering, Mechanical and Aeronautical Engineering, and Mining Engineering, as well as the GSTM.

Laboratory facilities

Research and academic programmes relating to asset integrity management require state-of-the-art laboratory equipment. The Sasol Laboratory for Structural Mechanics was established in the Department of Mechanical and Aeronautical Engineering in the early 1980s. It is home to C-AIM's structural fatigue, structural dynamics, vibration monitoring, diagnostics and prognostics research activities.

The laboratory's unique capabilities include its ability to conduct durability (fatigue) tests on structures with masses in excess of 15 tons, various certifications of large equipment (such as mining machinery), large-scale rotating machinery dynamics simulators for gear, as well as bearing and turbo machine blade damage investigations.

The laboratory has unique capabilities in terms of the optical measurement of vibration and structural dynamics, which enables cost-effective studies in applications that would otherwise have been difficult to deal with.

Resource development

To ensure that all its activities run smoothly, C-AIM has appointed a strong staff complement. It proudly employs 10 specialised academic staff members, who conduct research on critical aspects of asset integrity management.

Knowledgeable full-time researchers, engineers and technicians support the academic staff and help C-AIM to engage with industry partners.

As part of the EPPEI agreement with Eskom, C-AIM also has a formal agreement with the Tshwane University of Technology (TUT). C-AIM and TUT share resources to develop research expertise in asset integrity management related to power generation, transmission and distribution.

Since there is a rapidly growing need to manage physical assets optimally over their entire life cycle, C-AIM intends to be recognised locally and internationally for its academic excellence. It strives, in particular, to integrate its analysis and testing expertise in the assessment of the structural integrity and performance of mechanical and other physical assets with the ability to make short-, medium- and long-term asset management decisions in the context of asset life cycles.

→ *Taking optical measurements on structures with complex deformation modes.*

→ *Little Annie*

JCP proves that a little can go a long way

Dr Martina Jordaan

The Community-based Project (JCP) module in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria consistently proves that a small project can become something much bigger and have a much larger impact on a community than originally planned.

The JCP module requires students to dedicate 40 hours of their time to a community project that they plan and execute themselves. These are usually projects about which the students are passionate and in which they feel they can make a contribution in their personal capacities. The projects of three groups of students have captured the attention of the public. These projects involved an Antonov AN-2 aircraft, a life-changing trip to Stella in North West and the painting and furnishing of a new home in a rural township in Pongola.

Antonov AN-2 aircraft

The first group, comprising Rowan Price, Ross Coetzee, Ruan van der Westhuizen, Michael Oosthuizen and Jason Tollemache, assisted in the servicing, maintenance and ground support of an aircraft called *Little Annie*.

The AN-2 is the world's largest single-engine biplane designed to fly passengers and cargo to remote locations.

Little Annie was donated to the Just Love Mission, a non-profit organisation that aims to change the lives of communities in a positive way through aviation awareness and the spirit of *ubuntu*. The aircraft is its mascot. The original owners specially flew her to South Africa from Russia in 2013.

The trip, which had to overcome flight clearance issues, weather, corruption and the theft of precious Avgas fuel, took two and a half months instead of the planned two and a half weeks. During the trip, which covered 19 750 km (22 countries), approximately 19 500 litres of fuel and 470 litres of oil were consumed.

The students learn valuable skills from their involvement with a project of this nature. While reflecting on the project, Ross said: "I found the experience interesting and I rather liked it. To some, *Little Annie* is just an old plane with no potential, but to others with vision, she can be something much more."

The first Antonov AN-2 aircraft was flown on 31 August 1947

and, after 67 years, the Russians still affectionately call the aircraft Annushka, or Annie in English. The nickname is based on the classic comic strip and subsequent film, *Annie*. *Little Annie* and her story have already gained much attention in the aviation community and she can truly make a meaningful difference in communities that are difficult to reach.

