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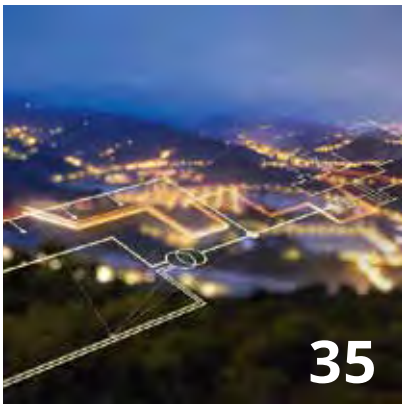
Innovation news

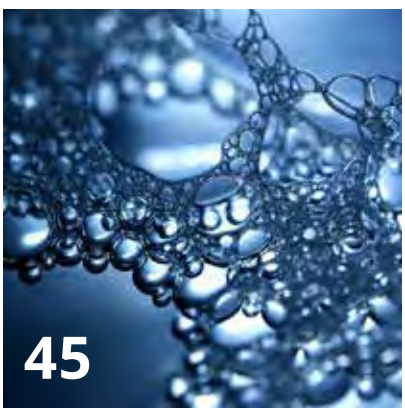
Faculty highlights

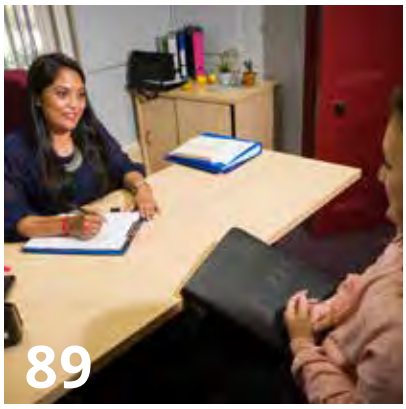
Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Content







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On the cover:

The five synergistic research focus areas of the Faculty of Engineering, Built Environment and Information Technology have the potential to drive research that can make a very real difference in people's lives. Researchers in the Faculty are encouraged to see this as an opportunity for collaborative work that can have a positive impact.

Technology and the future – not science fiction anymore!

Since the existence of the first people on earth, technology has had an impact on the way we have lived. Over thousands of years, the first primitive tool technologies used during the Stone Age have developed to the level of the very complex and sophisticated technology systems we use today. The original development and adoption of technologies were slow, but today every generation experiences waves of new technologies that not only impact on our lives as individuals, but also on our businesses, governments and nations as a whole.

Half a century ago, new technologies were often linked to science fiction adventures. Today we experience real disruption and transformation on a scale that has even attracted the attention of the World Economic Forum in the words of its Executive Chairman, Klaus Schwab: "We stand on the brink of a technological revolution that will fundamentally alter the way we live, work and relate to one another on a scale unlike anything humankind has experienced before". The term "Fourth Industrial Revolution" has become a reality of today and is certainly not seen as science fiction of the far future anymore!

Policy makers, business leaders and academics all over the globe have taken serious notice of the enormous technological changes on our doorsteps. Researchers and practitioners have created new concepts, such as Industry 4.0 (smart industries), Operations 4.0 (smart factories), Cities 4.0 (smart cities) and many more. Emerging technologies such as autonomous robots, autonomous vehicles, 3D manufacturing, Big Data analytics, artificial intelligence and many others are integrated into complex technology systems for application in factories, mines, process plants, hospitals, telecommunications and many others. Business leaders are excited about new markets, higher productivity and larger profits, but policy makers are extremely concerned about future employment, job losses and a shortage of skilled workers.

If ever there was an opportunity for researchers to delve into the development and impact of the new wave of emerging technologies, it is now! The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria focuses its research in five prominent areas: Big Data Science, ICT and technology innovation management, energy, environmental engineering (water), minerals and materials beneficiation, and smart cities and transportation. These areas are all high-priority areas for South Africa and our neighbouring countries. Our researchers have a huge responsibility on their shoulders to make sure that the right and most appropriate new technologies are available in the future for the benefit of our industries and social environments.

In this edition of *Innovate*, you will read about the excellent work our researchers are doing in this regard. There are also interesting articles on the education and learning initiatives and strategies in the Faculty, as well as how the research and educational activities are aligned to ensure the maximum benefit of the society we serve.

I trust you will enjoy this issue of *Innovate*!

Editor
Tinus Pretorius

Message from the Dean

Prof Sunil Maharaj

The Faculty of Engineering, Built Environment and Information Technology is a leading presenter of locally relevant and internationally competitive programmes in engineering, the built environment, information technology, and engineering and technology management at undergraduate and post-graduate level.

Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology.

It attracts high-quality students and staff, and offers extended programmes to facilitate inclusiveness. Through stakeholder involvement, the Faculty is well equipped in terms of research and teaching activities, and houses several research centres and institutes.

The close links maintained with industry support both the teaching and research programmes, and the Faculty's multidisciplinary nature facilitates interaction across disciplines in its teaching as well as its research activities. Through this unique approach, there is a high demand for the Faculty's graduates.

Extensive and cutting-edge teaching, learning and laboratory facilities are integrated into the excellent campus-wide suite of facilities and services offered by the University. Access to programmes is expanded through extended programmes. To shape its students as future leaders, the Faculty expects total commitment with regard to individual and group work.

According to the Thomson Reuters Essential Science Indicators for citations, it was ranked in the top 0.5% of engineering schools in the world in 2016.

In 2017, it appeared in five QS rankings for architecture and the built environment, computer science and information systems, chemical engineering, electrical, electronic and computer engineering, and mechanical engineering.

According to the Department of Higher Education and Training, almost 27.8% of all professional engineering graduates at South African universities graduate from the University of Pretoria. It is also proud to be the only university in Africa to have the USA-based Global Accreditation Centre for Project Management Education Programmes accredit its Master of Engineering (Project Management) and MSc (Project Management) for seven years.

In 2016, the School of Engineering was ranked in the top 0.5% of engineering schools in the world.

In 2016, the Faculty celebrated a legacy of 60 years in engineering education. It takes pride in the thousands of alumni who have ensured this legacy and have laid a firm foundation on which we can continue building. We believe that innovation brings about a positive change and change ignites hope within us – and hope is what our legacy is built on.

The Faculty is organised into four schools: the School of Engineering, the School for the Built Environment, the School of Information Technology and the Graduate School of Technology Management (GSTM).

Its School of Engineering is the largest school of its kind in South Africa in terms of student numbers, graduates and research contributions.

The School for the Built Environment also offers the entire spectrum of related programmes, with studio-based and computer-aided design education in the architectural degree programmes, and close ties and alignment with the construction industry.

The uniqueness of the School of Information Technology makes it a leader in the field in South Africa and its programmes and modern computer science, informatics and information science and collaborative laboratories offer students the advantage of an integrated approach to information technology.

Through various advisory boards, the Faculty has established a strong partnership with the industries it supports. This enables the University of Pretoria to be internationally competitive, while remaining locally relevant. Where applicable, its programmes are accredited by statutory and professional bodies at the national and international levels.

→ *The Engineering III Building, which houses the University's School of Engineering.*

Ultra-high strength concrete revolutionises infrastructure development

The development of an ultra-high strength concrete mixture has been a research focus of the University's Department of Civil Engineering for a number of years, and forms an important part of the emphasis of the Faculty of Engineering, Built Environment and Information Technology on smart, sustainable cities and transportation.

Over the years, successive groups of postgraduate students have worked on enhancing the properties of concrete mixtures by experimenting on which additives result in the strongest concrete mixture for use in construction, as well as for strengthened road pavements, trench covers, stormwater kerb inlets and similar structures.

Prof Elsabé Kearsley is supervising this research, and registered a patent related to the invention of an ultra-high strength cementitious material in 2009. According to Prof Kearsley, this invention is the outcome of about 20 years of postgraduate research in the Department. "What is significant about this ongoing research is that we are focused on finding an application in industry for our students' research to ensure that it is more than just an academic exercise, but impacts on the lives of individuals."

The specialised materials testing that forms part of this research takes place in the Department's Concrete Laboratory, which is equipped to conduct both applied and basic materials research. One of the outputs of this research has been the use of high-strength steel fibres to reduce the required thickness of concrete pavements and the manufacture of ultra-thin reinforced concrete panels. As the resulting product is stronger than traditional

Prof Kearsley and a student in the Concrete Laboratory.

Steel fibres are used to reinforce the concrete.

The ultimate aim of the research is to transfer this state-of-the-art technology to local communities.

→ *Civil Engineering students conduct research on the ultra-high strength concrete.*

concrete, it has less bulk, which has cost-saving implications for the client.

The research team is busy with two applications of this innovative high-strength cementitious material. The first is the development of concrete grid inlets to replace traditional steel inlets. The second is the manufacture of very thin concrete panels that can be used for the cladding of buildings or the construction of prefabricated structures to replace the asbestos panels that were used in the past. The criteria for these products were that the concrete grid inlets should have the characteristics of steel, while the concrete panels should contain all the qualities (in terms of strength) of asbestos in order to make them comparable to this material in their use, and therefore competitive in the market as a replacement product.

A problem that was identified with the use of steel grid inlets for stormwater drainage was that they were often stolen, vandalised or damaged by heavy vehicles driving over them. The research team therefore investigated the possibility of using its steel-reinforced concrete mixture to construct grid inlets that had little second-hand value, and would not be damaged as easily as the steel structures. These concrete grid inlets have now been perfected, and are ready for commercialisation, once a suitable licensee has been identified.

The second application was initiated to provide a product for use in prefabricated buildings that would not break easily, and did not have the health hazards that characterised the asbestos panels that were used in earlier years. The production of these panels is now past the experimental phase, and prototypes are currently being manufactured. Their first use will be as cladding for buildings.

According to Prof Kearsley, these inventions, which emanated from very high-quality experimental research, represent the development of state-of-the-art technology that can be transferred to local communities. The ultimate intention of the researchers is for these products to be manufactured locally using materials that are inexpensive and readily available to generate an income for the communities themselves. Another example of an application for the concrete panels is to use them in the superstructures of ventilated improved pit (VIP) latrines. In the process, the University will have succeeded in its objective of being locally relevant and making an impact on the country's economic development.

Developing autonomous vehicle control

Theunis Botha

Most vehicle manufacturers are investing in the development of autonomous vehicles in order to improve the safety and efficiency of road-based transport. These developments currently only manifest themselves as vehicle safety systems, such as lane-following systems, parking assist and adaptive cruise control. However, the ultimate goal is to develop fully autonomous vehicles that do not only perform the simple repetitive tasks of driving, but also improve vehicle safety in the event of an imminent collision.

The Vehicle Dynamics Group (VDG) in the University's Department of Mechanical and Aeronautical Engineering has been conducting research into the control of autonomous vehicles over the past few years. The focus of the research has been the autonomous steering of off-road vehicles at the limit of their capabilities. The steering of off-road vehicles is a particular challenge due to the soft suspension and high centre of gravity of these vehicles. This results in a vehicle that is more difficult to control than a typical passenger vehicle. The autonomous control of the vehicle steering at a low speed or during low lateral acceleration can be easily achieved with simple control strategies.

However, as the vehicle speed and lateral acceleration increase, the vehicle control becomes more complex due to the tyre reaching its traction limit. Research done by the VDG has shown that, by modelling the vehicle dynamics more accurately to account for the change in vehicle dynamics, the vehicle can be successfully controlled during a rigorous accident-avoidance manoeuvre. However, this method requires many vehicle parameters to be known beforehand. This is not always possible, as the vehicle parameters may change as the road condition changes or as the vehicle load changes. Additional development led to an adaptive controller that adjusts to the vehicle's handling.

Testing the autonomous steering of off-road vehicles at the limit of their capabilities.

The controller continuously records the vehicle steering input and vehicle handling. It uses the recorded steering input to model the measured vehicle handling. The controller, therefore, adapts to the changes in the vehicle handling for the provided steering input. This creates a robust control strategy that does not require any prior vehicle information. It can handle changing road conditions without any external adaptation of the controller.

The controller was successfully validated on an actual off-road vehicle at a testing facility. The vehicle performed rigorous accident-avoidance manoeuvres using a global positioning system (GPS) to provide position feedback of the vehicle. The controller successfully allowed the vehicle to perform the manoeuvre up to speeds where the vehicle was at 90% of its limit and performed better than the average driver on both on- and off-road conditions.

The goal is to develop autonomous vehicles that will also improve vehicle safety.

The controller forms part of the requirements for autonomous vehicles to operate in emergencies. The controller is not only a requirement for a fully autonomous vehicle, but can also be used in driver-assist systems to take control of the vehicle to prevent an accident.

Converting solar energy into electricity

Developing renewable energy solutions is an important research focus area in the Department of Mechanical and Aeronautical Engineering. An invention that will be able to harness energy from the sun has attracted the attention of the Technology Innovation Agency (TIA), which provided funding for the development of a prototype small-scale dish-mounted solar thermal Brayton cycle.

This invention is the brainchild of Dr Willem le Roux, who designed, constructed and tested the initial version of the device as part of his PhD study in 2014. The idea was for it to power homes in off-the-grid and water-scarce areas in South Africa, but he now believes that it may even be able to be used in industrial applications.

The device makes use of a sun-tracking dish reflector, solar receiver, recuperator and micro-turbine to generate power in the range of 1–20 kW. The parabolic dish reflects and concentrates the sun's rays onto the receiver aperture so that the solar heat can be absorbed by the inner walls of the receiver. The heat is transferred to air as the working fluid, which makes this cycle particularly attractive in arid countries such as South Africa. In the recuperator, hot turbine exhaust air is used to preheat compressed air before it enters the receiver. The compressed and heated air then expands in the turbine, which produces rotational shaft power for the compressor and the electric load. The compressor, turbine and generator are mounted on a single shaft, and all spin at the same rate. It is simple, robust and easy to maintain.

The prototype is currently being constructed on the roof of the University's Engineering II Building, and Dr le Roux, who has since joined the University as a lecturer, is supervising ongoing research related to the device, such as upgrading the dish and tracking system, which will contribute to its further development and eventual commercialisation.

According to Dr le Roux, he developed an interest in energy and concentrated solar power (CSP) during his undergraduate studies at the University of Pretoria.

The concept of getting free energy from the sun fascinated him, and he decided to focus on the idea of using air as a working fluid to generate heat rather than water. This was the inspiration for his PhD research, which aimed to convert solar energy into electricity through a micro-turbine. Most of his work involved building and testing a solar collector dish with a diameter of 5 m and a solar cavity receiver.

Dr Le Roux describes its functioning by comparing it to someone taking a lens and focusing the sun's rays onto a small leaf. "Instead of a leaf," he explains, "the energy is focused onto a solar cavity receiver that heats air". The heated air can power what is technically known as a recuperative solar thermal Brayton cycle, which is essentially a micro-turbine that can produce up to 5 kW of power.

He says that this system provides several advantages over photovoltaic (PV) systems (solar panels) and other CSP plants, such as the heliostat field being built in the Northern Cape. Although the system is more expensive than solar panels, it offers much greater solar-to-electrical efficiency, as it boasts a conversion rate of around 30%, compared to 10% to 15% for solar panels.

Compared to conventional CSP plants, advantages are found in the way this system converts solar energy to power. Whereas most CSP plants use the sun's energy to heat either water or salts, the use of heated air means that this system can be used in regions where water scarcity is a problem. Ultimately, it will be able to function as a small-scale hybrid system that can heat water with the heated air in addition to generating electricity. The system will also be able to function around the clock as gas can be used to power the turbine.

Ongoing work related to the development of the device and developing components to optimise its functioning may deliver new inventions that could evolve into potential patents. Master's student Tamryn Wolff is currently working with Dr Le Roux. Her research focuses specifically on the coil receiver that makes the Brayton cycle possible. Kyle Dellar, a research assistant in the Department is also involved in the project, and is assisting with the construction of the prototype. He also manages its day-to-day operation and ensures that all the components function correctly. He plans to enrol for a master's degree under Dr Le Roux in 2018. His research will focus on improving the efficiency of the solar dish recuperator and turbine.

Dr Le Roux hopes that more postgraduate students will join this research endeavour, which has the potential to generate not just electricity, but can also supply hot water. It can provide electricity for 24 hours due to the fact that the turbine can also be powered by gas, which makes it ideal for use in isolated rural communities that do not have easy access to the national grid.

→ *Tamryn Wolff, Kyle Deller and Dr Willem le Roux standing in front of the prototype.*

EBIT inventions showcased at Innovation Bridge event

The University of Pretoria's Technology Transfer Office (TTO) in the Department of Research and Innovation identifies, protects and commercialises intellectual property (IP) that emanates from research and innovation developed at the University of Pretoria. It maximises the advantages created by the University's research output, exploits the IP of the University's scientists and postgraduate students, and provides support in bringing these to commercial fruition.

One of the avenues it uses to expose the University's IP to potential investors is the Innovation Bridge Technology Showcase and Matchmaking event, which was held at Gallagher Estate, Johannesburg on 15 September 2017. This event is held biennially and is attended by academics, innovators and government agencies. It provides a valuable opportunity for national and international technology-based companies, entrepreneurs, investors and other commercialisation partners to access the latest technology offerings from South Africa's universities and science councils.

At this year's event, the TTO selected four inventions emanating from the Faculty of Engineering, Built Environment and Information Technology to showcase. These were the following:

- Controlled release repellent formulations for malaria control
- Polyolefin biocomponent filaments for malaria control as slow release devices for liquid actives
- Improved alkaline-activated slag composition (the development of ready-to use alkali slag cement)
- Innovation in 5G technology (the development of novel on-chip bandpass filters and digital signal processing blocks, as necessitated by future 5G technologies)

These inventions generated much interest from the public and potential investors, and enhanced the University's research profile.

In terms of the University's Strategic Plan, it is committed to maximising the advantages created by its research outputs, thereby supporting economic development and competitiveness, and exploiting its IP by bringing its research outputs to commercial fruition.

Exploiting cross-cutting research and innovation

With the appointment of Prof Jan Eloff as Deputy Dean: Research and Postgraduate Studies in August 2016, the Faculty of Engineering, Built Environment and Information Technology initiated a process of crafting a progressive research strategy to position itself to exploit the research of world-class experts who engage in multidisciplinary research and innovation over multiple academic departments, schools and faculties within the University of Pretoria.

This research strategy encourages research and innovation that is not restricted to finding solutions to challenges within particular disciplines only, but rather to developing initiatives that will have an impact locally, regionally and across the globe. In order to achieve its primary goal of strengthening the University's research and international profile, the Faculty identified five cross-cutting focus areas across its various academic departments and schools with the potential for wider research collaboration.

The deployment of several highly visible research and innovation projects within these focus areas forms the essence of the Faculty's research strategy. These research areas were determined by identifying existing pockets of research excellence that could be leveraged, and were defined as follows:

- Big Data Science, ICT and Technology Innovation Management
- Energy
- Environmental Engineering (Water)
- Minerals and Materials Beneficiation
- Smart Cities and Transportation

Promoting research excellence

Within each of the research focus areas, a number of catalysts and projects, as well as key priority areas, were identified, which would contribute to addressing local, regional and global challenges.

The Faculty's research focus areas were determined by identifying existing pockets of research excellence that could be leveraged.

Big Data Science, ICT and Technology Innovation Management

Within this focus area, the key priority area is the development of a multidisciplinary, interdisciplinary and transdisciplinary research institute for Big Data and Data Science at UP. The main goal is to establish the University as the leading authority in Big Data and Data Science in South Africa and on the African continent.

The five research focus areas:

- **Big Data Science, ICT and Technology Innovation Management**
- **Energy**
- **Environmental Engineering (Water)**
- **Minerals and Materials Beneficiation**
- **Smart Cities and Transportation**

Cross-cutting research in this focus area is mainly being conducted in the departments of Electrical, Electronic and Computer Engineering, Informatics, Information Science, Industrial and Systems Engineering, Civil Engineering and Computer Science. The potential for collaboration with departments in other faculties at the University includes the departments of Computational Biology, Family Medicine, Radiology, and Exercise and Sport Medicine in the Faculty of Health Sciences, and the departments of Physics, Statistics, and Mathematics and Actuarial Sciences in the Faculty of Natural and Agricultural Sciences.

Potential applications of this research to make a difference locally and globally include articial intelligence, transportation, sport science and medicine, computational finance and economics, intelligent approaches to road-infrastructure maintenance, radio-astronomy (the Square Kilometre Array (SKA)), digital forensics, cyber-security and e-governance.

Energy

The key priority areas in this focus area are energy efficiency

and demand-side management, advanced materials for energy systems, clean and renewable energy, nuclear and energy modelling.

Research in this focus area is of a multidisciplinary nature and is being conducted in the departments of Electrical, Electronic and Computer Engineering, Chemical Engineering, Mechanical and Aeronautical Engineering, as well as the Graduate School of Technology Management. There is potential for collaboration with the Department of Physics in the Faculty of Natural and Agricultural Sciences.

Environmental Engineering (Water)

Water resource engineering and management, water utilisation and environmental engineering are among the key priority areas within this focus area. Goals in this regard include developing the utilisation of hydropower as a viable renewable energy source in South Africa for the benefit of industries and communities, and understanding and improving the security, efficiency, reliability and sustainability of South Africa's water resources.

Cross-cutting research in this focus area includes that being conducted in the departments of Chemical Engineering, Civil Engineering, and Mechanical and Aeronautical Engineering, while the UP Water Institute in the Faculty of Natural and Agricultural Sciences also offers potential for collaboration. This research can be applied in the fields of hydropower and sustainable water resources, biomass resources and support infrastructure.

Minerals and Materials Beneficiation

In this focus area, the priorities are twofold: to enhance the activities of the University's Mining Resilience Research Centre (MRRC) and – through the research strengths in chemical and metallurgical engineering – to work towards the establishment of a Future Cluster on Minerals and Materials Beneficiation. The goal is to upscale South Africa's mining industry by focusing research efforts on mechanisation and automation, rock-breaking and explosive engineering, management and leadership, safety and health, risk management, mine ventilation engineering and rock engineering. Research on minerals and materials beneficiation is being conducted in the departments of Chemical Engineering, Materials Science and Metallurgical Engineering, and Mining Engineering. The Department of Geoinformatics and Geosciences in the Faculty of Natural and Agricultural Sciences also offers potential for collaboration. This research can be applied in the fields of industrialisation, diversification and mining resilience.

Smart Cities and Transportation

The first priority in this research focus area is to establish a Building Sciences Living Laboratory. The second priority is to develop the facilities on the University's civil engineering, materials testing and research facilities on the Experimental Farm. These facilities will form part of a future transportation activity for rail, road and autonomous vehicles. The partnerships with Transnet, the Railway Safety Regulator and the South African National Roads Agency SOC Limited (SANRAL) are key drivers of this agenda.

Cross-cutting research in this focus area is being conducted in the departments of Civil Engineering, Electrical, Electronic and Computer Engineering, Mechanical and Aeronautical Engineering, Architecture, and Town and Regional Planning. Potential applications of this research include energy efficiency, smart building, smart grids, green retrofitting, social learning spaces and occupant behaviour so as to model future sustainable and smart cities, especially related to the African continent.

Research strategy

Several initiatives have already been identified that will be launched over the short term to transform the Faculty's research approach into one that is globally visible. These include, among others, determining the extent of the publication of the Faculty's research in high-impact journals in order to set achievable targets for the next five years, and developing research indicators to improve research outcomes and global rankings.

Emphasis is also placed on the development of a research profile for all academic staff of the Faculty. These research profiles will focus on the productivity and quality of all researchers in the Faculty of Engineering, Built Environment and Information Technology.

Through TuksNovation, the Faculty's new business technology incubator (see article on p 33), the idea is to start nurturing a culture of innovation, and specifically to bridge the chasm between research and innovation. In this regard, an incentive scheme will be developed for the participation and contribution of academics without necessarily compromising research outputs.

According to Prof Eloff, the plan is to develop and implement a Faculty research agenda within the next two years that clearly reflects the identified research focus areas, and how they relate to high-visibility projects. Stakeholder alignment will be sought for the University's research agenda, while launching activities within the Faculty that will ensure growth and investment opportunities for partners in industry.

By 2020, the Faculty hopes to formalise both a Faculty Stakeholder Model and a Faculty Collaboration Model that will focus on global collaboration. This will contribute to achieving the University's mission to be a leading research-intensive university in Africa, recognised internationally for its quality, relevance and impact, and also for developing people, creating knowledge and making a difference locally and globally.

Research synergy:

Big Data Science, ICT and Innovation Technology Management

Establishing UP as the leading authority in Big Data Science, ICT and technology innovation management

Big Data Science, ICT and technology innovation management are considered strategic research focus areas in the Faculty of Engineering, Built Environment and Information Technology. Research in this focus area includes Big Data, data management, machine learning, statistical learning, the Internet of Things, data fusion, digital forensics, cyber-security and visualisation, among others.

In support of this focus area, the Faculty has launched a Master's in Information Technology (Big Data Science) degree with participation from multiple academic departments across different faculties. It is envisaged that this degree will contribute to increasing the number of PhDs in the Faculty with 20% by 2020. Funded research programmes that will provide scholarships will be developed to grow the next generation of researchers, as well as the number of postgraduate students in the Faculty.

It has also developed an interdisciplinary Data Science Institute, which will contribute to establishing UP as the leading authority in Big Data Science in Africa. The international visibility of the institute will be leveraged by the University's highly recognised research profile, notably through its A-rated scientists in artificial intelligence and, in particular, machine learning.

Several existing initiatives related to Big Data Science, ICT and technology innovation management are also contributing to strengthening the Faculty's research profile. These include the South African Research Chairs Initiative (SARChI) Chair in Advanced Sensor Networks, the Sentech Chair in Broadband Wireless Multimedia Communications, the Carl and Emily Fuchs Institute for Micro-electronics (CEFIM) with its leading mm-wave laboratory (the only one in Africa), as well as ongoing research in human-computer interaction and applied data science.

The current alignment of research in cognitive radio networks, advanced sensor networks and cyber-security will strengthen the opportunity to exploit forthcoming bilateral agreements between the National Research Foundation of South Africa and the National Science Foundation of the USA.

Further endeavours to enhance the Faculty's research profile include the potential for establishing new research chairs in Data Science, Digital Forensics, Machine Learning, Cyber-security and Statistical Learning. A research collaboration model will be developed with well-ranked international universities, such as Rutgers University in the USA. Postdoctoral fellows will also be recruited and appointed, which will attract a strong postgraduate fraternity in Big Data Science.

Leveraging hidden knowledge through Big Data

Today, just about every sector of the economy has access to huge amounts of data, in a number of different formats, and accumulates more data at a rate that by far exceeds capacity. Many industries do not yet extract any value from their data archives and warehouses. It becomes more and more the case that data is simply captured and stored, and nothing is done to leverage hidden knowledge embedded in such data. This is mainly due to a dearth in Big Data and data science expertise, both nationally and internationally.

In the Faculty of Engineering, Built Environment and Information Technology, Big Data Science, information and communication technology (ICT) and technology innovation management are considered to be strategic focus areas that are exposed through teaching and research in the fields of Big Data, data management, machine learning, statistical learning, the Internet of Things, data fusion, digital forensics, cyber-security, e-governance and visualisation, among others.

What is Big Data?

Although the term Big Data was first coined in the 1990s, academically, it first made its appearance in 1998 to describe working with large volumes of data. Big Data is the term used for a collection of data sets so large and complex that they become difficult to process using on-hand database management tools or traditional data-processing applications.

Gartner (2014) describes Big Data according to its underlying characteristics. It mentions that Big Data is a collection of high-volume, high-velocity, high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making. The fact that we have too much data to consume is not new. The term "information overload" was popularised by Alvin Toffler in 1970 in his book *Future shock* (Toffler, 1970). This term has evolved into what is known as Big Data.

Data science refers to the scientific investigation that employs innovative approaches and algorithms for managing, processing and analysing data. With reference to Big Data, challenges include data capture, data curation, efficient search or querying, data sharing, storage, transfer and privacy issues.

Data analytics is not a new concept. Tools to store, retrieve, manipulate and analyse data have been developed and used since the early 1960s. Machine learning and statistical learning technologies are in abundance, and have been very successfully applied to identify and better understand hidden trends in data, extract knowledge from data and mine data. However, these early tools mostly considered structured data and data of a modest size.

Data analysis and understanding have become a more complex problem with the increase in the amounts of data to be analysed, as well as the requirement to analyse data of different formats to include text, images, audio and video. Even considering these complexities, efficient tools have been developed to provide insights into hidden trends. Solutions have also been developed for applications that require multiple data sources to be integrated.

The main challenge in data analytics came with the tremendous increase in the amount of data generated, to be stored, analysed and archived. We are no longer faced with data sets of megabytes or gigabytes, but data sets are reaching terabytes and even petabytes. This increase in data, as well as the demand for new efficient data analysis techniques, has spawned the Big Data revolution.

In addition to the increase in data, the complexity of data analytics is further increased due to the fact that data becomes incrementally

available (it is continuously streamed). This not only requires new scalable data analytics tools, but also requires tools that can detect change in underlying data distributions, requiring one to continuously adapt the data model. Big Data requires the capability to manage such huge amounts of structured and unstructured data, at acceptable speeds and within time frames that allow for timeous insights into hidden trends. Typically, Big Data consists of data from a number of related and unrelated sources of different types, and may consist of static data sources or dynamic data streams.

The complexities inherent in Big Data and Big Data analytics demand sophisticated infrastructure, including physical computing resources, security and authentication, and analytical tools, thereby opening up new research opportunities in the entire life cycle of a Big Data Science project.

Big Data Science and ICT research at UP

The significance of Big Data for teaching and research lies in the fact that it has grown from being a concept into something tangible with measurable characteristics. Within the Department of Computer Science, the Computational Intelligence Research Group (CIRG) is very active in research related to artificial intelligence, machine learning, and data analytics and data mining research. Furthermore, the Cyber-security Research Group is focusing on the intelligent detection of fake identities on Big Data platforms such as social media (particularly Twitter). The newly established Data Science Institute is also poised to strengthen the University's research profile with regard to Big Data and data science research.

However, despite Big Data Science and ICT traditionally being the domain of the Department of Computer Science, it is not the only department to conduct research in this field. The Department of Informatics also has focused research activities in data-driven technologies, data warehousing, and explorative data analysis and data mining. In the Department of Information Science, information ethics, research data management, multimedia for Big Data visualisation, and virtual reality are key research areas.

Big Data Science is traditionally the domain of Computer Science.

Beyond the School for Information Technology, the Intelligent Systems Group in the Department of Electrical, Electronic and Computer Engineering is also very active in research related to artificial intelligence, and machine and statistical learning, as well as Big Data-enabling platforms and technology, data fusion and data analytics, image processing and computer vision. In the Department of Chemical Engineering, researchers have developed a software package that is being used in the development and simulation of stochastic models for value chains. In the Department of Civil Engineering, data analysis systems are being used to measure the behaviour of strain-bearing structures such as integral bridges, which will assist in the development of stronger structures. Under the auspices of the multidisciplinary Centre for Transport Development, vast amounts of data about traffic patterns are being generated and analysed in the Department of Industrial and Systems Engineering and the Department of Civil Engineering.

The application of Big Data for research even extends beyond the Faculty of Engineering, Built Environment and Information, Technology. In the Centre for Geoinformation Science in the Department of Geography, Geoinformatics and Meteorology, research is being conducted on spatial data. In the Department of Mathematics and Applied Mathematics, research is being conducted in data-driven modelling, bio-mathematics and financial engineering. In the Department of Actuarial Sciences, research is being conducted in risk management and financial modelling.

Other departments and entities within the University's various faculties are also producing vast amounts of data, which can benefit from the insights to be gained through data analysis. These include the Department of Family Medicine, the Institute for Sport, Exercise Medicine and Lifestyle Research, the Genomics Research Institute, the Centre for Bioinformatics and Computational Biology and the Institute for Cellular and Molecular Medicine.

The application of Big Data Science, ICT and technology innovation management at the University of Pretoria has unlimited potential and impacts on every aspect of people's lives.

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Big Data is the term used for a collection of data sets so large and complex that they become difficult to process using on-hand database management tools or traditional data-processing applications.

State-of-the-art developments in Big Data and data science

In recognition of the potential of a research institute for Big Data Science, the University of Pretoria established a Data Science Institute, within the Faculty of Engineering, Built Environment and Information Technology, to enhance its international profile and visibility, increase its impact through high-quality multidisciplinary research and publications, and produce high-quality postgraduate students to fill the gap in the availability of Big Data and data science experts. It will contribute to establishing UP as the leading authority in Big Data and data science in South Africa, as well as the leader on the African continent.

Due to its existing world-class expertise in multiple disciplines related to Data Science, the University is well positioned to host such a research institute. This expertise includes Prof Andries Engelbrecht, an A-rated scientist who is a leader in computational intelligence on a global level, and Prof Jan Eloff, a B-rated scientist who specialises in cyber-security.

The vision of the Data Science Institute is to become a recognised, world-class facility for research in Big Data Science, as well as in technologies, human capital development and the delivery of innovative solutions.

This vision will be implemented by means of the following:

- Developing a co-stakeholder model, which includes industry, academic and public sector partners.
- Building a multidisciplinary and interdisciplinary Big Data Science group within UP across various academic faculties, departments and institutes.
- Delivering world-class research outputs that contribute to the advancement of Big Data and Data Science in general.
- Implementing advanced human capacity building and the provisioning of relevant educational Big Data Science programmes for industry at undergraduate and postgraduate levels.
- Focusing on the delivery of innovative data science solutions for real-world problems, which are of value to South Africa and the developing world.

The plan is to leverage existing research chairs or establish new ones, which could include the following:

- Big Data Science for e-Government
- Big Data Analytics
- Artificial Intelligence (Machine Learning)
- Optimisation
- Cyber-security
- Digital Forensics
- Applied Data Science
- Information Ethics
- Information Fusion

In the short to medium term, the research activities of the Data Science Institute will focus on or support the development of innovative solutions in a number of applications, including image analysis, cyber-security, digital forensics, financial services, biodiversity, computational biology and information fusion.

Key education initiatives in the Department of Computer Science that are closely related to the Data Science Institute include the master's degree in Information Technology (Big Data Science), as well as short courses to industry that can be used for professional career development and the reskilling of existing staff. These courses include Introduction to Big Data Science, Introduction to Machine Learning and Introduction to Big Data Platforms, which are presented through Enterprises UP.

The software infrastructure comprises an open-source component and a propriety component. Funding for the commercial software will be sought from major industry stakeholders, such as IBM, while funding for the start-up hardware has been obtained with the assistance of a grant of R2.3 million from the Department of Science and Technology (DST).

Using Big Data Science to predict insurance claims fraud

David Kenyon and Prof Jan Eloff

The cost of insurance in South Africa has increased due to new legislation. If this cost is not offset by reducing other costs, insurance in South Africa could become increasingly expensive. This is further compounded by an increase in fraud that is plaguing the insurance industry. Fraud costs the insurance industry of South Africa an estimated R8 billion a year, of which claims fraud is a substantial contributor.

To reduce this cost, researchers in the Department of Computer Science investigated the development of a secure framework using Big Data Science to predict whether an insurance claim is fraudulent. This was done within the bounds of the fact that alternate new legislation, such as the Protection of Personal Information (POPI) Act, limits how data about a person can be stored and what it can be used for.

Insurance fraud can be defined as the wrongful or criminal deception of an insurance company for the purpose of wrongfully receiving compensation or benefits. Insurance fraud can further be split into hard and soft fraud or planned and opportunistic fraud. Criminals who create false accidents or injuries are seen as an example of planned (hard) fraud. In comparison to this, policy holders who overinflate their claims to increase their monetary gain can be seen as an example of opportunistic (soft) fraud.