Stella High School

The second group comprised ten engineering students: Benjamin van der Merwe, Hein Naudé, Eleandri Oosthuizen, Hanrie Steyn, Maretha Strydom, Hennie Louw, Niel Verwoerd, Carel Wessels, Ruda Oosthuizen and Rudolph Dinkelman.

They originally planned to visit the Stella community to improve the high school's athletics field by laying a new long-jump runway. While planning this project, the group was approached by a member of the community who had initiated a feeding scheme in the informal area. They were asked to further assist the community by building a structure under which the children of the community could receive food and shelter from the extreme weather conditions in the area. They completed both these projects with the help of donations from Afriforum and Wesmelk.

Pongola township development

The third group, a group of BSc Quantity Surveying and Construction Management students, decided to dedicate their time to help an elderly woman who cares for orphans in a rural township in Pongola.

Nico Brecher, Wessel Badenhorst, Chanel Morris, Frans Gerber and JP van Rensburg all worked together to paint and furnish a home the local Bible study group had built for the woman.

The group built two tables for the kitchen, a wardrobe and a bedside table for her new home. They were very thankful for the opportunity to help those in need. The paint needed for the outside and inside of the house was sponsored by Junk Hardware. On the last day, they used the rest of their money to buy food to feed the orphans.

JCP students preparing the soil to lay down a new long-jump track at Stella High School.

Looking good! The finished long-jump track at Stella High School.

The JCP team with the furniture they built and the food they sponsored in the rural township in Pongola.

Collaboration with MIT opens doors

Prof Josua Meyer

The University of Pretoria is always looking for opportunities to collaborate with other innovative institutions around the world. In recognition of this effort, it has established an exchange programme with the Massachusetts Institute of Technology (MIT) in the USA.

→ *The Principal of Bekekayo Intermediate School, Thobela Mashiloane, with the nine MIT students, two UP students (Ivan Mbulaheniki and Nkosinathi Lekaba) and a student from Switzerland (Marina Morawietz). Marina was doing a one-month voluntary community outreach project at UP.*

The exchange programme makes it possible for students from the Department of Mechanical and Aeronautical Engineering to study at MIT for a year and for MIT students to study at the University of Pretoria for a year. The exchange programme is very successful and many students have benefited from it. Initially, the programme was established for a period of five years, but it has been renewed for another five years.

As part of this programme, a group of nine students from MIT visited the University during their spring break in April 2014. In addition to a campus tour and a visit to the laboratories of the Department of Mechanical and Aeronautical Engineering, they also visited the wind tunnels at the Council for Scientific and Industrial Research (CSIR), the Hartbeespoort Dam and Lesedi Cultural Village.

In order to experience South Africa's rich natural heritage, the MIT students visited the Rhino and Lion Nature Reserve, Pilanesberg Nature Reserve and the Cradle of Humankind. Dr Martina Jordaan, lecturer in the Community-based Project (JCP) module, organised the visit. The JCP module is a compulsory module in the Faculty of Engineering, Built Environment and Information Technology.

During their visit, the students visited the Bekekayo Intermediate School, a farm school near Bapsfontein. The school is one of the JCP module's 450 community partners. The purpose of the project was to give the MIT students the opportunity to interact with learners from the school and to do a community outreach project in South Africa. The students painted games on cement, created a volleyball court and repainted the wall at the entrance to the school. The MIT students' feedback on their visit and community project was very positive and they felt that it was a memorable experience.

→ *The Mining Industry Study Centre was developed to provide additional teaching and research facilities to engineering students. It forms part of a strategy to address the shortage of engineering skills in South Africa.*

Mining Industry Study Centre receives excellence award

The University of Pretoria once again showcased its excellent property development initiatives in the Innovative Excellence in Property Development Awards Competition 2014, presented by the South African Property Owners Association (SAPOA).