Having large data sets adds little value unless enhanced insight can be gained from it. Therefore, there is an overlap between Big Data, data science and predictive analytics.

The financial services and insurance sector is becoming increasingly susceptible to cyber-security threats, such as malware, phishing and the abuse of internal access rights, as well as theft or loss of hardware and information. To mitigate this risk, the private and public sectors must undertake preventative measures, such as technical (hardware and software) prevention, training and vendor management.

One prevention method involves masking any personal information that can be used to uniquely identify a person. If data is hashed enough so that policy holders' information is no longer valuable to an external attacker, then the cyber-security risk can be seen to be partially mitigated.

Research framework

The Big Data Science process can be split into four phases: data preparation, machine learning, knowledge application and model maintenance.

The data preparation phase comprises data pre-processing (removing outliers, fixing or removing missing values and repairing discrepancies in fields such as names), data masking, data extraction, data cleaning, data import and data transformation. Open-source tools such as OpenRefine are used to standardise the fields in order to eliminate any discrepancies that may affect the results.

In normal operating procedures, pre-processing would ideally happen after data extraction. However, due to the sensitivity of the data, pre-processing needs to occur before data masking. Data masking is necessary in cases where anonymity is important. Owing to the fact that this research aims to protect privacy, data masking is an integral step in the process. The data needs to be anonymised in such a way that a policy holder cannot be identified by a record, but where the data would still be usable in the machine learning process. This includes being able to uniquely identify a policy holder based on alternate personal information, such as gender, postal code and birth date.

Data extraction is the process whereby the data that has already been pre-processed and masked is moved from the source system into the target data source. Considerations such as different

The prediction of insurance claims fraud is one of the many applications of research in the field of Big Data.

operating systems, software platforms, communication protocols and the structure of the data need to be taken into account.

To apply this research to short-term insurance in countries other than South Africa, the data extracted should be generic enough to apply to property and casualty insurance on the global domain. To do this, the Association for Cooperative Operations Research and Development (ACORD) standards for data extracts should be used.

Once the data has been moved into a staging area for data cleaning, the second attempt at data pre-processing takes place. The original data pre-processing step exists to prevent erroneous data after masking. The data-cleaning step, however, includes the bulk of the pre-processing.

Once the data has been cleaned, it is stored. In a Big Data Science solution, the data is often stored in a cluster computing file system. This is due to the fact that the cluster computing framework accommodates large-scale analytics.

Although data transformation in an extract, transform and load (ETL) process often includes data cleaning, this step focuses on filtering and converting a finite set of input values to a finite set of output values.

To run Apriori Association Rules on a model, it is often expressed that the variables in the model need to be discrete instead of continuous. To do this, the variables are discretised; an example of this is placing the continuous variables in factors that express a numeric range instead of a floating point number.

Another example of data transformation that exists in this use case would be to create calculated fields. For the short-term insurance application, the date difference between the policy start date and the date of the claim is calculated.

Once the data has been fully pre-processed, cleaned, masked and transformed, the advent of machine learning takes place. Machine learning techniques to predict fraud are not commonly published due to the fact that they need to be kept confidential for security reasons.

The machine learning phase comprises two sub-phases: model training and accuracy testing. To train the model, one needs to import the data from the Big Data structure. Predictive model creation is often seen as an iterative process instead of a single-phase approach. The model is trained by adding half of the data set to the model and applying the data mining or machine learning algorithm to this data set. This process is repeated with different combinations of variables. The second half of the data set is used to test the model.

Once the model is created, the accuracy needs to be tested. Here, the variables that skew the results or are unnecessary are removed from the training dataset.

Appplying knowledge after it has been extracted to systems is a key step in the Big Data Science process. The main purpose of knowledge elicitation is to provide end-users with automatic recommendations. Instead of requiring analysts to portray the important knowledge and rules generated from these systems in the form of rules, ratings and concept maps, it can be beneficial to create automatic rules that can be applied to existing systems.

The rules that are generated by algorithms are often not immediately usable by end-user systems. Therefore, the rules are converted to XML and imported into the system and applied to new claims without having to rebuild hard-coded business rules.

If these business rules are applied to new claims, automatic

recommendations can be made as to whether there is a fundamental issue with a claim. If the Apriori Rule indicates that a claim is possibly fraudulent, this recommendation is made. If a business rule is broken based on Apriori Rules, this will also be indicated.

Once the model has been generated and applied, the rules should not be static. Very few organisations maintain their models long after they have been created. Ensuring a successful predictive analytics model is an integral step as it can minimise overheads, could result in increased reuse of the model and could increase performance.

To facilitate the aforementioned process, a specific architecture to perform Big Data Science and produce automatic recommendations is suggested. File systems such as HDFS within Hadoop can be maintained using a data warehouse structure such as Hive. Hive translates SQL-like language to MapReduce to facilitate data manipulation.

To perform machine learning on the data within Hadoop, analytics tools are widely used. These Data Science tools include software such as R, RapidMiner, SAS, SQL and Python, of which R is the most commonly used. Alternate versions of R, such as Microsoft R Open and Microsoft R Server (Revolution R), have been developed to make the analytics performed by R more scalable and work with bigger data sets.

Alternately, there are machine learning tools that form part of the Apache Software Foundation, such as Mahout. It is suggested that R is used for optimal results with smaller data sets. Mahout is suggested for bigger data sets to increase performance.

Testing the model on insurance claims fraud

From the aforementioned process and architecture, the application of Big Data Science on insurance claims fraud was tested with privacy preserving data mining (PPDM).

The validity of a rule is often classified using values such as lift, confidence and support. Lift indicates the measure to which event A and event B are not independent. Confidence, however, is the ratio of the number of transactions with the correct input and output factors to the number of transactions with the correct input factors. Lastly, support is all items with the correct input and output factors that generate a rule; the support can also be seen as a percentage of the total number of transactions in the record set.

For this research, the researchers used lift as the most valuable indicator of the importance of a rule. They therefore created a model with 34 distinct fields. These fields included information such as sum insured, total policy revenue, insurer, broker, policy start date, policy end date, personal information, and calculated fields such as loss ratio and the difference between the date of the claim and the policy start date.

From these fields, the Apriori model is run with a confidence threshold of 0.5, and a support threshold of 0.4. With these thresholds, 181 distinct rules are generated. Importantly, personal information has not filtered through to the rules. This is due to the fact that the measures of validity for a rule include support. The personal information of a policy holder would not occur frequently enough to create a rule in a sufficiently large dataset.

However, it should be said that having high lift, confidence and support might reduce the knowledge gained from the machine learning algorithm. One could therefore reduce the support threshold to infer more information. This could be done to gain knowledge based on personal details where the number of times that the same information occurs is low. This will mean that the data-masking step of the Big Data Science process is highly important. If it is assumed that the intent of the machine learning algorithm is to find rules based on any facts. For example, if a syndicate committed fraud multiple times with the same alias across different insurers, brokers and agents, it can be said that the necessity to mask personal data is valid. This can be seen as a viable way to apply a machine learning algorithm to data while maintaining anonymity.

From the research presented, the value of using Big Data Science to predict and prevent insurance claims fraud can be seen. Techniques that add value and can reduce cost will surely be welcomed by the insurance industry of South Africa and abroad, due to the increase in the cost of insurance. Although predicting insurance claims fraud through Big Data Science cannot be said to be completely accurate, the value that is gained is the indication that there are fundamental issues with a claim and that a claim breaks rules. Finally, if the antecedent of an association rule is the fraudulent claim indicator, then one can predict with confidence that the claim is fraudulent.

Due to the POPI Act, the use of Big Data Science reduces the chance of cross-broker and cross-insurer use. With the use of PPDM, data hashing and the anonymisation of data, there is a higher chance that adopting Big Data Science will be acceptable. Insurers and brokers can have a higher assurance that they are not at risk of losing policy holders to competitors if they share this information, as there is not enough information to identify a person.

In conclusion, it is proposed that if the insurance industry can agree to share information in this way, incidence fraud can be reduced. This will benefit them separately and as a whole.

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A Big Data Science experiment: identity deception detection

Estée van der Walt and Prof Jan Eloff

Identity deception detection is a problem on social media platforms today. Not only are there challenges towards determining people's authenticity, but also with analysing the data that forms part of the communications. This heterogeneous data includes photographs, videos and audio. Furthermore, most social media platforms operate in an uncontrolled environment. Anyone can contribute content and take part.

Even though there are age restrictions in place, these are not necessarily enforced and the public is expected to be honest. This is dangerous for minors in particular, as they are either unaware of the dangers or are not mature enough to be responsible for their actions online. Online predators are aware of this fact and target this group specifically. A study conducted in the University of Pretoria's Department of Computer Science presents a work-in-progress towards developing an intelligent Identity Deception Indicator (IDI). It is envisaged that this research could eventually assist authorities in conducting large-scale observation on public social media platforms, such as Twitter. Those personas whose behaviour and online content do not agree with the age group they are conversing with would be of particular interest.

Deception is defined as a "deliberate attempt, without forewarning, to create in another a belief that the communicator considers to be untrue". According to an article published in *IEEE Internet Computing,* identity deception can be defined according to three different types: hiding your real identity, using an identity of another real person, and counterfeiting an identity. Of particular interest is the case of counterfeiting an identity. It is easy for a predator to counterfeit an identity and go unnoticed in a Big Data environment, such as social media platforms.

New innovative solutions are needed that can minimise the risk of identity deception. Large-scale innovations are those that will be beneficial to society as a whole, including intelligent identity deception tools that can aid the prosecution of harmful people. Small-scale innovations are tools that can provide safe browsing on the internet. These will be beneficial to the individual.

Big Data, combined with machine learning and predictive modelling, allows the extrapolation of value out of the large volumes of data. Literature refers to the three characteristics (volume, velocity and variety) of Big Data as the three Vs. Many other characteristics of Big Data have been proposed like value, viability, validity and veracity. Because data from social media platforms originates from uncontrolled environments, it makes minors especially vulnerable to harmful behaviour, paedophiles and the like. Social media platforms provide the ideal platform for an attack, mainly because of its Big Data nature and the complexity of its non-textual data. It is easy for a predator to go unnoticed in this environment.

Figure 1 illustrates the convergence of the particular fields that are of interest to this study and shows that there is an emanating risk of identity deception as a result of this convergence.

Despite extensive educational campaigns on online privacy and safety, minors are still being exposed to threats such as cyber-bullying and paedophilia. Protecting minors is complicated even more by the fact that many minors lie about their age when communicating online. Deception is common in everyday life and lying on online social networks is quite common. Deception is always used to accomplish goals, and sometimes to a detrimental effect.

Law enforcement agencies usually find identity deception difficult to detect on a large scale, as they rely on machines to find exact matches.

Large volumes (Big Data) and the reliance on historic data, however, pose a problem, as the crime is usually detected after it has already occurred.

It is imperative that all the different characteristics of Big Data are understood and considered when searching for solutions to detect identity deception on social media platforms. From a cyber-security perspective, the goal is to minimise the risk of minors being exposed to harmful behaviour on social media platforms. This risk should be reduced by designing the appropriate countermeasures, such as the proposed IDI. The authenticity of an identity also needs to be determined, considering the online activities of minors and perpetrators on social media platforms.

Figure 1: The convergence of Big Data and Data Science, cyber-security and human factors.

A Big Data Science experiment

Experimental work completed prior to the current study identified Twitter as the social media platform to be used. Two sets of Twitter data were retrieved. The first set was an initial set of tweets where the hash tags "school" or "homework" were used. These hash tags were chosen because they were deemed to be the words mostly applicable to minors. The second set comprised the last 200 tweets of the first set, including the last 200 tweets of their followers and friends. Combined, these two sets created a Big Data set of a network of social media messages between potential minors.

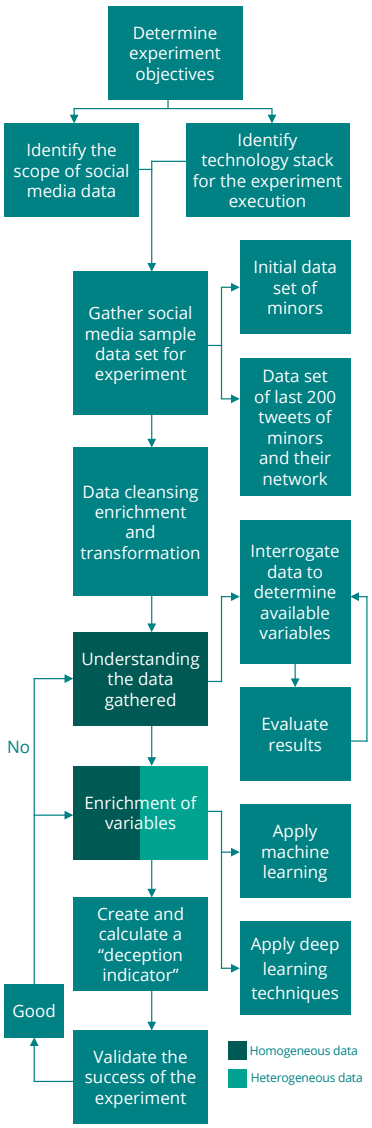

Figure 2: The methodology followed in this study.

The researchers postulated that the tweets themselves could carry some indication of age. Furthermore, the data indicated that heterogeneous data, like profile images, could also hold valuable information.

The initial results of the data analysis showed that hash tags were most likely to be found with another hash tag. For example, a user who uses the hash tag #read will next use the hash tag #book. This can be useful in the case of minors to understand what they will most likely talk about or tag next.

The identified set of hash tags will be used as input to train a machine learning algorithm to classify tweets as originating from minors or not. The classification of a tweet as not originating from a minor, in this example, should raise concerns for investigation towards protecting minors on social media platforms.

Conclusion

Minors are at risk and need to be protected. Research following this study could work towards an early warning mechanism in the form of an IDI. Based on the research, many useful variables were identified towards the creation of an intelligent IDI. However, it appears that much more enrichment and data clean-up is required to work with a data set that is fit for analysis.

For example, it was found that the phrase "budget cut" was most prevalent in tweets from the sample set. As this is unrelated to "school" and "homework", it is indicative that some advertisement tweets are still contained in the sample set. This irrelevant data could render inaccurate results.

The data clean-up will be addressed in follow-up research and further work will be done towards applying machine learning and deep learning for variable enrichment. Additional machine learning techniques will be investigated to understand their usefulness in creating an IDI. It is envisaged that the experiment will culminate in a more mature IDI for social media Big Data sets, which are complex in nature.

Acknowledgment

The support of The Hasso Plattner Institute Future Service-Oriented Computing (SOC) Research Lab in Potsdam (Germany) is acknowledged for making available powerful infrastructure to conduct the research activities.

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MAD about UX at the Informatics Design Labs

Helene Gelderblom

Every bit of technology that we use was conceptualised and designed by some person or group of people. Someone saw a need or an opportunity that prompted a process of prototyping, testing, developing and selling the idea. The competitive environment for mobile applications compels designers to create a user experience that will give their product the edge. This is not a straightforward process and many people with good ideas never get the chance to develop them into products because they lack the skills and resources to do so.

The Informatics Design Labs in the University of Pretoria's Department of Informatics offer the space, technology and skills required to help organisations and individuals design, develop and evaluate technology products. They consist of a mobile application development (MAD) lab and a user experience (UX) lab to support the design of exceptional user experiences, as well as the evaluation of user interfaces with eye-tracking technology.

Solving problems by adopting UX practices

The aims of the Department's UX research are to develop a complete understanding of the contextual issues (which may or may not be unique to South Africa) that define the environment in which the adoption of UX practices is hindered, and to develop suitable approaches for UX and usability design and evaluation that will lead to a more natural integration of these practices into information systems development. The researchers hypothesise, for example, that objective approaches to analysing user data, such as employing Big Data Science and modern eye-tracking equipment, in addition to traditional human-computer interaction (HCI) methods, will provide the means to effectively communicate the value of greater emphasis on proper UX and usability practices in IT systems design. They also hope to show, through this research, that deep knowledge of cognitive psychology and its direct relationship with users' experience of IT systems will affect the success of UX design and evaluation, as well as how the value of these practices is communicated to organisational management. Several PhD candidates and master's degree students enrolled at the Department of Informatics are involved in this research.

Evaluating e-textbook implementation in schools

Prof Machdel Matthee, an associate professor in the Department, is involved in evaluating e-textbook implementation in schools. The project aims to understand and manage change in school environments where e-textbooks are introduced. It also investigates the relationship between communication, trust and the acceptance of the e-textbook platform. The role of the Informatics Design Labs is to evaluate the usability of e-textbooks, improve usability through participatory design and develop guidelines for the design and implementation of e-textbooks and their platforms.

In 2017, the researchers conducted evaluation studies with learners and teachers at a local private school using the miEBooks interface. Through eye-tracking observation, individual interviews and a focus group interview, they established the children's point of view and made recommendations to the system developers accordingly.

For a practical assignment, the honours HCI class conducted usability studies and user testing on the ITSI (www.it.si) web-based storefront for buying the e-textbooks and provided the developers with detailed recommendations.

KidsteamSA: Giving children voice in design

KidsteamSA is based on the Kidsteam at the University of Maryland in the USA. This design team, which comprises children, assists the Department's research and design work. Prof Helene Gelderblom, who spent six months working with the University of Maryland's Kidsteam during a

Researchers conducting an eye-tracking study on the miEBooks interface.

Fulbright visiting scholarship, coordinates the team. There she learnt to apply the cooperative inquiry technique of designing with young children.

Children are natural designers and are excellent partners on any design project. They love coming up with ideas and are much less concerned with sounding stupid than adults generally are. They are very generous in sharing their ideas and can come up with a complete prototype of a complicated artefact in a very short period of time.