On 11 June 2014, SAPOA announced that the University's Mining Industry Study Centre had been nominated in the Refurbishments Category. The No. 1 Silo at the Victoria and Alfred Waterfront in Cape Town was crowned the overall winner.

This is not the first award to be presented to the University in this competition. In 2013, the Aula and Engineering 3 precinct won the Mixed-use Category.

Entries for these awards have rocketed by 65% in the past two years, demonstrating the value the industry attaches to these accolades. A multidisciplinary expert panel of judges, comprising leaders in their fields, decided on the award winners.

Among other things, the property developments are judged according to their economic and financial considerations, design concept and environmentally sustainable design. The panel evaluates all submissions in a first-round elimination process to select finalists in each category. SAPOA hosts an exhibition for the finalists, and announces the category winners at a convention. The winning projects in each category are presented in an electronic visual format, which are screened during the convention. All the finalists are also featured in an issue of *SA Property Review.*

"The winners highlight excellence in design and innovation. They meet today's challenges and tomorrow's needs and reflect the cutting edge of design in South Africa and globally," says Neil Gopal, CEO of SAPOA.

Tukkie student wins IOM³ world lecture competition

Cornelis van Niekerk, a student in Metallurgical Engineering at the University of Pretoria, won the Young Persons' World Lecture Competition of the Institute of Materials, Minerals and Mining (IOM³) in Hong Kong in October 2013.

Van Niekerk, whose paper was entitled "Novel technique for *in situ* laser alloying of AISI 410L stainless steel with nitrogen during laser cladding", is studying towards his master's degree in the Department of Minerals Science and Metallurgical Engineering.

He studied BEng (Metallurgical Engineering) and graduated from the Department of Materials Science and Metallurgical Engineering at the University of Pretoria in 2010. In the same year, the Southern African Institute of Mining and Metallurgy (SAIMM) recognised him for the best final-year project for his work on the sensitisation of ferritic stainless steels during low-heat input welding.

After obtaining his master's degree, Van Niekerk will continue his studies towards a doctoral degree. His current research interests include welding engineering, especially welding metallurgy, as well as laser metal deposition and alloy design through laser alloying to improve the lifespan of continuous caster rolls in the steel-making industry and turbine blades in the electricity industry in South Africa.

IOM³ is a major engineering institution in the United Kingdom (UK). Its activities encompass the entire materials cycle. This cycle includes the process from exploration and extraction, characterisation, processing, forming, finishing and application, to product recycling and land reuse.

The competition is open to research candidates under the age of 28 years. It is based on research in the fields on minerals, materials, mining, packaging, clay technologies and wood sciences. The candidates are required to present a lecture on their research topic, and they are adjudicated on the basis of their performance during this presentation.

Van Niekerk's paper explained how nickel-alloyed AISI 410L stainless steel is used in applications where components experience high wear rates (for example, rolls used in a continuous caster, where steel is cast) and are susceptible to high-temperature creep (for example, turbine blades). The high cost of nickel, however, makes this alloy an expensive material to use. The current trend to reduce the cost of nickel-bearing stainless steels is to replace the nickel with nitrogen.

The feasibility of replacing nickel with nitrogen (to improve the wear and creep resistance of AISI 410L) was investigated for laser-cladding applications. This novel method of alloying with nitrogen entails the dissociation of Si_3N_4 during the laser-cladding operation (which is the melting of stainless steel powder onto a medium carbon steel substrate) using the heat generated by a laser beam. A change in the microstructure of the cladded layer, with a consequent increase in hardness (and hence wear resistance), was observed.

The competition was held at the Hong Kong Jockey Club and competitors came from Brazil, Hong Kong, Ireland, Malaysia, Singapore, South Africa, the UK and the USA. Finalists enjoyed a few field trips in Hong Kong before the competition. Activities included visits to a recycling plant, a local university, the underground construction of the mass transit railway (MTR) system and a visit to Hong Kong Aero Engine Services Limited (HAESL), a company that specialises in overhauling and repairing Rolls-Royce aircraft engines. They also enjoyed a cruise to Lamma Island.

→ *Some of the candidates and IOM³ representatives at the MTR underground construction site.*

→ *The candidates and IOM³ representatives at the HAESL facilities, in the testing cell where the engines are tested after being overhauled.*

→ *Top right, below left and right: Candidates at the Hong Kong Jockey Club on the day of the competition. Bottom right: All the delegates from the countries that were represented in the competition.*

UP student receives prestigious prize in Architecture

Craig Mitchell, a student in the Department of Architecture at the University of Pretoria, received one of three bursaries worth R50 000 each from the Carl and Emily Fuchs Foundation. Dr Riaan Els, CEO of the Carl and Emily Fuchs Foundation, announced the three recipients at a function in Durban in April 2014. The other bursary recipients were Laura Graham from the University of Cape Town and André Meyer from the University of the Free State.

From left: Bursary recipients André Meyer from the University of the Free State, Laura Graham from the University of Cape Town and Craig Mitchell from the University of Pretoria with Dr Riaan Els (CEO of the Carl and Emily Fuchs Foundation).

The competition was conceptualised by Prof Paul Kotze of the University of the Witwatersrand, who has been the convenor of the competition since its inception. Architects from practice and academia, each nominated by the eight schools of Architecture they represent, were adjudicated on their portfolios of undergraduate projects and enquiries, their full academic record and a 24-hour project.

This year, the project investigated the design opportunities that address the needs of foreign migrants at Warwick Triangle, a well-known market precinct and transport node at the edge of inner-city Durban.

In response to receiving the prize, Craig said: "The Department of Architecture attaches importance to the appropriateness of architectural intervention and formulating a response to a well-informed argument. This helped me significantly, as the focus of this year's Fuchs Competition was on accommodating migrant workers moving into Warwick Junction. Part of the process was to develop a position statement as a group in reaction to the complexities of the site."

The Carl and Emily Fuchs Foundation is a private funder or grant-making organisation that mainly operates in South Africa. Dr Carl and Mrs Emily Fuchs established the Foundation on 1 August 1969, primarily as a result of the wealth created by the CJ Fuchs (Pty) Ltd Group of Companies they had established in 1929. Sadly, no children were born to them. The Foundation was further strengthened by the proceeds from their personal estates.

The University of Pretoria has another tie with the Foundation, as it established the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University in 1981.

CEFIM is a research centre of the Department of Electrical, Electronic and Computer Engineering.

Mining professors converge on Gauteng from all over the globe

It was with great enthusiasm and excitement that the Department of Mining Engineering at the University of Pretoria and the School of Mining at the University of the Witwatersrand co-hosted the 25th annual meeting and conference of the international Society of Mining Professors (SOMP) in South Africa. This was also the first time that the Society's annual meeting and conference was held on African soil.

→ *Delegates of the annual meeting and conference explore the University's campus (from left): Prof Hein Lieberwirth (Germany), Prof Oscar Restrepo (Colombia), Prof Pinyo Meechumna (Thailand), Prof Vlad Kecojevic (USA), Prof Jurgen Kretchman (Germany) and Prof Huwe Philips (South Africa).*

The Society of Mining Professors, which was established on 21 October 1990 when a group of some 20 professors of mining gathered at the Montanuniversität in Leoben, Austria, held its annual meeting and conference from 26 to 30 June 2014. The conference was officially opened by Prof Cheryl de la Rey, Vice-Chancellor and Principal of the University of Pretoria, at the Maslow Hotel, Sandton, Johnnesburg on 27 June 2014.

The programme of the annual meeting was organised by Prof Ronny Webber-Youngman, President of SOMP for 2013/14 and Head of the Department of Mining Engineering at the University of Pretoria. After introducing Prof De la Rey, Prof Webber-Youngman gave delegates an overview of Mining Engineering at the University of Pretoria.