Although the technologies designed in collaboration with the Kidsteam children are mostly educational or entertainment applications aimed at children, corporate clients can also use Kidsteam to generate ideas during the design process of innovative business and technology solutions.

Recent Kidsteam projects include The TitanTutor – a prototype of a web-based, cross-age tutoring system that was designed and developed by Prof Gelderblom and Dr Bester Chimbo, who is a lecturer at Unisa's School of Computing.

Through this system, teenagers from privileged communities will provide online (Skype-like) homework support to young children who do not have such support at home.

The prototype system has been co-designed by nine teenagers from high schools in Pretoria and six children in Grade 3 and Grade 4 who live in a privately owned children's home in Pretoria. (See Gelderblom (2014) and Chimbo and Gelderblom (2014) for more details.)

Another KidsteamSA project that was conducted in 2016 was the design of a web-based platform for the Edublox reading and learning clinics. Edublox specialises in cognitive training and reading, spelling, comprehension and mathematics development through face-to-face sessions, as well as computer-based exercises.

Prof Gelderblom and a team of nine children assisted with the design of the web application that would incorporate Edublox's computer-based exercises. (More information on this project is available in Gelderblom (2017).)

Conclusion

These projects are just a taste of what the Informatics Design Labs can offer researchers and commercial clients. A biannual MAD Challenge is also held for high school learners, where they are taught the programming skills they would need to develop their own mobile or web applications. The researchers are currently working on establishing a Tech Launch Pad where any UP student can pitch their design ideas to experts. Promising proposals will then be developed into high-fidelity prototypes that can be used to sell the idea to investors. The Informatics Design Labs will provide the necessary support during the design and development process.

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Developing stochastic simulations with open-source software

Edgar Whyte, Carl Sandrock and Gerrit Streicher

A software package called Automatic Modelling Operations using Stochastic Simulation (Amoss) is being developed in the Department of Chemical Engineering to assist Sasol in the development and simulation of stochastic models for its value chains. The software is being specially developed to fit Sasol's current simulation methodology and needs.

A value chain can become quite complex and small changes can have a big impact on a completely different part of the operation, making it difficult to bring about change to the value chain.

This is a classic case where process simulation can be applied with great effect. Over the years, Sasol has developed a modelling methodology, Modelling Operations using Stochastic Simulation (MOSS) (Meyer et al., 2011) to determine the impact of modifications on value chains. The strength of such a simulation lies in the ability to quantify the impact of a change over the whole value chain and, in the process, reduce the amount of subjective decision making. However, the existing simulation method does not easily deal with value chains that have tightly coupled feedback loops where resource optimisation is a prerequisite.

To cope with such processes, the existing simulation method had to be modified to simulate the operation with an acceptable level of accuracy. The modification included a number of complex mathematical formulas that had to be derived, programmed and tested. This added a significant amount of model development time, resulting in a delayed, but accurate set of results, which triggered the search for an alternative set of stochastic simulation tools.

A number of alternative software tools were identified, but it soon became clear that it would take too long to complete a proper study with the existing model to manage existing projects. The University of Pretoria was contacted and requested to submit a modelling solution. The existing stochastic model (Streicher, 2013), the existing optimisation model and the existing steady-state model were provided to the University as usable references.

Software features and capabilities

The goal of the Amoss project is to create and simulate stochastic simulations in the most logical and user-friendly way. To achieve this, the package must relieve the user from most of the manual, menial labour and focus on the aspects that make each simulation unique.

Much project development time was spent on automating the common aspects not only across the stochastic simulation of chemical plants, but also across Sasol-specific commonalities. The following commonalities were identified:

- Equation generation
- Mass balance equations, which are also known as the laws of nature
- Equations determining how components are split at a separator (distillation column)
- Equations determining how components are distributed into other components in reactors
- Mixing equations, determining the composition of process streams at mix-points and mixers, which includes process buffer tanks
- Incorporating operating rules into the system of equations
- Priority-based distribution of process mass flow to sections based on unit availability and maximum capacity
- Easy sampling of known or custom stochastic distributions

Simulation setup

To create a new simulation, a graphic representation of the value chain, drawn in OpenModelica (OM) is required (see Figure 1). The OM diagram contains the connectivity of the process, as well as the operational units of the value chain.

In addition to the OM graph, the following need to be specified:

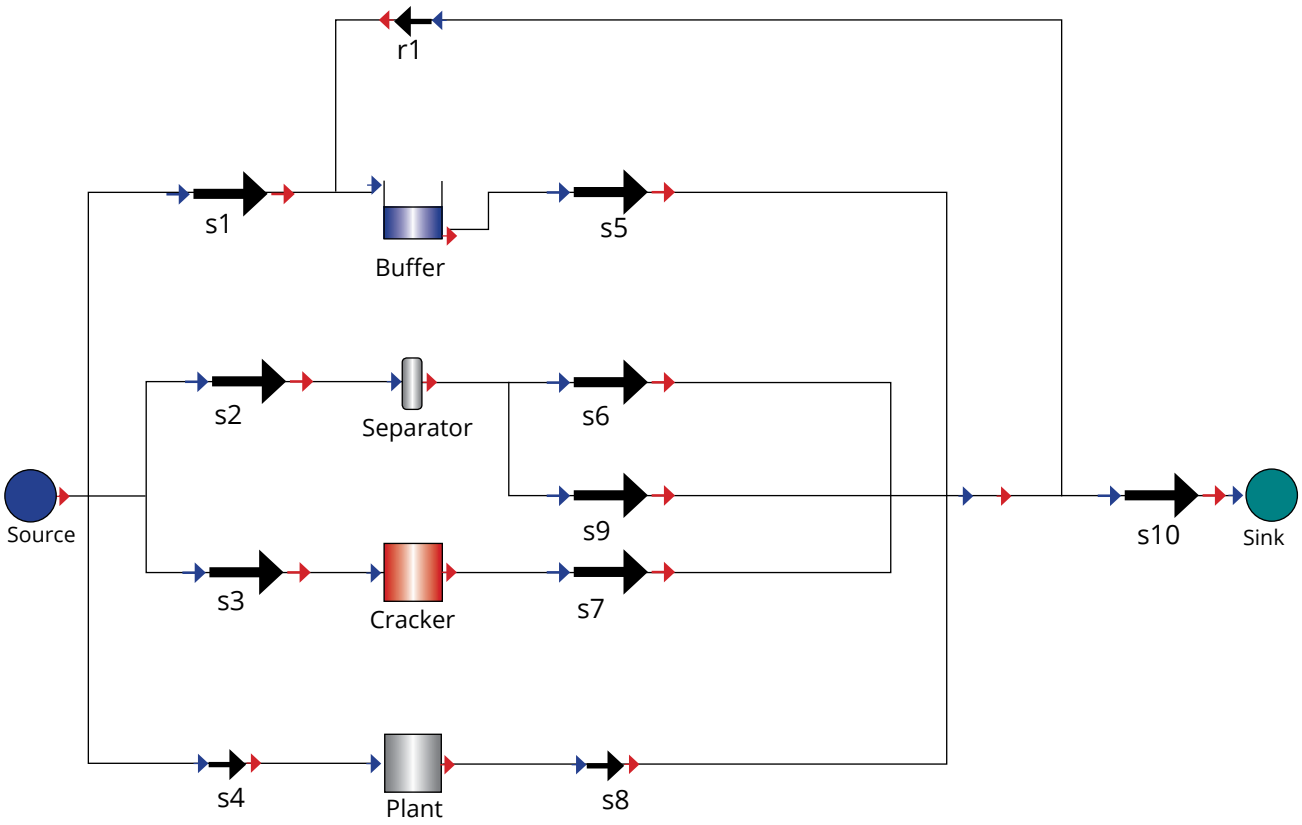

Figure 1: Defining the connectivity and network node type attribute.

- Components in the system
- Input variables to the system (known variables)
- Separator split data
- Reactor in/out component distribution data
- A file with the mathematical representation of the operating rules

Given these inputs, Amoss will automatically generate the equations that describe the system and link the operating rules with the system equations to produce a simulation of the value chain.

Equation ordering and solving

Once all the equations have been created, they need to be solved. Solving equations simultaneously using numerical methods is very costly in terms of computational time. Implementing an equation-ordering algorithm will help to solve the system of equations more efficiently by ordering the equations to be solved in a sequential manner, instead of solving all the equations simultaneously.

The Hessenberg ordering algorithm is used. Figure 2 shows an incidence matrix of 152 equations that are unordered. An incidence matrix shows which variables each equation depends on. A row in the incidence matrix represents an equation and a column represents a variable that needs to be solved. Each black pixel in the incidence matrix shows which variables each equation contains.

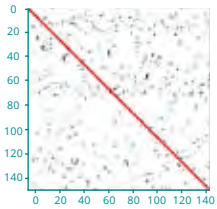

Figure 2: The example of an incidence matrix of 152 unordered equations.

The Amoss project has shown itself to be a capable tool for developing stochastic models and simulations. The automation of equation generation and the efficient solving of these equations resulted in reduced development time, which gives it the potential to become a valuable aid to Sasol and future modelling projects.

A set of equations that does not require simultaneous solving will have an incidence matrix with the diagonal (red) line fully populated, and all the other pixels below the diagonal line.

Figure 3 shows the incidence matrix of the same set of equations reordered by the Hessenberg ordering algorithm. The ordering algorithm attempts to order the equations to minimise the columns with pixels above the diagonal. It has six columns with pixels above the diagonal line, therefore only six of the 152 equations need to be solved.

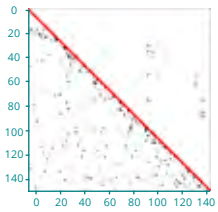

Figure 3: An example of an incidence matrix of 152 ordered equations.

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Using Big Data to develop smart infrastructure

Dr Lin Chen, a lecturer from the Chang'an University, one of the leading universities on road and transportation in China, located in Xi'an in the Shaanxi Province, spent a month at the University of Pretoria conducting postdoctoral research under the supervision of Prof Alex Visser in the Department of Civil Engineering. Her research was part of a joint project between the two universities that formed part of a Memorandum of Understanding that was signed earlier in the year.

Dr Lin Chen and Prof Alex Visser conducted Big Data research in the Department of Civil Engineering.

This research used a large infrastructure data set to establish principles and procedures for the Big Data analysis of Civil Engineering behaviour and performance. Data obtained from various types of structural sensors, as well as environmental sensors, were analysed over an extended time period to establish linkages between the various data sets. It is becoming an increasing trend that Civil Engineering infrastructure is being monitored using large combinations of different sensor types over extended periods.

Traditional methods of statistical analysis are unable to handle the large volume of information collected, and special techniques, using various Data Science principles, have to be developed. The preliminary work has developed initial procedures for this type of analysis and will be followed by more in-depth evaluation of other infrastructure where the University had access to similar large data sets.

This analysis is linked to Dr Chen's PhD research, which involved developing a multi-objective optimisation model for roads, in which she examined models used in countries such as the USA, Canada, Europe and New Zealand. As each country has a specific model that is designed to meet its unique requirements, her study of South African conditions and the handling of large data volumes will give her a broader perspective of how transport infrastructure will behave.

Civil Engineering research makes use of Big Data analysis.

Instrumentation project receives Fulton Award

The Van Zylspruit Integral Bridge was a joint winner of the Innovation in Concrete Category at the 2017 Fulton Awards. The Fulton Awards for Excellence in the Design and Use of Concrete (named after the late Dr Sandy Fulton) provides an industry platform to recognise concrete projects and initiatives at the forefront of innovation and technology, and showcases these projects to inspire excellence in concrete design and use.

The bridge, which has no expansion joints or bearings, was constructed on the N1 between Bloemfontein and Colesberg in the Free State. It is the longest integral bridge in South Africa, measuring approximately 90 m. Sarah Skorpen, a lecturer in the Department of Civil Engineering, working with technicians Rikus Kock and Sarel Coetzer, together with Prof Elsabé Kearsley, instrumented the bridge for the South African National Roads Agency SOC Limited (SANRAL) to measure approximately 500 channels of instrumentation.

The instrumentation includes strain gauges to measure strains in the bridge deck, as well as temperature sensors, tilt-meters and earth pressure sensors behind the bridge abutments. The data from the instrumentation is logged at 15-minute intervals and is remotely downloaded once a day to a web server where researchers can access it.

The data will reveal how long integral bridges behave under South African conditions where temperature variations can be significant and the climate is very dry. The benefits of this research will lead to a better understanding of the behaviour of integral bridges and hopefully the wider use of integral bridges in South Africa, thus saving employers ongoing bearing and joint maintenance costs over the life span of the bridges.

Sarah Skorpen at the Fulton Award ceremony.

In addition, a pilot study is being undertaken on the bridge to test the use of a fibre optic strain measurement system in collaboration with the Cambridge Centre for Smart Infrastructure and Construction. Fibre optic strain measurement allows strains to be recorded with unprecedented accuracy and resolution.

This project demonstrates how civil engineers can benefit by applying the latest technology to learn about the behaviour of unusual structures, allowing designers to design these structures with more confidence.

Installing the sensors on the Van Zylspruit Bridge.

New business technology incubator accelerates innovation

Prof Elma van der Lingen

South Africa is faced with serious challenges related to unemployment. According to Trading Economics (2017), the youth unemployment rate is extremely high at 55.9%. The University of Pretoria is aware of this challenge and plans to establish a high-tech business incubator and accelerator in the Faculty of Engineering, Built Environment and Information Technology.

Members of the TuksNovation Board of Directors (from left): Mr Horst Weinert (SEDA), Adv Lawrence Baloyi (UP's Department of Research and Innovation), Prof Sunil Maharaj (Chairperson and Dean of the Faculty), Mr Naeem Moolla (UP Finance Department), Prof Elma van der Lingen (Graduate School of Technology Management) and Dr Elmar de Wet (Enterprises UP).

This business technology incubator, known as TuksNovation, will promote job creation by providing support for the commercialisation of technology, networking, mentoring and sustainable spin-off technology companies.

In a knowledge-driven economy, universities play a major role in regional socio-economic development. Innovations arising from a university's intellectual capital can stimulate economies through new product development. Universities are thus highly valued in terms of economic potential.

Although the creation of spin-offs is one of the key mechanisms that universities can leverage to promote socio-economic development, few universities in South Africa have done so, and the impact has been very modest. This low success rate can be attributed to the absence of an entrepreneurial culture, limited access to funding, as well as technology transfer offices at universities that lack critical skills and capacity.

TuksNovation is based on the triple helix model of Etzkowitz and Leydesdorff (1995). According to the University of Stanford Human Sciences and Technologies Advanced Research Institute (H-STAR) (2011), the triple helix concept comprises three basic elements. Firstly, it allows universities to play a more prominent role in innovation, on par with industry and government in a knowledge-based society. Secondly, there is a movement towards collaborative relationships among the three major institutional spheres, in which innovation policy is increasingly an outcome of interaction, rather than a prescription of government. Thirdly, in addition to fulfilling their traditional functions, each institutional sphere also performs

new roles. Institutions that are currently taking on non-traditional roles are viewed as a major potential source of innovation.

Over the long-term, the business incubator aims to enable the development of industrial clusters with a positive economic impact in Tshwane. It is set up in partnership with the Department of Small Business Development's Small Enterprise Development Association (SEDA). TuksNovation also aims to build strong networks among academia, government and industry to create new spin-offs that can benefit society.

According to Prof Elma van der Lingen, Chairperson of the Graduate School of Technology Management (GSTM) at the University of Pretoria, the TuksNovation model is based on allocating seed funding to students who are keen to become entrepreneurs and are conducting research on projects that have the potential to develop commercially viable technology. "Annual TuksNovation competitions will be held on campus and interested students will be able to participate in order to qualify for TuksNovation seed funding to develop their ideas into commercial products," she says. The competitions will have strict guidelines and will be evaluated by a committee comprising mainly representatives from industry and technopreneurs.

The technology development phase of the projects will be conducted in a virtual incubator in the University's laboratories and at facilities at local industries. The students will receive expert technical guidance from academics at the University, as well as technological entrepreneurship training. Various in-kind contributions will also flow from building strong industry networks. Some benefits from this relationship could include the use of industry facilities, research on industry-related problems, employment for students and mentorship.

Funding for the business phase of the projects is secured from external funders, such as venture capitalists, investors, and corporations. Students with commercially viable technology will make pitches and submit business plans to potential investors in order to secure funding. SEDA covers the incubator's initial operational costs.

TuksNovation will initially support the development of spin-offs in the Faculty of Engineering, Built Environment and Information Technology, but can be expanded to other faculties involved in science and technology at UP, depending on the availability of funding.

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Research synergy:

Energy

Promoting energy efficiency through the use of renewable sources

Energy is a key priority area for development in South Africa and the broader African continent. Research in this focus area relates to energy efficiency, demand-side management, advanced materials for energy systems, clean renewable energy, nuclear energy, and energy modelling and optimisation. Visibility on an international level is propelled by research into smart grids for energy in collaboration with the South African National Energy Development Institute (SANEDI), and research through the Centre of Excellence in Nuclear Safety and Security (CNSS) in partnership with the National Nuclear Regulator (NNR), the National Research Foundation (NRF) and Eskom as the key players.

Several existing initiatives related to energy are contributing to strengthening the Faculty's research profile. These include research conducted in the Graduate School of Technology Management in support of the South African government's energy objectives. The Centre of New Energy Systems in the Department of Electrical, Electronic and Computer Engineering focuses particularly on energy efficiency and demand-side management aspects for the national grid, as well as improving energy efficiency for various industrial processes and for buildings. The Clean Energy Research Group in the Department of Mechanical and Aeronautical Engineering has also delivered some credible findings related to concentrated solar power, nanofluids, heat exchangers and nuclear energy.

Endeavours to further enhance the Faculty's research profile include improving its research impact by publishing in top high-impact, relevant journals, networking and delivering presentations at top international conferences. The Faculty also aims to establish productive research collaborations with leading institutions and researchers in the field of renewable energy and advanced materials, as well as nuclear energy.

Furthermore, plans to enhance the socio-economic impact of its research include developing human capital in the field of energy research, offering advisory services to government and local municipalities in terms of energy, and offering consulting services to industry. It will also continue to engage in collaboration agreements with government and industry stakeholders.

Key activities that will be undertaken to grow the next generation of researchers, as well as the number of postgraduate students, include appointing more academic staff members to supervise doctoral students, sourcing more external funding to recruit high-quality doctoral students, and recruiting top students from UP, as well as other local South African and African universities. A 5% growth in PhD students is expected annually.

Key research focuses on ensuring South Africa's energy security

The University has, for some years, recognised the need to conduct focused research in the field of energy in an effort to address the energy crisis that is facing South Africa. Therefore, the research conducted in the University's departments of Electrical, Electronic and Computer Engineering, and Mechanical and Aeronautical Engineering is focused on mitigating this crisis.

South Africa's national electrical grid system is under increasing strain due to aging infrastructure, insufficient maintenance, and a lack of real-time monitoring. Meanwhile, renewable energy infrastructure is being integrated into this system, with unknown repercussions for grid stability and power supply for everyday users.

From a world-class energy infrastructure in the 1980s, South Africa's electrical grid has deteriorated steadily to the state it is in today. Failures in generation, transmission and distribution are all due to insufficient maintenance of the grid and the power stations that generate power. Coupled with ageing infrastructure, the chances of grid instability and failure are rapidly increasing. Despite concerted efforts in demand-side management (DSM) over the last 15 years, Eskom is struggling to provide electricity to meet South Africa's residential and commercial demands.

Not only is the national grid ageing, it is also technologically out of date. Modern communication technology holds the potential to provide a wealth of data about the state and functioning of the grid and its various components. This is important in maintaining a sprawling national electricity system, but currently, the grid does not incorporate any of this new technology.

With the advent of renewable energy generation, new solutions to producing electricity have become feasible, particularly photovoltaic (PV), or solar, and wind energy technology. These technologies hold great promise in South Africa, where getting electricity to the entire population is difficult and the conditions for renewable energy generation are so good.

However, integrating these new technologies into an old, decaying grid is a significant challenge – one for which South Africa is not fully prepared. In addition, as these are often new and untested technologies, many unforeseen challenges lie ahead to decrease South Africa's reliance on fossil fuels. One particular challenge here is to develop standards for renewable energy integration.

Beyond the national electricity system, efficiency in electrical systems could be improved in residential, commercial and industrial sectors by reducing wastage, and integrating alternative sources of energy for specific tasks.

South Africa faces significant challenges in maintaining its national electrical grid. At the same time, introducing renewable energy generation and communications technology threaten the overall stability of the power supply.

Research currently being conducted in the Centre of New Energy Systems in the Department of Electrical, Electronic and Computer Engineering, as well as by Department of Mechanical and Aeronautical Engineering's Clean Energy Research Group, are contributing to enhancing the Faculty's research profile with regard to energy-related research, and will go a long way to not only improve the wellbeing of people, especially in rural communities, but also to promote economic development.

Integrating renewable energy into the national grid

Prof Xiaohua Xia

Several research groups in the University of Pretoria's Department of Electrical, Electronic and Computer Engineering are working with industry and government to address energy-related challenges by improving energy efficiency and demand-side management (DSM). In the process, they are ensuring that renewable energy is effectively integrated into the national grid. They are also developing smart grids to provide more information to engineers and managers, from residential to industrial energy systems.

The largest of these groups is the Centre of New Energy Systems (CNES), headed by Prof Xiaohua Xia, an A-rated research who focuses on energy optimisation and management. The CNES focuses particularly on energy-efficiency and DSM aspects for the national grid, as well as improving energy efficiency for various industrial processes and for buildings.

The research conducted in this centre is helping to make the national grid safer, more stable and more efficient, guiding the integration of sustainable energy sources and improving the data available to engineers working on the grid. This research is improving energy efficiency and reducing waste in homes, buildings and factories around South Africa. Some effort has also been exerted to look into sustainable and renewable energy supply, but integrating these systems into the national grid comes with its own set of challenges.

DSM has ensured that South Africa's power supply is stable, but that does not address the issue of an ageing fleet of power stations. South Africa has a promising environment for renewable energy generation. Wind and solar power are slowly being added to the mix, despite major challenges with integration.

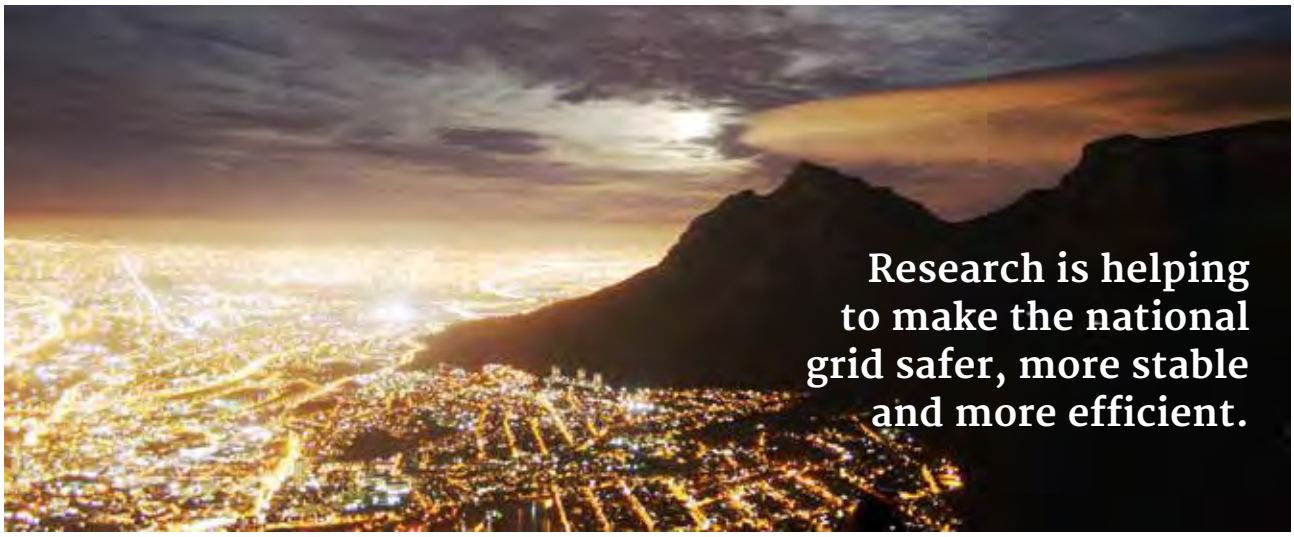
A lot of the work done in the Department of Electrical, Electronic and Computer Engineering is directly or indirectly geared towards improving South Africa's energy sector in one way or another. This is mostly achieved through a number of collaborations and working agreements with the South African National Energy Development Institute (SANEDI), South Africa's national energy research agency.

Direct efforts to address South Africa's energy challenges include those performed by the National Hub for Postgraduate Programme in Energy Efficiency and Demand-side Management (EEDSM), which is hosted in the CNES.

Research in the Centre for New Energy Systems

The energy systems work of Prof Xia and his colleagues at the CNES makes a valuable contribution to the University's research profile. The CNES is looking specifically at technology, equipment, operation and performance aspects for energy efficiency. It has also gained a reputation as being a premier research institute in the area of energy management, both nationally and internationally. It is the only Centre of Excellence in energy optimisation and standardisation in South Africa to address the research, education, development and industrial applications of energy optimisation and management. The focus on energy management includes both supply-side and demand-side management. It collaborates with research centres on energy management both locally and internationally.

Among other things, the CNES conducts research into improving the efficiency of industrial energy systems and buildings. It is also the major provider of measurement and verification services for Eskom and for South African municipalities, with more than 400 projects (covering approximately a third of the country) in place at one time. The CNES hosts the Exxaro Energy Efficiency Chair. Exxaro is a coal-mining company that sponsors research into energy efficiency in the coal-mining sector. In the industrial sector, CNES works on the energy efficiency of mining equipment and factory processes like conveyor belts. It also develops new technologies for more efficient pumps and motors.



Research is helping to make the national grid safer, more stable and more efficient.

South Africa was the first country in the world to have an energy-efficiency measurement and verification standard, SANS 50010. From the technological side, CNES researchers develop new water heating systems, improve air-conditioners, and look at ways to improve overall energy efficiency, for instance through lighting, insulation technology or better building design.

Furthermore, CNES works on hybrid energy systems – combinations of different generating technologies that can provide power more efficiently, depending on the user's needs. Examples of this would be hybrid diesel and PV systems, or using a fuel cell to supplement standard electrical power from the grid.

The CNES is also working on a wind-PV-hybrid heat pump water heater. This research develops an optimal control model of a heat pump water heater (HPWH) supplied by a wind generator-PV grid system. The objective function is energy cost minimisation, taking into account the time-of-use electricity tariff, which is an important control parameter. The control variables are the supply switch to the HPWH and the power from the grid, while the hot water temperature inside the tank is the state variable. The model meets both the HPWH's technical and operational constraints in providing hot water at a desired temperature, and achieves load shifting. This problem is solved using a mixed integer linear programme. The results show a 70.7% cost reduction upon implementation of this intervention. Following a case study, the optimal control model showed significant potential in both energy and cost saving in comparison to the digital thermostat controller used in most HPWHs on the market.

Another research project conducted in the centre investigates the evolutionary game theoretic DSM and control for a class of networked smart grids. In a paper published as a result of this research, a new DSM problem of networked smart grids was formulated and solved, based on evolutionary game theory. The objective was to minimise the overall cost of the smart grid, where individual communities could switch between grid power and local power according to strategies of their neighbours. The distinctive feature of the proposed formulation was that a small portion of the communities was cooperative, while others pursued their own benefits. This formulation can be categorised as control networked evolutionary game, which can be solved systematically using the semi-tensor product. A new binary optimal control algorithm was applied to optimise transient performances of the networked evolutionary game.

The CNES is also working on the optimal dispatch for a micro-grid, incorporating renewables and demand response. The research group proposes an optimal economic dispatch of a grid-connected micro-grid. The micro-grid consists of solar PV, diesel and wind power sources. An incentive-based demand response programme is incorporated in the operation of the grid-connected micro-grid. The optimal dispatch strategy was obtained by minimising the conventional generator's fuel cost and the transaction costs of the transferable power, and maximising the micro-grid operator's demand response benefit, while simultaneously satisfying the load demand constraints, among other constraints. The developed mathematical model was tested on two practical case studies. A sensitivity analysis of the model to key parameters was also performed. The first case study consisted of three conventional generator units, one wind generator, one solar generator and three rural customers. The second case study involved a much larger micro-grid, and was chosen to test the applicability of the researchers' model to larger micro-grids, and also to verify the scalability of their algorithm. Results showed that the demand response programme curtailed significant grid-relieving amounts of energy in the two case studies considered. The integration of incentive-based demand response programmes into the micro-grid energy management problem introduces optimality at both the supply-side and demand-side spectrum of the grid.

Promoting wellbeing through clean energy research

The Department of Mechanical and Aeronautical Engineering's commitment to quality is aligned with the University's vision to be a leading, research-intensive university in Africa, and its status as one of the foremost providers of high-level intellectual capital. In support of the belief that the University can make a positive contribution to the economic and social development of the country, the Department's research agenda is focused on topics that are relevant to South Africa's future energy security.

The Department is also renowned for its unique approach to innovation and design, as well as its international status and links with industry, which gives it a competitive advantage in international technology development. It has a rich traditional background in fundamental and applied engineering, which it has maintained through research areas that focus on increasingly narrower topics within subject disciplines.

This heritage provides the Department with the breadth to offer a sound undergraduate education. At the same time, the specialisation of academic staff provides a stimulating environment for research. The Department enjoys international recognition and its academic staff members have received many prizes for excellent research and peer-reviewed articles, and have delivered contributions by invitation to conferences on numerous occasions.

According to Prof Josua Meyer, Head of the Department, the Department's core business is its academic endeavours, excellent teaching and education of students, and relevant research of the highest standard. The pursuit of excellence, quality, international competitiveness and local relevance is the prevailing hallmark of these primary tasks.

The Department considers a contribution to the competitiveness of the country and the improvement of the quality of life of its citizens to be an important part of its mission. It is not surprising, therefore, that it has chosen to focus its research efforts on areas that have a direct impact on the wellbeing of the industry.

CLEAN ENERGY RESEARCH GROUP

The Department has been active in research on energy systems – including thermoflow systems – since the early 1980s. Research areas originally focused on heating, ventilation and air-conditioning (HVAC) systems and engines.

Since the early 1990s, however, there has been a growing emphasis on computational research in the thermoflow field, with applications like electronics cooling and industrial computational fluid dynamics (CFD) gaining ground. These activities are currently balanced by a growing group in experimental heat transfer and CFD research.

The applications of these research areas have been consolidated into a broader focus on clean energy systems and components. The research of the Clean Energy Research Group (CERG) is currently focused on energy systems, renewable energy (solar, fuel cells, wind and ocean engineering), nuclear energy, energy efficiency and optimisation, heat exchangers, nanofluids, gas turbines and aerodynamics.

The CERG is involved in experimental and numerical heat transfer research focused on clean energy applications. It comprises 10 researchers, headed by Prof Josua Meyer, and has a number of world-class experimental facilities that are focused on heat transfer, balanced by a CFD division. Research focuses specifically on concentrated solar power (CSP), nanofluids and heat exchangers, and nuclear energy.

Concentrated solar power

Three studies related to CSP research can be highlighted due to their impact on the University's research profile. The first study, conducted by Prof Ken Craig and his team, evaluated the use of CFD in the form of the commercial CFD code ANSYS Fluent v15 and v16 to model the reflection, transmission and absorption of solar irradiation from diffuse and specular surfaces found in linear CSP applications. Two-dimensional CFD solutions, such as line concentration, were considered. To illustrate and validate this method, two sources were used. The first included test cases from literature with published solutions, while the second entailed a combined modelling approach where solutions were obtained using both finite volume and ray tracing (with SolTrace). For all the test cases, good agreement was found when suitable modelling settings were used to limit both ray effect and false scattering errors.

The second study, conducted by Dr Willem le Roux under the supervision of Prof Josua Meyer, modelled a small-scale dish-mounted solar thermal Brayton Cycle (STBC). This set-up makes use of a sun-tracking dish reflector, solar receiver, recuperator and micro-turbine to generate power in the range of 1-20 kW. The modelling of such a system, using a turbocharger as a micro-turbine, is required so that the optimisation and further development of an experimental set-up can be done. As a validation, an analytical model of the small-scale STBC was developed in Matlab, where the net power output determined from an exergy analysis was compared with Flownex, an integrated systems CFD code. A parabolic dish with a diameter of 4.8 m with open-cavity tubular receiver and plate-type counterflow recuperator was considered based on previous work. Since the recuperator operates at a very high average temperature, it was modelled according to a method, which takes heat loss to the environment into account. Compressor and turbine maps from standard off-the-shelf Garrett turbochargers were used. The result showed that, for the calculation of the steady-state temperatures and pressures, there was good comparison between the Matlab and Flownex results, except for the recuperator outlet temperature. With the use of Matlab and Flownex, it was shown that the small-scale open STBC, with an existing off-the-shelf turbocharger, could generate a positive net power output with solar-to-mechanical efficiency of up to 12%, with much room for improvement.

Research in the Department of Mechanical and Aeronautical Engineering focuses on concentrated solar power, nano-fluids and heat exchangers, and nuclear energy.

The third study, under the supervision of Prof Craig and Prof Meyer, investigated a response surface method optimisation of the cavity absorber of a linear Fresnel reflector (LFR). Optimisation methods to increase the efficiency of CSP plants are an important research topic in this field. This research focused on applying an integrated optimisation technology to a solar thermal application, more specifically for the optimisation of a cavity absorber of an LFR CSP plant. LFR technology has been developed since the 1960s, and while large improvements in efficiencies have been made, there is still room for improvement. One such area is in the receiver design where the optimal cavity shape, coatings, insulation thickness, absorber pipe selection, layout and spacing need to be determined for a specific application. This research used a commercial tool to find an optimal design for a set of operating conditions. The objective functions that were used to judge the performance of a two-dimensional cavity were combined heat loss through convention, conduction and radiation, as well as wind resistance areas. Eleven parameters were used as design variables, of which nine were geometrical and two optical. Based on a sample set requiring 151 CFD simulations, a global Utopia point was found that minimised all three objectives. The most sensitive parameters were the insulation thicknesses and coating emissivities. Based on the results, the multi-objective genetic algorithm (MOGA), as contained in ANSYS DesignXplorer, was shown to be effective in finding candidate optimal designs, as well as the Utopia point.

Nanofluids and heat exchangers

In terms of research related to nanofluids and heat exchangers, two studies can be highlighted. The first study, conducted by Prof Meyer and Prof Mohsen Sharifpur, together with two co-workers, was an experimental and numerical study of the thermal and hydrodynamic characteristics of laminar natural convective flow inside a rectangular cavity with water, ethylene glycol (EG)-water and air. Laminar natural convection in a rectangular cavity with three different heat transfer fluids were attached to the cavity walls. All other walls were properly insulated. Early experiments revealed that it was hard for the heated and cooled walls to reach a uniform temperature when the cavity was filled with water or EG-water, while a uniform distribution

of temperature was achieved when the cavity was filled with air. Commercial CFD software, ANSYS Fluent 15, simulated the entire set-up to include two special heat exchangers and the cavity between them to investigate all the transport phenomena. The simulation results were in good agreement with the measured data. The distortion of air flow was much higher than with the other two fluids. Water flow inside the cavity was flatter and a big circulation area was captured in the middle of the EG-water fluid flow.

The second study, conducted by Prof Meyer, Prof Jaco Dirker and a third co-worker, entailed the implementation of liquid crystal thermography (LCT) as a wall temperature measurement technique for a tube-in-tube heat exchanger.