The industry keynote address was delivered by Roger Baxter, Chief Operating Officer of the Chamber of Mines. The SOMP keynote address was delivered by Prof Oliver Langefeld from the Universität Clausthal, Germany, who considered what universities will be like in fifty years' time with regard to mining education. A number of interesting presentations followed by specialists in the field of mining education.

The second day of the conference was hosted by the University of the Witwatersrand. Prof Fred Cawood, Head of the School of Mining Engineering at the University of the Witwatersrand and co-host for SOMP 2014, gave an overview of research activities at the Wits School of Mining and also introduced the industry keynote speaker, Nick Holland, Chief Executive Officer of Gold Fields.

The final day of the conference, 29 June, was held on the UP campus, where the delegates were welcomed by Prof Webber-Youngman and Prof Roelf Sandenbergh, Dean of the Faculty of Engineering, Built Environment and Information Technology. The conference was concluded with two mine visits on 30 June: one to a deep gold mine, Mponeng, and the other to an underground coal mine, Zibolo Colliery, which proved a memorable experience.

The roots of industrial engineering – The Gilbreths: Cheaper by the dozen

Compiled by Prof Paul Kruger

Frank Bunker Gilbreth (1868–1924) and Lillian Evelyn (née Moller) Gilbreth (1878–1972) could perhaps be regarded as the mother and father of modern industrial engineering. They were an innovative husband-and-wife team that revolutionised the way we do things today.

Frank was the youngest of three children. He was a young man who had to support his mother and aunt financially. He came from a long line of New Englanders. He was born on the USA's East Coast. He started his adult life as an assistant bricklayer with no formal education beyond high school.

Lillian was the oldest of nine children. She came from a family of German descent. She was born on the West Coast. She was an educated woman with social standing and grace. She started her adult life as a student of English literature. She lived a privileged early life as a member of a wealthy family.