A methodology was developed in which the wall temperatures could be determined without using thermocouples in a water-operated heat exchanger. It was found that thermochromic liquid crystals (TLCs) have a sufficient temperature response with which local temperature distributions can be determined. The obtained temperature fields also showed large temperature variations close to the inlet of the heat exchanger, which might be problematic when using low sampling average wall temperature measurement techniques. The wall temperature uncertainties were found to be very low, which indicated that LCT could be an invaluable tool for measuring wall temperatures. The measured temperature distributions that were used to calculate local heat transfer coefficients were, however, found to be higher than the predictions by the majority of the other correlations considered. This was probably due to a developing boundary layer near the inlet of the heat exchanger.

Nuclear energy

Prof Johan Slabber and a team of researchers conducted significant research on nuclear safety. Through this research, they developed a microvan plasma process operating at atmospheric pressure for the synthesis of silicon carbide (SiC) nanoparticles. The process utilised methyltrichlorosilane (MTS) as a prescursor, acting as both the carbon and silicon source, along with an additional hydrogen feed to ensure a fully reducing reaction environment. In addition, argon served as the carrier gas. The parameters studied were the H2:MTS molar ratio and the total transmission electron microscopy (TEM) micrographs. It was found that an increase in enthalpy and a higher H2: MTS ratio resulted in smaller SiC particle sizes. The adhesion of particles was a common occurrence during the process, resulting in larger agglomerate sizes.

Optimising wind farm layout for increased energy generation

Prof Ken Craig and Hendri Breedt

In the Department of Mechanical and Aeronautical Engineering, Prof Ken Craig and master's student Hendri Breedt are looking at how computational fluid dynamics (CFD) can be used to optimise the layout and configuration of wind farms in South Africa. Wind energy and solar photovoltaic (PV) energy have become the dominant forms of renewable energy because of the rapid reduction in costs associated with both solar cells and wind turbines. The placement of wind turbines in a wind farm, choosing the correct turbine for the site conditions and also deciding where such a wind farm should be situated are critical for the successful rollout of this form of energy.

The turbine configuration and location are traditionally accessed by extrapolating measured wind data from on-site meteorological masts to each proposed turbine location. These masts are erected at candidate sites and operate for a minimum of one to two years to gather sufficient data of the atmospheric boundary layer required for wind farm design. Traditional flow models like WAsP Engineering® from DTU Wind Energy use linear flow models for modelling the wind conditions on site. These models can, however, only be used in predominately flat terrains and neglect the complex motions of atmospheric flows. These motions are the driving factor behind variations in wind speed, wind direction and turbulence intensity across turbine locations and are crucial for the design of wind turbines, the suitability of turbines to the site and also the energy production of the wind farm. Being able to accurately predict these conditions allows the siting of wind turbines in locations where they can extract maximum energy from the wind using the optimal turbine, while ensuring that it is suitable to withstand the loading during the wind farm life cycle. Complex terrains are increasingly being exploited, and CFD simulations are the leading technique used for modelling these sites. The simulations focus primarily on modelling a neutrally stratified atmospheric surface layer. However, reduction in uncertainties can be achieved by modelling all the physical mechanisms of the atmospheric boundary layer.

One factor that plays a large role in atmospheric flow is the stability of the atmosphere, which can be classified as stable, neutral and unstable. The buoyancy associated with each stability condition can result in highly differing conditions at the turbines. In stable conditions, ambient turbulence and vertical fluxes are suppressed by buoyancy forces. This suppression of turbulence leads to delays in wake recovery from wind turbines and can lead to excess energy losses associated with velocity deficits caused by the wake. The lack of vertical motion increases vertical wind shear and can lead to the turbine rotors being unevenly loaded. In unstable conditions, the increase in vertical motion increases the boundary layer height and is also categorised by higher ambient

turbulence. These higher turbulence levels affect the blade fatigue loading. In a 24-hour diurnal cycle, stable conditions are typically seen at night with cooler land temperatures, while unstable conditions appear in the day with heightened temperatures. Figure 1 shows the mean stability classification during a diurnal cycle obtained from one year of data. Typically, non-neutral conditions dominate for wind speeds lower than 15 m/s, which is the predominate condition for wind farms. This leads to the conclusion that it is important to include atmospheric stability in wind farm simulations and that a change of the standard CFD model equations is necessary.

Modelling atmospheric stability using CFD software is one of the main contributions in this research. The stability effects are incorporated using user-defined functions that modify the turbulence model equations. The modification parameters are derived from the measured time series data for each wind farm location. In such locations, where measured data is not available, a study is conducted into the correlation of the measured data to synthesised meso-scale data sets obtained from weather research and forecasting models. The results will form part of a guideline for including stability effects on proposed commercial wind farms.

Due to the size and complexity of the terrains, coupled with the high accuracy needed from these CFD models, the Centre for High Performance Computing (CHPC) in Cape Town is utilised for running the simulations.

Figure 2 shows the typical complex terrain of a proposed wind farm. Contour data obtained from digital elevation models are then used to construct a computational model of the terrain. Figure 3 shows a meshed version of this terrain, with candidate wind turbine locations at the expected highest-wind locations. Figure 4 shows a streamlined visualisation of how the terrain can cause deviations in the wind flow up the terrain.

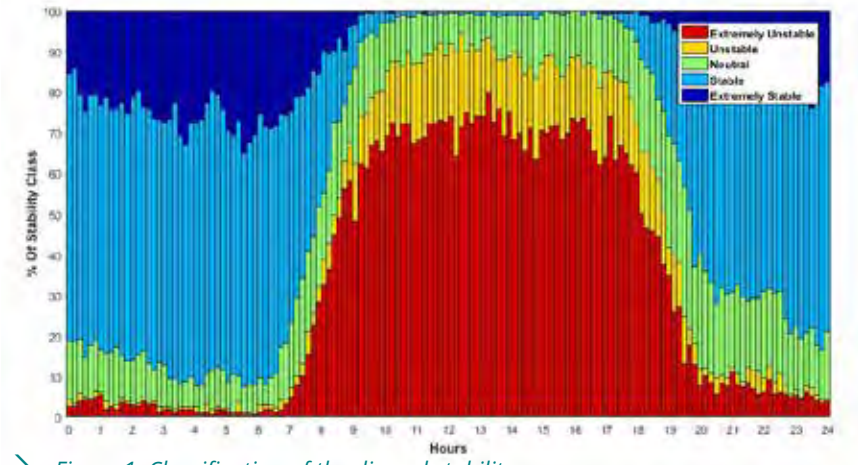


Figure 1: Classification of the diurnal stability.

Figure 2: Proposed wind farm terrain.

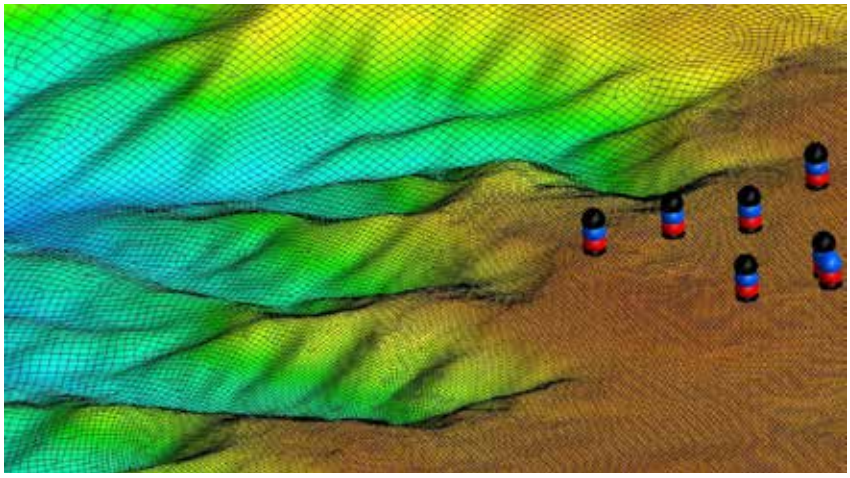


Figure 3: Computational domain of the terrain created using ANSYS® ICEM CFD.

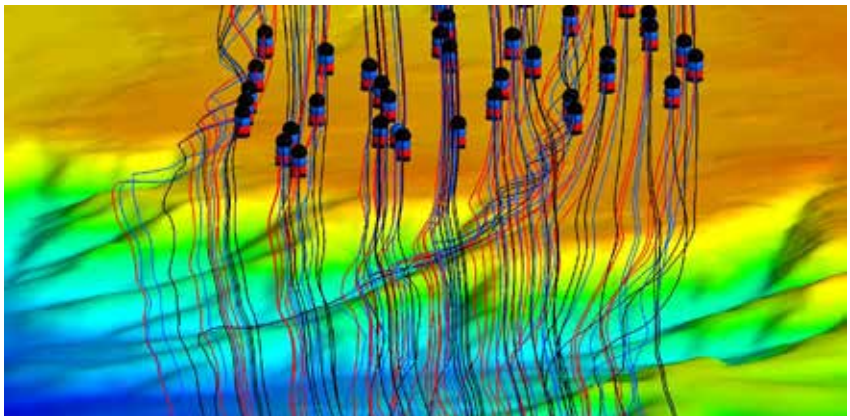


Figure 4: CFD simulation using ANSYS® CFX software: streamlines through the proposed turbine positions.

Research synergy:
Environmental Engineering (Water)

Improving the sustainability of South Africa's water resources

An understanding of the security, efficiency, reliability and sustainability of South Africa's water resources is essential for development. Through the environmental engineering (water) research focus area, the Faculty participates in research related to the so-called "water-energy nexus" and the development of expertise in water resource engineering and management.

This includes a focus on the development and utilisation of hydropower as a viable renewable energy source in South Africa and on the quality and treatment processes for, among others, the management of biological wastewater and the production of drinking water. Collaboration with the Water Institute in the Faculty of Natural and Agricultural Sciences is of key importance for the success of this research focus area.

All research efforts in the water-energy nexus will be aligned with national strategies and initiatives, in particular those of the Department of Energy, and the Department of Water and Sanitation. Energy-efficiency initiatives offer opportunities for delivering significant water savings, and likewise, water-efficiency initiatives offer opportunities for delivering significant energy savings. The scope of this research focuses on utilising these inextricable linkages between water and energy to supply both, as well as to improve security, reliability and sustainability.

South Africa is one of the driest regions in the world. Water conservation and water demand management are therefore crucial interventions towards improved water use efficiency, and effectively contribute to water security. The scope of this research focuses on the enhanced understanding of the water supply and distribution system to improve security, efficiency, reliability, sustainability, and water conservation and demand management.

Endeavours to strengthen the Faculty's research profile include improving its research impact by publishing in top high-impact, relevant journals, networking and delivering presentations at top international conferences. The Faculty also aims to establish productive research collaboration with leading institutions and researchers active in research related to the water-energy nexus, as well as water resources engineering and management. Key activities that will be undertaken to grow the next generation of researchers, as well as the number of postgraduate students, include developing selected undergraduate students for research positions utilising external funding, attracting international specialists for collaboration and knowledge-sharing, and obtaining additional funding to further expand its research output.

An annual growth in PhD students of 10% in programmes related to environmental engineering, and 25% in chemical engineering is anticipated.

Optimising water resources through innovation and effective resource management

South Africa is considered to be a water-scarce country. It is commonly acknowledged that if the current rate of water usage continues, demand is likely to exceed supply at some point not too far in the future. Improving water conservation measures, water quality and water-use efficiency is therefore a key national priority. Compared to the global average rainfall of 870 mm per annum, South Africa only receives 450 mm. This makes it the world's 30th driest country. Some projections estimate that South Africa already exploits about 98% of its available water supply resources.

Responding to the urgent need to optimise the country's existing resources, the Faculty of Engineering, Built Environment and Information Technology has identified environmental engineering (with a particular focus on water) as a key research priority. Its research efforts are aligned with the strategies and initiatives of the Department of Water and Sanitation. An important initiative in this regard is the development of sustainable hydropower, together with water conservation and water demand management interventions.

Improving water use efficiency will contribute to the water security of this precious resource. In the Department of Chemical Engineering, an important focus is on water utilisation and environmental engineering. Research in this department includes the development of water management models for industrial activities, environmental management in a first/third-world developing country, and quantifying and mitigating the effect of industrial and mining activities on air quality. Since algal problems are encountered globally in the water industry, research is also aimed at the control of algal growth, the determination of carbon cycling and improving the treatability of algal metabolites in the interim.

In water utilisation engineering, the primary focus is on quality and treatment processes for and the management of biological wastewater, industrial water and effluent, the disposal of slurries, sludges and solid water waste, and the production of drinking water. Environmental engineering research focuses on air quality management by assessing the impact of mining and power generation on ambient air quality on the Highveld, alternative

household energy supplies to reduce community air pollution exposure and the reduction of gaseous and particulate emissions from the ferro-alloy industry. Various aspects of bioremediation and fermentation using natural organisms is also a topic that is receiving attention.

An exciting new area of research in the Department of Chemical Engineering is environmental nanotechnology, which examines the effect that nano-materials have on the environment. Understanding how the inherent physico-chemical properties of engineered nano-materials and water chemistry influence and impact on the ecology is studied using both experimental and modelling techniques.

Collaboration with the University's Water Institute in the Faculty of Natural and Agricultural Sciences provides important multidisciplinary research potential.

Hydropower research addresses community power needs

Marco van Dijk, Thato Seabi, Chantel Niebuhr and Deon Bonthuys

Despite the fact that South Africa is the country with the second largest installed hydropower capacity in Africa, it produces less than 5% of its total electricity generating capacity from hydropower. This clearly highlights the lack of and the need for hydropower installations in Africa. The Hydropower Research Group in the University's Department of Civil Engineering saw this lack of hydropower generation in Africa not as a burden, but as an opportunity.

In 2009, the research group conducted a high-level scoping investigation into the potential of energy generation in the supply of water through pressurised conduits, and installed a small pilot installation at the Queenswood Reservoir in the City of Tshwane.

Since the scoping study and pilot installation in 2009, the research group has broadened its horizons and has compiled numerous technical reports, ranging from retrofitting hydropower to existing dams in South Africa, to conduit hydropower potential in water distribution systems and low-head hydropower applications at waste water treatment plants.

The Hydropower Research Group has been involved in the design and construction of several successful hydropower installations throughout South Arica. It focuses on research and the discovery of new, innovative ways to recover energy and generate electricity from existing water infrastructure and natural water resources in a viable and sustainable manner through hydropower installations.

Boegoeberg canal system

During 2016 and 2017, the installation of kinetic hydropower turbines in the existing Boegoeberg canal system in the Northern Cape was further developed and is currently being tested and optimised. The project aims to showcase a simple installation where existing infrastructure is used as a tool to aid rural municipalities to produce their own electricity. The canal system is about 172 km long, starting at the Boegoeberg Dam close to Groblershoop where water is abstracted from the Orange River, winding its way along the Orange River, providing water for irrigation needs.

Seven turbines, each capable of producing a maximum of 5 kW, were imported from Smart Hydro Power in Germany. The turbines are being installed in this canal system at two potential sites. Groblershoop and Wegdraai water treatment works (WTWs) are both in close proximity to the canal. These WTWs provide water for most of the residents of these towns and use a large amount of electricity.

→ *Installation of kinetic-type turbines in a canal.*

This project aims to assist in these areas, reducing electricity expenses and providing greater income to the municipality. The ultimate goal will be to showcase a way of bringing electricity to rural villages that are not connected to the existing grid and that will not be connected in the near future due to the great distance to the nearest existing electricity infrastructure.

Currently, the turbines are being placed in the water, at different positions along the width and length of the canal, to determine the optimum installation for the maximum power output and safety for the community. This is a complex process, as it is the first kinetic installation in South Africa. The installation must therefore be tested for cases specific to South Africa, such as climate, debris conditions, as well as social consequences and risks, before the installation of kinetic hydo-turbines can be scaled and installed on other irrigation canal systems in South Africa.

Kwa Madiba stand-alone hydropower-driven mini-grid

Small-scale hydropower technology, even though considerably smaller than conventional storage schemes or hydroelectric dams, still requires robust engagement with and the involvement of several relevant government departments and stakeholders. Through the Hydropower Research Group's successful engagement with stakeholders, a pilot project for the Kwa Madiba community in the Mhlontlo Local Municipality, Eastern Cape, began construction in April 2016.

This project, funded by the Department of Science and Technology (DST) and implemented via the Water Research Commission (WRC), is designed as a run-of-river scheme on the Thina River, where water will be abstracted at the top of the Thina waterfall and routed through a penstock drilled through the mountain adjacent to the waterfall. This installation will benefit a community of 54 households through a stand-alone mini-grid. The system utilises a cross-flow turbine installed in a modular containerised turbine room that will generate 51 kW at the bottom of the waterfall. Construction was mostly done with local labourers from the neighbouring communities.

Installed containerised turbine at the bottom of Thina Falls.

Thato Seabi supervising the local construction team.

A major achievement, from the implementation not only of this project, but for all future small-scale run-of-river hydropower projects, is that the Hydropower Research Group was able to successfully participate in and influence the public consultation process of the review of a General Authorisation (GA) in terms of the National Water Act, Act No. 36 of 1998. The revised publication of the GA now allows for small-scale run-of-river hydropower projects, which adhere to specific requirements, to only require compliance with the conditions of the GA instead of engaging in a potentially costly and lengthy full water-use licencing process.

The project is near completion, with the intake already installed and the pipework of the headrace tied into the intake. Access stairs over the mountain to the bottom of the waterfall have been constructed, helping to gain access to the turbine room, assisting in the construction of the foundation, and placing the containerised turbine room, complete with turbine, generator and electronic controls.

The electrical distribution network has been completed and the transmission line to the hydropower plant has been installed. Testing and commissioning is to be undertaken soon. Once the penstock has been

Installed turbine and control panel (Kwa Madiba).

finalised, the hydropower plant will be ready for commissioning to light up not only the Kwa-Madiba community, but also the progress on rural small-scale hydropower in South Africa.

Bloemwater conduit hydropower plant integration

The Hydropower Research Group successfully implemented a 96 kW conduit hydropower plant at Bloemwater in Bloemfontein, which was launched in 2015. The Caledon-Bloemfontein pipeline supplies potable water from the Welbedacht Dam to Bloemfontein. The treated water is pumped from the Welbedacht Dam to De Hoek Reservoir, from where it gravitates to the Uitkijk Reservoir and further to the Brandkop Reservoir at Bloemwater's head office in Bloemfontein. The conduit hydropower installation at Bloemwater recovers some of the energy in the system, which was previously dissipated through pressure-reducing valves at the Brandkop Reservoir.

The recovered energy helps to power the operations of the Bloemwater Head Office and contributes to the beginning of a small circular economy.

Section of the automatic changeover panel (Bloemwater).

Bloemwater hydropower plant.

The Hydropower Research Group continually assists Bloemwater in optimising the utilisation of this plant to increase resilience and ensure sustainability.

The turbine, based on the available pressure and flow, generates a constant output. From this output the electricity required for running the Head Office is used and the excess is dumped via heating element regulators. Initially when the turbine could not match the demand, a manual changeover was utilised to switch between the hydropower and Centlec (the electricity supplier), switching the full load from one source to another.

To maximise the utilisation of the hydropower, an automatic changeover panel was developed and constructed to deal with the variable demand. The office building's electrical distribution was divided into six distribution boards to allow each sector to be supplied and switched individually.

For each distribution board, Centlec and Hydro supply power meters were installed, linked with a CompactLogix PLC, which constantly evaluated the incoming hydro supply against the demand from the office building. Subsequently, it executed switching by controlling six motorised changeover switches between Centlec and Hydro for maximum utilisation of the hydropower. The CompactLogix PLC constantly evaluates and subsequently executes switching actions so that Bloemwater can utilise maximum capacity of the hydropower, but also limits power interruptions to a minimum because of these switching actions.

The research work conducted by the research group thus far has been compiled in numerous research reports and journal publications with the aim of creating awareness for the administrators and operators of water systems. Increased awareness will assist in the processes of identifying and evaluating the hydropower potential within their systems, along with highlighting the benefits obtained from generating even small amounts of energy from untapped sources.

Achievements of the research group

The Hydropower Research Group has had the opportunity to share its work on the development and implementation of hydropower in South Africa internationally.

In June 2017, it made technical presentations at the Hydrovision 2017 Conference, which was attended by more than 3 000 delegates. Thato Seabi, a master's degree student in the Department of Civil Engineering, presented a technical paper entitled "Maximising the energy use of islanded rural hydropower electrification systems". His paper won second place in the Social and Environmental category. This project also earned Marco van Dijk the University of Pretoria's Community Engagement Award at its Academic Achiever Award function held on 10 May 2017.

A proud Thato Seabi with his second-place award for the best technical paper at the Hydrovision 2017 Conference.

Research receives Community Engagement Award

Marco van Dijk is a lecturer in the Department of Civil Engineering and a principal researcher for the research projects of the Water Research Commission (WRC). He received the Community Engagement Award at the University of Pretoria's Academic Achiever Awards on 10 May 2017. This award provided recognition for his supervision of students in the WBK 890 module.

This module gives students the freedom to excel and use their specific skills, such as construction supervision, community engagement, design, as well as regulatory and policy application, to successfully complete their research topics. In 2015, he also received the Knowledge Tree Award in the category New Products and Services for Economic Development by the WRC as ongoing recognition for his contribution in the water-energy nexus.

Van Dijk has been actively involved in finding ways to get environmentally friendly, renewable, sustainable energy accepted as an alternative reliable supply of electricity in urban and rural areas. He aims to promote the technology, as well as the leading role the University is playing in this field. He has successfully brought the University closer to rural communities by presenting community engagement opportunities at workshops, public participation events, council meetings and one-on-one discussions with numerous councillors and community leaders.

Small hydropower schemes can play a critical role in providing energy access to remote areas in South Africa as stand-alone, isolated mini-grids.

The rural electricity situation in South Africa

The Reconstruction and Development Programme White Paper of 1994 laid the foundation for South Africa's developmental trajectory, focusing, inter alia, on providing basic water, electricity, health care, and education infrastructure and services to all the people of South Africa. The electrification of urban areas in South Africa, including many informal settlements, reached its culmination in recent years. However, the electrification of rural areas still has a long way to go before most of the rural communities will be provided with a reliable and sustainable supply of electricity.

The national electricity grid, managed by Eskom, has been experiencing difficulties due to various reasons, particularly since 2008. The further development of rural electrification is, at present, in the doldrums, mainly due to Eskom's shortage of generation capacity.

The current available generation capacity needs to be available to users who are already connected to the national grid. Urban and rural communities are starting to feel the increases in electricity tariffs. The primary electricity infrastructure is rapidly becoming insufficient and cannot sustain supply against the demand for electricity from the existing and future users who are connected to the national grid.

Small hydropower schemes can play a critical role in providing energy access to remote areas in South Africa as stand-alone, isolated mini-grids. Rural electrification is the provision of long-term, reliable and satisfactory electricity service to households in remote, rural communities via a grid,

decentralised or centralised, renewable or non-renewable supply of energy.

Many consider electrification to be a fundamental strategy for poverty alleviation in terms of financial, energy and sustainable developments.

In 2011, the WRC made R2.5 million available for the Hydropower Research Group to work in the specialised field of renewable energy, which has been an important focus of government.

The output of the study in 2011 stimulated further investment by the City of Tshwane for R1.4 million in 2013. The Department of Science and Technology (DST), through the WRC, injected R8.1 million in 2014 and R10 million in 2015 for capacity-building projects for the implementation of small-scale hydropower developments for rural electrification in South Africa.

The DST funding is part of the Innovation Partnership for Rural Development Programme (IPRDP). It commissioned capacity building in some of the 23 identified distressed municipal areas in South Africa, as defined by the Department of Rural Development and Land Reform (DRDLR) in conjunction with The Presidency. Within the uMzinyathi District Municipality in KwaZulu-Natal and the OR Tambo District Municipality in the Eastern Cape, numerous sites were identified for the implementation of hydropower schemes to supply a basic service, such as for the Kwa Madiba community with 54 households in the Mhlontlo Municipality.

Much of the success achieved with these projects would not have been possible without the research input of Van Dijk and the Hydropower Research Group.

Using bacteria to tackle lead pollution

Deon Brink

Lead is an extremely useful industrial metal. It is used in battery plates, electrical cable sheathing, ammunition, radiation shielding, type metal, bearing metal and solder. Unfortunately, the global supply of lead is finite, with only an estimated 15 years' supply of lead remaining globally.

In contrast, each year an estimated 600 000 new cases of infant mental retardation and approximately 143 000 deaths can be attributed to lead pollution globally. This burden is carried disproportionately by the developing world, specifically by marginalised people, women and children. The prevalence of lead is almost entirely anthropogenic, with the main contributors being the industrial processing of silver, platinum and iron, the use of lead-based material, and the combustion of lead in petroleum products.

Traditionally, lead remediation technologies have had many drawbacks. These technologies do not always target lead specifically. They produce toxic sludge and have pH and redox requirements far from those of their natural environments, and therefore require a significant dosing of chemicals.

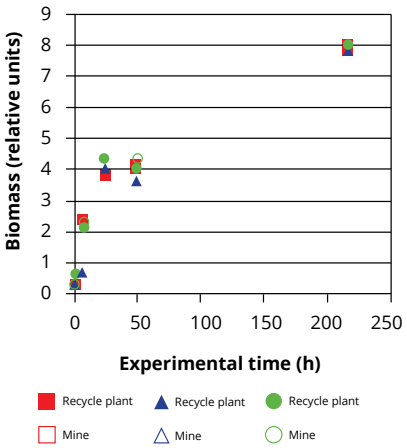
A study conducted in the Department of Chemical Engineering attempted to remove lead from a solution with bacteria obtained from a lead mine in Northern Cape and a lead-recycling factory in Gauteng. The idea was that the bacteria would be resistant to elevated concentrations of lead, with the possibility of either immobilising lead by removing it from the solution as a self-defence mechanism or having the ability to use lead as part of its metabolism.

Experiments

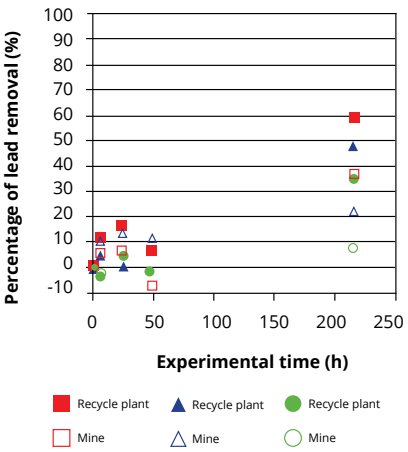
The research group ran batch experiments with (aerobic) and without (anaerobic) oxygen to determine the effect oxygen would have on the growth and possible removal of lead from the solution.

The aerobic experiments showed that the biomass increased by a factor of more than 10. However, when the lead concentrations were measured, it appeared that a relatively limited range of lead fractions (10 to 60%) was removed. The removal only happened after more than two days of growth.

It was clear from visual observation that significant bacterial growth took place in the presence of lead, while no precipitate was observed during the experiment. This indicated that the microbes were able to grow well in the presence of lead and oxygen, while only removing lead once significant growth had taken place. The absence of precipitate in the medium was an indication that the microbial surfaces were likely employed as immobilisation



Biomass growth during the experiment (aerobic).



Percentage of lead removed during the experiment (aerobic).

Beginning of the experiment (aerobic).

End of the experiment (aerobic).

Beginning of the experiment (anaerobic).

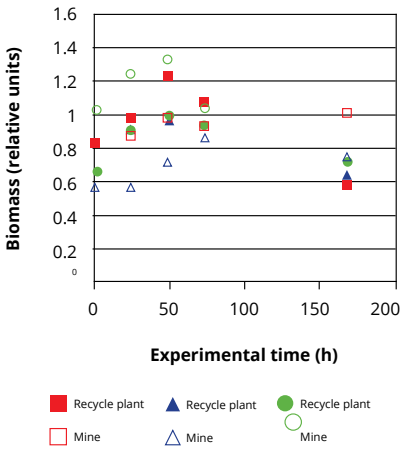
End of the experiment (anaerobic) – side view.

End of the experiment (anaerobic) – bottom view.

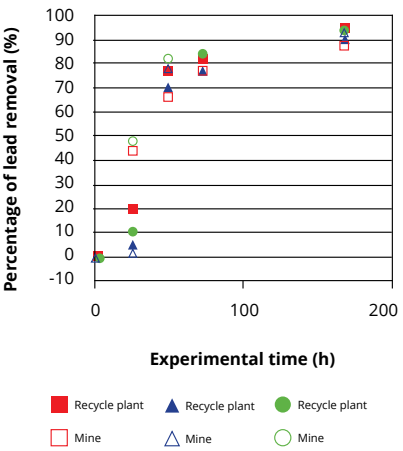
sites, where the lead stuck to the microbial surfaces as soon as enough of these surfaces were available. However, the removal of lead was not repeatable or, in most cases, significant enough to warrant further investigation.

In the case of the anaerobic experiments, a limited amount of growth was measured. This growth was significantly less than the growth observed in the aerobic experiments. This was anticipated, as the energy available under aerobic conditions exceeds that which is available under anaerobic conditions by a significant margin. Interestingly, the amount of lead removed was repeatable for all experiments and exceeded 90% after seven days for most of the runs. This observation indicated that a limited and similar subgroup of microbes was likely active in the removal of lead from the solution, even though the microbes came from very different parts of the country. Visual observation indicated a dark grey precipitate that formed at the end of the experiments, which was likely elemental lead formed by the organisms "breathing" in the lead in the absence of oxygen.

Results from the study indicated that the microbes could repeatedly remove most of the lead in the absence of oxygen, most likely by using the lead as part of its metabolism instead of oxygen. This indicates that further studies should focus on anaerobic conditions. The system should also be repeated on a larger scale to simulate industrial conditions.



Biomass growth during the experiment (anaerobic).



Percentage of lead removed during the experiment (anaerobic).

Research synergy:

Minerals and Materials Beneficiation

Upscaling South Africa's mining industry

Research related to minerals and materials beneficiation has the potential to lead to the upscaling of South Africa's mining industry. Research activities relate to fields such as mechanisation and automation, explosive engineering, risk management, safety and health. Minerals beneficiation also focuses on promoting long-term industrialisation and industrial diversification, while assisting the South African minerals and metallurgical industry to become more competitive. This includes developing expertise in minerals and energy recuperation from waste products. The interdisciplinary nature of this research focus area warrants collaboration with other faculties within the University.

The Faculty plans to strengthen its research profile through the further expansion of the Centre of Excellence for the Mine Health and Safety Council in the Department of Mining Engineering, as well as by expanding the Faculty's training capabilities with regard to virtual reality training in Africa. It emphasises the importance of postgraduate research, especially as this forms part of a broader strategy to make mining and minerals beneficiation safer, healthier and more profitable in South Africa. Potential new research chairs that will support this initiative include those in Gravity Separation, Flotation Process Engineering and Waste Product Minerals, and Energy Recuperation.

Endeavours to further enhance the Faculty's research profile include the development of a research collaboration model and strategic alliances with national and international universities, as well as with industry stakeholders in South Africa. This will include increasing the Department's global footprint by leveraging the facilities of its Kumba Virtual Reality Centre. It also plans to enhance the role of the Mining Resilience Research Centre (MRRC) as a facilitator of multidisciplinary research.

Initiatives planned to improve its research impact over the next five years include publishing in top high-impact, relevant journals, delivering presentations at top international conferences, and building research collaborations with international experts in the fields of minerals processing, hydrometallurgy, pyrometallurgy and mining.

Key activities that will be undertaken to grow the next generation of researchers, as well as the number of postgraduate students, include the establishment of sustainable research projects to support the research themes. It is envisaged that government's Mining Phakisa project, which is driven by the Chamber of Mines, will support mining research through the establishment of a Mining Hub. It believes that it can provide higher qualified graduates to the South African job market, who can potentially become entrepreneurs and create their own businesses.

Beneficiating the minerals and materials industry

Minerals and materials beneficiation has become one of the key drivers in advancing the empowerment of historically disadvantaged communities in South Africa. It also creates opportunities for the development of new entrepreneurs in both small and large mining industries.

According to the Department of Mineral Resources, the government department tasked to formulate and implement policy to ensure the optimal use of the country's mineral resources, mineral beneficiation is a form of value-added processing, and involves the transformation of a primary material, which is produced by mining and extraction processes, to a more finished product that has a higher export sales value. Beneficiation involves a range of activities, including large-scale, capital-intensive activities, such as smelting, sophisticated refining plants and labour-intensive processes such as metal fabrication and the making of jewellery. Each successive level of processing allows the product to be sold at a higher price than the previous intermediate product of original raw material and adds value at each stage.

The concept of beneficiation is not new in South Africa, but took major steps forward during the 1990s when the South African mining sector changed from being predominantly an exporter of primary commodities to becoming a world exporter of processed materials. Despite these developments, South Africa still has the potential to further raise the level of beneficiated mineral output, particularly in the production of finished goods.

At the University of Pretoria, research into minerals and materials beneficiation is primarily conducted in the Department of Mining Engineering and the Department of Materials Science and Metallurgical Engineering. These two departments conduct complementary research in the mineral sciences supply chain in order to address national, regional and global challenges in the mining sector.

Research in the Department of Mining Engineering is focused on the extraction and exploitation of the country's mineral reserves. The Department of Materials Science and Metallurgical Engineering, on the other hand, focuses on the processing and refining of mineral resources into viable materials and the performance of the materials in service.

Mining Engineering

Research topics that receive particular attention in the Department of Mining Engineering include those of rock mechanics and underground mine design, rock breaking and surface mining, mine management and leadership, mine ventilation engineering, risk management, mineral economics, and underground mining methods and mine design. With the support of industry, the Department operates the Harmony Chair in Rock Engineering and the Mining Resilience Research Centre, which conduct research into some of the pertinent issues facing the mining industry, both in South Africa and internationally.

The Department also has an excellent relationship with the Mine Health and Safety Council (MHSC), and has been involved in several research projects for the Council, as well as for the MHSC's Safety in Mines Research Advisory Committee (SIMRAC). It is also an active participant in the South African Mining Extraction Research, Development and Innovation (SAMERDI) Strategy, which aims to improve the competitiveness of local mining equipment manufacturing firms, and to develop technological solutions to improve safety and productivity, reduce costs, and extend the life of mines and their benefit to communities.

As a partner of the SAMERDI initiative, the Department

collaborates with the Council for Scientific and Industrial Research (CSIR), the University of the Witwatersrand and the University of Johannesburg. As such, the partner institutions are currently engaged in research to support the modernisation drive of the South African mining industry. Modernisation will help to improve health and safety, facilitating the quest for zero harm. It will also contribute to increased skills development, employment, exports and revenue.

The Department is involved in a number of priority programmes under the SAMERDI initiative. These include research projects related to advanced ore body knowledge, the modernisation of mining, the mechanisation of gold and platinum group metals (PGM) commodities using drilling and blasting, non-explosive rock breaking, real-time information management systems and human factors.

The campaign for increased innovation in mining has culminated in an allocation in the national budget for research and development in the South African mining industry (in the extractive phase of the value chain) on an unprecedented level compared to historical initiatives.

From these outcomes, as part of the detailed plans that arose during the Mining Phakisa to accelerate the modernisation drive, a Mining Hub was established. This Mining Hub (now called the Mining Precinct) will facilitate public-private relationships and collaboration, and coordinate mining equipment manufacture and skills development by mining companies, original equipment manufacturers, skills development entities and research entities such as the University's recently established Mining Resilience Research Centre (MRRC).