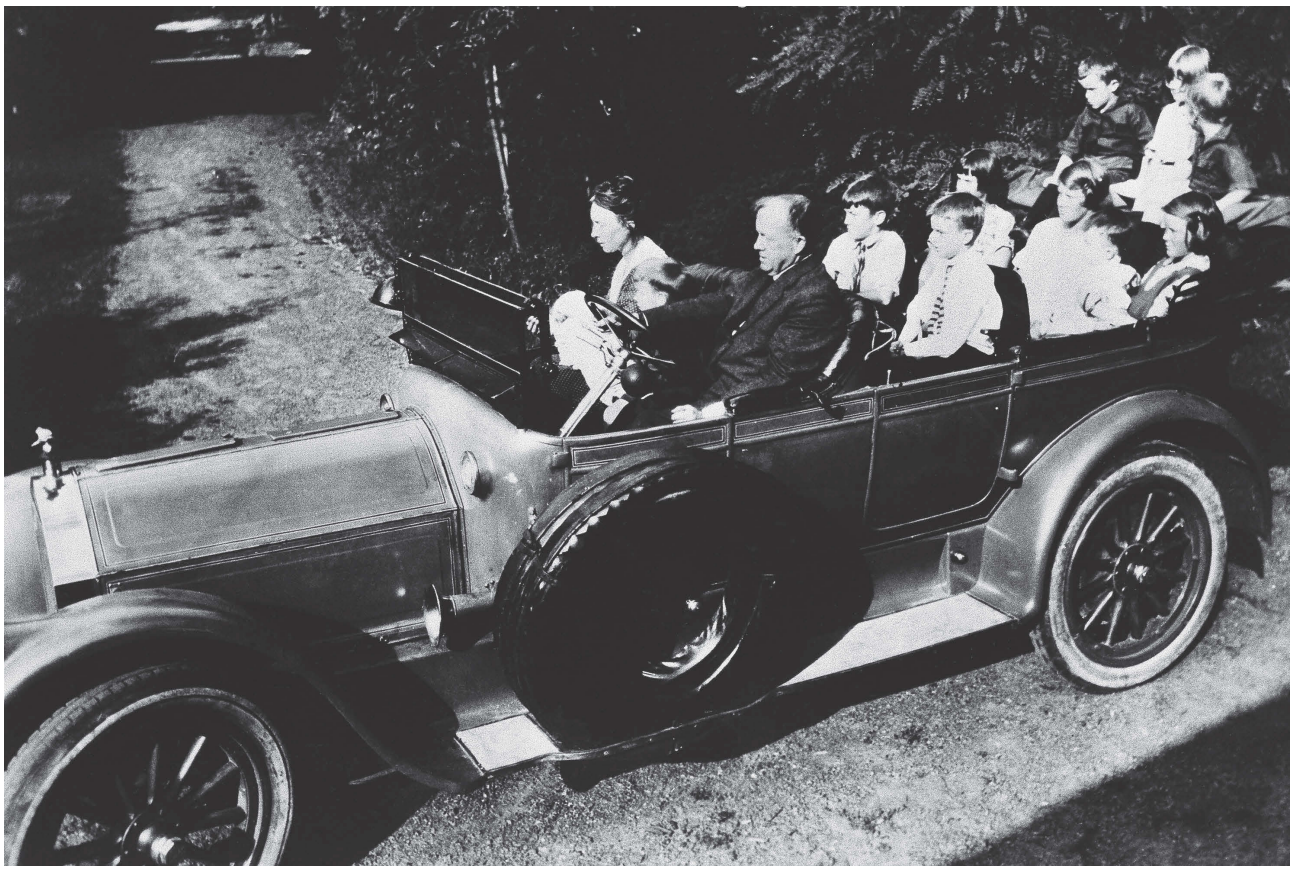
→ *Frank and Lillian Gilbreth.*

They met in Boston in 1903, when Lillian was on her way to tour Europe, and they were smitten with each other. They got married in 1904, had a very happy and successful marriage, equally sharing their family and professional commitments and responsibilities. Lillian gave birth to 13 children, 11 of whom survived into adulthood. One child died at birth and the second eldest, Mary Elizabeth, suffered from diphtheria and died in 1912 at the age of six. The other children were Ernestine, Frank Jr, Anne, Martha, William, Lillian, Frederick, Daniel, John, Robert and Jane.

The Gilbreths perhaps became the best-known and most successful husband-and-wife team in the world of engineering of the early 20th century. They made significant and innovative contributions to science and engineering in disciplines such as motion study, scientific management, ergonomics, human factors, continuous improvement and psychology. They can claim credit for numerous patents and innovative designs aimed at finding and implementing "the one best way" of doing a job. This includes the definition of the so-called "18 fundamental motions" or therbligs, including search, find, select, grasp and position, many of which are still part of modern-day computer user interfaces. These motions are used to study motion economy in the workplace.

After World War I, Frank and Lillian contributed extensively to the improvement of surgical and rehabilitation procedures for returning soldiers.

One day, when a mailman observed the Gilbreth "brood", he asked: "How d'ya ever feed 'em?" Frank responded: "Oh, they come cheaper by the dozen."



→ *Frank B. Gilbreth, his wife and children in their family car, nicknamed "Foolish Carriage", in an undated photograph.*

And so this phrase became a mantra for 20th-century mass production and automation.

Frank's story

Frank was born on 7 July 1868 to John and Martha (née Bunker) Gilbreth of Fairfield, Maine. After his father's sudden death from pneumonia in 1871 and for financial reasons, his mother was forced to move Frank and his sisters, Anne and Mary, to Boston where she opened a boarding house. After passing the Massachusetts Institute of Technology (MIT) entrance examination in the summer of 1885, Frank decided to forgo higher education and entered the construction trade as a bricklayer's assistant. Frank noted that the bricklayers with whom he trained all had different approaches to bricklaying and soon devised a method that eliminated unnecessary motion and greatly increased productivity.

Frank quickly worked his way up in the company and was soon able to support his mother and aunt. In 1895, he started his own contracting firm, Frank Gilbreth and Company. The company became famous for its ability to finish projects early and under budget. In 1902, Frank's firm finished building the Augustus Lowell Laboratory for MIT in 11 weeks, a feat unheard of at the time. Frank's firm became highly successful, completing major construction projects all over the USA and abroad. Soon after marrying Lillian, he sold the business and started a consulting firm, Gilbreth Inc., with Lillian as a full and equal partner. This was possibly the first industrial engineering and management consulting firm in history. Frank was the first to propose that a surgical nurse should serve as a "caddy" (Gilbreth's term) to a surgeon by passing surgical instruments to him or her as requested. Gilbreth also devised the standard techniques used by armies around the world to teach recruits to disassemble and reassemble their weapons quickly, even when blindfolded or in total darkness.

Frank developed many improvements in bricklaying. He invented a scaffold that permitted the quick adjustment of the working platform so that the worker would be at the most convenient level at all times. He equipped the scaffold with a shelf for bricks and mortar, so that the builder no longer had to bend down and pick up each brick. Frank also had other labourers stack the bricks with the best side and end of each brick always in the same position, so that the bricklayer no longer had to turn the brick around and over to look for the best side to face

> Life is like a coin. You can spend it any way you wish, but you only spend it once.
> – Lillian Gilbreth

> We should be taught not to wait for inspiration to start a thing. Action always generates inspiration. Inspiration seldom generates action. – Frank Gilbreth

outward. The bricks and mortar were placed on the scaffold in such a way that the bricklayer could pick up a brick with one hand and mortar with the other. As a result of these and other improvements, Frank reduced the number of motions made in laying a brick from eighteen to four and a half.

Frank was a member of the American Society for Mechanical Engineers, the Taylor Society and a lecturer at Purdue University. He suffered a heart attack and passed away while waiting for a train. He was 56 years old.

Lillian's story

Lillian was born on 24 May 1878 to William and Ann Moller of Oakland, California. Her father was a store owner and the large family enjoyed a privileged lifestyle. Her mother was often ill and Lillian had to care for her three younger brothers and five younger sisters. She excelled in school and was mainly interested in music and poetry. Despite this, her parents did not expect her to go to college. They thought it was more appropriate for a girl of her social standing to marry a rich man and become a homemaker like her mother. She enrolled at the University of California at Berkeley against her parents' wishes and majored in English, Foreign Languages and Philosophy, planning to become a teacher. She continued her graduate studies at Columbia University and Berkeley and received a doctoral degree in Psychology from Brown University in 1915. This was a remarkable achievement, considering her responsibilities as a wife, mother and full-time consultant. After marrying Frank, she became a full partner in his consulting company. She may be one of the first female industrial engineers to hold a doctoral degree.

In 1900, after graduating with honours from Berkeley, she was asked to present the commencement speech at the graduation ceremony. She was the first woman in Berkeley's history to receive that honour. This was only the first of many "firsts". She became the first female member of the Society of Industrial Engineers in 1921 and received the first Gilbreth Medal for distinguished contributions to management from the Society of Industrial Engineers. In 1966, she was the first woman to receive the Hoover Medal for distinguished public service by an engineer. She also became the first female professor at the University of Purdue's Engineering School and became a full professor in 1935. She taught at Purdue until her retirement in 1948 at the age of 70. She also received 22 honorary degrees from universities like Princeton, Brown and Michigan.

As a consultant to Macy's, Lillian was so successful in improving productivity that she was asked to train the company's executives in the implementation of her management techniques. While working with General Electric, Lillian set out the principles of good kitchen design, including the "best" height for kitchen appliances. These principles are still adhered to today. She invented the foot-pedal dustbin and the shelves inside a refrigerator. These shelves included one for holding eggs, which is still found in most modern refrigerators. She was also the first person to integrate psychology into concepts of industrial management. Lillian stressed her belief that every housewife and mother should be a homemaker, but above all, an effective and efficient manager. She was a member of the Society of Mechanical Engineers from 1924, and in 1944, she and Frank received the Gantt Gold Medal from the Society of Mechanical Engineers and the American Management Society. The medal was awarded to Frank posthumously. Lillian served as an advisor to former US presidents Hoover, Roosevelt, Eisenhower, Kennedy and Johnson on matters of civil defence, war production and the rehabilitation of the physically handicapped.

She and Frank have a permanent exhibit in the Smithsonian National Museum of American History, and her portrait hangs in the National Portrait Gallery. She died peacefully at the age of 94.

A formidable team

Although the Gilbreths' work is often associated with that of Frederick Winslow Taylor, there was a substantial philosophical difference between the Gilbreths and Taylor. Taylorism was primarily concerned with reducing the time it took to perform processes. The Gilbreths sought to make processes more efficient by reducing the motions involved. They saw their approach as being more concerned with workers' welfare than Taylorism was. The typical worker often saw Taylorism as management's attempt to increase profit at the worker's expense. Their emphasis on the "one best way" and the therbligs predates the development of continuous quality improvement.

The Gilbreths' lifelong quest consists of finding "the one best way" to make the task faster, but also easier. They aimed to achieve higher productivity without negatively affecting working conditions and to make more profit while making the job easier for the worker. It was a philosophy that pervaded home and school, hospital and community; in fact, life itself. It was something that could be achieved only by cooperation between engineers, educators, physiologists, psychologists, psychiatrists,

→ *Frank and Lillian Gilbreth with eleven of their thirteen children (one died at birth, and the other died at the age of six).*

economists, sociologists, statisticians and managers. Most importantly, the individual's comfort, happiness, service and dignity are at the core of everything.

Frank and Lillian wrote several books together, such as *A primer of scientific management* (1912). None of these books, however, named Lillian as co-author, because the publishers thought that the books' credibility would suffer if it was known that a woman had co-authored them.

The book *Cheaper by the dozen,* written by two of the Gilbreth's children, Frank Jr and Ernestine Gilbreth Carey, offers some light-hearted anecdotes about life in the Gilbreth household.

For example, if irregular jobs had to be done, such as painting the back porch or removing a stump from the front lawn, each child who wanted extra pocket money had to submit a sealed bid stating their willingness to do the job, together with the completion time and cost. The lowest bidder got the contract. Frank would oversee and control the project's execution using the same principles he applied with such success to his construction projects.

In an effort to export his philosophy to the planning and improvement of his family's activities in the house's only bathroom, Frank used activity charts, process charts, work charts and other industrial engineering tools to schedule and control bathroom activities. He also controlled the sequence in which these activities should be performed, the time allowed and even the specific motions to be used.

With this purpose in mind, he took motion pictures of his children performing these everyday bathroom activities and analysed them to specify the most efficient way of completing the task. He was possibly one of the first people to use this technique for activity planning. Furthermore, every child who was old enough was required to initial the charts in the morning after they had completed the prescribed activities, such as brushing their teeth, taking a bath, combing their hair and making their beds. If anyone did not do it, Frank would blow a whistle. All the children immediately had to assemble for a family conference. At this meeting, the culprit was identified and suitably chastised.

Adapted primarily from Cheaper by the dozen *by Frank B. Gilbreth Jr and Ernestine Gilbreth Carey, Pioneers in improvement and our modern standard of living,* IW/SI News *18 (September 1968),* Business and economic history second series *18 (1989): available at http://web.mit.edu, and many other easily available websites, such as http://gilbrethnetwork.tripod.com, http://vectorstudy.com, https://www.asme.org, www2.webster.edu and www.feministvoices.com.*