Materials Science and Metallurgical Engineering

Research in the Department of Materials Science and Metallurgical

According to the World Bank, Africa is home to about 30% of the world's mineral reserves, 10% of the world's oil and 8% of the world's natural gas. South Africa's mining industry is responsible for an estimated 19% of all economic activity and supports at least another 25% of upstream and downstream economic activities.

Engineering is focused on six key areas related to the processing, refinement and application of mineral resources and the metals extracted from them. These are pyrometallurgy, welding engineering, minerals processing, hydro-metallurgy, corrosion engineering and physical metallurgy. Globally relevant research is enabled by three industry-sponsored chairs and an established research institute that conducts contract research for industry.

The Anglo American Chair in Pyrometallurgy performs internationally competitive research that is relevant to the local pyrometallurgical industry. It conducts research on aspects such as ore, sinter and pellets, reductant and flux characterisation, process thermodynamics and mechanisms, process optimisation and development, refractory materials performance characterisation and by-products valorisation. The research group has close links with industry.

The Glencore Chair in Pyrometallurgical Modelling aims to support the local industry with basic and applied research to promote knowledge transfer in the field of pyrometallurgical processes and related materials. It focuses specifically on five areas of research: material property modelling, computational thermochemical analysis, process modelling, the multiphysics modelling of pyrometallurgical systems and techno-economic modelling.

The South African Institute of Welding Chair in Welding Engineering focuses on postgraduate research in welding engineering and the postgraduate training of welding engineers and technologists according to fully accredited international programmes. Research is conducted in the on-campus welding laboratory and at the facilities of various industrial partners. This includes research on the welding of industrially important base metals and the characterisation of the welded joint.

The Industrial Minerals and Metals Research Institute (IMMRI) hosts leading experts in the metallurgical engineering industry. It is funded by industrial partners to do contract research within the academic environment. Its strong industrial focus and project-based approach provides leading research, especially in the field of physical metallurgy, but it does work in other fields as well.

UP launches multidisciplinary Mining Resilience Research Centre

The Mining Resilience Research Centre (MRRC) was launched on the Hatfield Campus on 25 May 2017 following thorough industry consultation. The need to establish such a centre within the Department of Mining Engineering was identified prior to a number of very exciting and game changing events within the South African mining context, such as the Mining Phakisa and the establishment of the South African Mining Extraction Research, Development and Innovation (SAMERDI) initiative. The centre will play an important role in these initiatives, while simultaneously addressing the need to develop the next generation of mining researchers.

Eugene Preis and Jónatan Jacobs, project managers in the Mining Resilience Research Centre.

The MRRC strives to link all the expertise related to mining research at the University, as well as to harness the skills of local and international associates. In this endeavour, it will continuously strive to expand its multidisciplinary network by forming partnerships with leading local and international universities. This will involve student and lecturer exchanges, joint research activities and opportunities for postgraduate study.

The focus of its multidisciplinary research activities will be driven by an attempt to deliver an enhanced product or service that takes inputs from various disciplines, and not purely technical engineering solutions, into consideration. The centre hopes to develop technical solutions that will assist the mining industry to bridge the future gaps that mine modernisation and mechanisation will bring. This will take into account the skills gap, as well as what the future mining engineer must be able to manage and engineer in the mine of the future.

The main aim of the MRRC is to provide modern approaches, world-class facilities and globally relevant topics, making it possible for researchers to excel and for the industry to build capacity. It has already established several multidisciplinary collaborations, which will succeed in addressing a number of issues of relevance to the mining industry. These include issues such as future mining education, future new technologies, the future socio-economic aspects of mining and future mining governance in Africa to meet the highest standards.

Researchers in several faculties at the University are currently taking part in the activities of the MRRC.

Research focuses on enabling mine modernisation

Jónatan Jacobs and Eugene Preis

The Mining Resilience Research Centre (MRRC) has delivered a number of research projects aimed at mine modernisation. The drive to modernise the mining sector lies in its contribution to improving health and safety, facilitating the quest for zero harm and increasing skills development, employment, exports and revenue. Jónatan Jacobs and Eugene Preis, project managers at the MRRC, recently conducted progressive individual research projects in this field.

According to Jacobs, it is vital for organisations and individual operations to have access to a platform with technology-related information to consider for further research and development. His research therefore sought to facilitate mine modernisation through technological advancement throughout the mining life cycle by developing a technology map.

Developing a technology map

To achieve this, a platform was created to represent the mining life cycle that incorporates each of the phases in the mining life cycle: exploration, project evaluation, mine design, operations, closure and post-closure. The constituent value drivers for each phase were investigated and included in the technology map. These were identified as mineral resource management, production, productivity and asset efficiency, profitability and cost control, supply chain, socio-economic factors, health, environment, safety, and legal (see Figure 1). These formed the seven pillars of the general mining cycle, and were chosen to represent the platform on which the technology map was created.

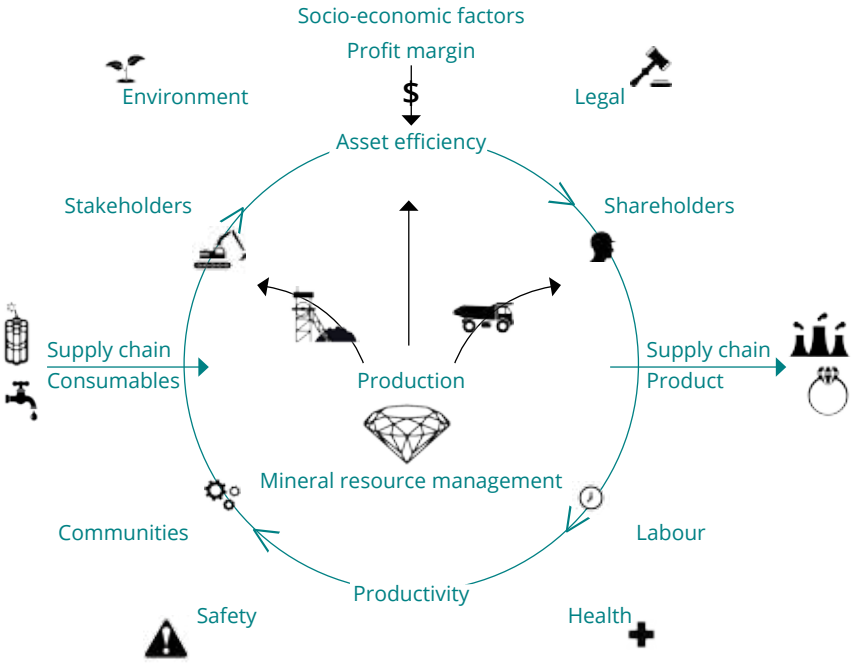


Figure 1: A visual representation of the mining cycle.

Mine modernisation is facilitated through technological advancement throughout the mining life cycle.

Technologies, both physical and digital, with the potential to add value to these focus areas, were incorporated into the platform to create a technology map. This potential to add value, if applied or modified for application, was assessed on any combination of five factors (the ability to increase production, increase productivity, increase efficiency, improve safety, or reduce the risk of human error).

The primary focus in the technology map was on technologies currently classified as disruptive and/or exponential, such as the Internet of Things, cloud computing, advanced robotics, genomics, 3D printing and artificial intelligence. Other emerging technologies were also investigated. These included automation, machine learning, renewable energy generation, energy storage and advanced materials.

To illustrate how the technology map was designed from the platform of the mining cycle and its constituent value drivers, one could consider an example from the operations phase under the mineral resource management pillar for the two chosen main value drivers of geology and geotechnical planning (see Figure 2).

In this technology map, innovative technologies related to geology would examine technologies that could be used for exploration, monitoring, and mapping and modelling. Examples of innovative technologies related to geotechnical planning could include technologies such as unmanned aerial vehicles, Big Data, advanced analytics, 3D point-cloud geo-spatial technology, virtual reality, augmented reality and predictive modelling.

Another example could be considered from the operations phase under the productivity pillar, with a specific focus on underground development as the main value driver. For this example, the chosen supporting value driver would be mineral/ore and waste extraction, which would, in turn, branch out to drill and blast, and mechanised, autonomous mining, as illustrated in Figure 3.

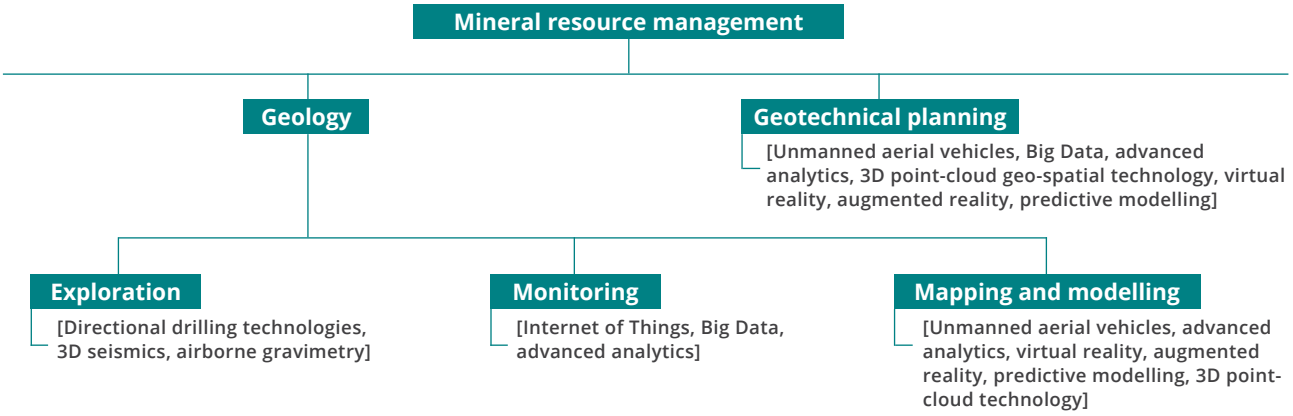


Figure 2: A technology map for the mineral resource management pillar.

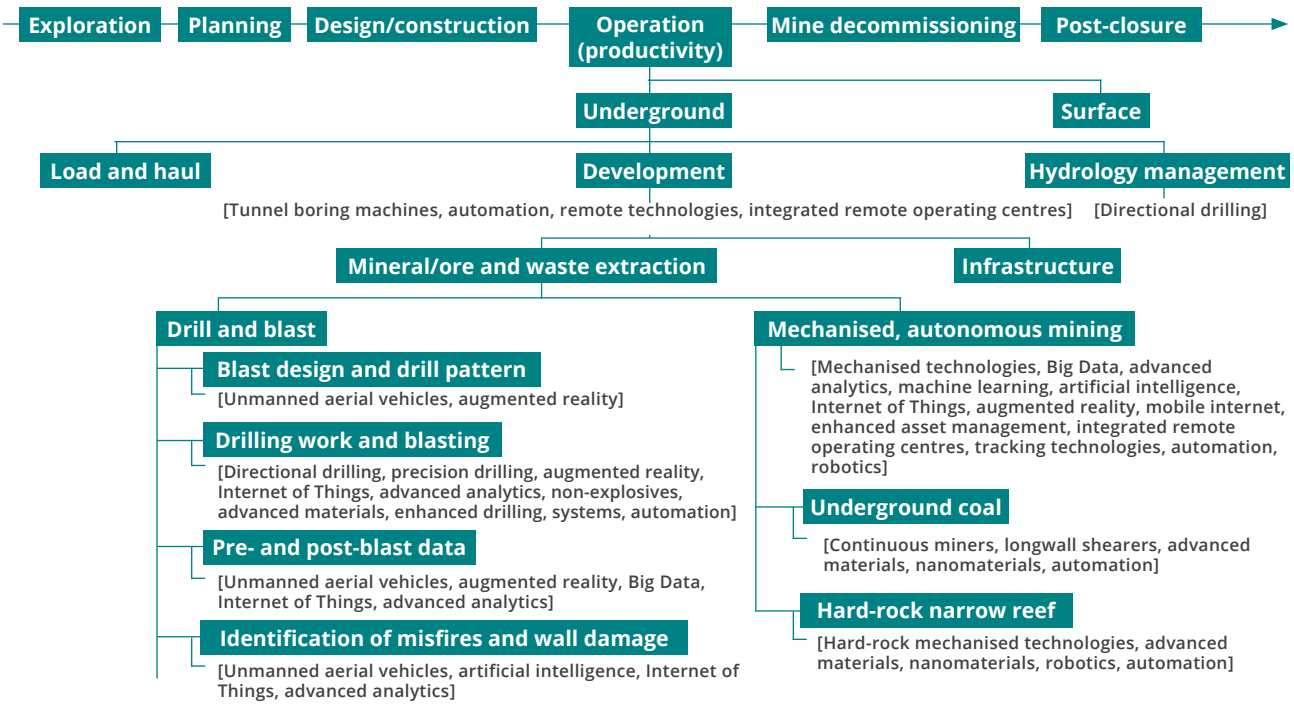


Figure 3: A technology map for the productivity pillar.

In the technology maps developed for each pillar in the mining cycle, selected innovative technologies could be adapted for or developed in mining, as well as other new technologies in non-mining industries with the potential to add value to mining. In this way, technology maps could be developed that covered the entire life cycle of a mining venture.

Technologies that can be considered to modernise mining include the following:

- Advanced analytics and Big Data
- Advanced materials and nanomaterials
- Advanced robotics
- Airborne gravimetry
- Artificial intelligence and machine learning
- Augmented reality and virtual reality
- Automation and automation of knowledge
- Directional drilling
- Energy technologies
- Genomics and precision agriculture
- The Internet of Things
- Tracking technologies
- Additive manufacturing (3D printing)

By applying some, or a combination, of these technologies in innovative ways, operations may stand to gain significant business value.

Implementing R&D as a modernisation process

Preis's research investigated what is known as the stage-gate model as a research and development (R&D) implementation process to modernise the mining industry.

He explains that, in recent years, innovation in the mining industry has shifted from being a non-essential business activity to a necessity. Key challenges in the last decade, such as declining ore grades and increased mining costs, have forced companies to focus on innovative business initiatives in order to gain incremental cost and productivity improvements.

These key challenges have placed the mining industry in a difficult position. They are substantial and, in many cases, complex in nature.

In order to ultimately solve (and not merely mitigate) these challenges, fundamental innovation step changes are required. The success of the potential implementation of these changes is to rethink the "starting point" of innovation, namely the R&D strategy and process. Contrary to popular belief, innovation does not occur spontaneously. It is, in the majority of cases, a product of meticulous planning, thinking, testing, iteration and implementation.

His study focused on firstly deriving a skeleton stage-gate model to conduct further research into the associated key gate criteria, stage activities and critical success factors. His research findings were used to develop a proposed stage-gate model, which was then assessed at the hand of a South African mining case study (the missing person locator system).

The need for an innovative R&D process in the mining industry has given rise to a new product development (NPD) process. As NPD processes do not always work as well as they should, a clear need was identified for the use of an innovative R&D process.

NPD processes have been classified into first-, second- and third-generation processes. Second-generation processes are largely referred to as stage-gate models as they comprise discrete stages followed by review points or "gates". A typical stage-gate process is a conceptual and operational framework that is used to guide NPD projects from the initial idea through to the launch of the idea. It acts as a "blueprint" for managing the NPD process effectively and efficiently. Essentially, it is a tool that breaks down the innovation process into a predetermined number of stages, where each stage defines a set of prescribed, cross-functional, parallel activities, with best practices and critical success factors built into each individual stage.

In order to advance from one stage to the next, a gate has to be passed. These gates serve the purpose of controlling the process, ensuring quality of work, and making a decision on whether the process can advance to the following stage. The different gates in the process are similar in nature and structure, and each consists of required deliverables, criteria against which the project is judged and defined outputs.

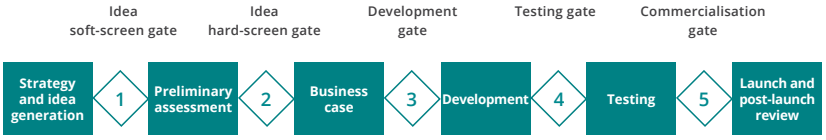


Figure 4: An overview of the stage-gate system.

From Preis's research findings, proposed stage-gate model and the case study evaluation, he concluded that the stage-gate model has the potential to assist in the successful modernisation of the South African mining industry through focused R&D efforts into the industry's key problem areas and challenges. The study further recommended that, in general, the outcomes of the study should be used to conduct R&D in the South African mining industry in order to more effectively and efficiently conduct R&D in the industry, and ultimately modernise mining in South Africa.

The outcomes of his study (and in particular, the proposed stage-gate model) could be tested by conducting an actual R&D effort into a new value proposition. The actual application of the proposed model would reveal the degree of value that the stage-gate approach could deliver, and could serve as proof that the stage-gate model and approach could work as a tool in modernising the South African mining industry.

The need for innovation in mining

Eugene Preis

Innovation is a word that has been used increasingly in the 21st century. A report by Deloitte Touche Tohmatsu Limited, *Tracking the trends 2016: the top 10 issues mining companies will face in the coming year*, defines innovation as the creation of a new, viable business offering.

Innovation has traditionally been regarded as something that simply happens. It is romanticised as something that stems from a single genial person. In unique cases, this may be true, but in most cases, it is not. There are different ambition levels of innovation, which depend on the type and magnitude of the value they create, as well as their intended purpose.

The Organisation for Economic Cooperation and Development (OECD) classifies innovation into product innovation, process innovation, marketing innovation and organisational innovation.

Innovation can be achieved anywhere. The key is to understand its diversity and not limit thinking to new products or inventions. The application of existing inventions into a new field can also be seen as an innovation. Essentially, whether an invention is new or not, something can be classified as an innovation if the value it creates in the application field is new. This is particularly relevant in the field of mining.

Considering the current state of the mining industry, it is evident that mining companies will have to make critical decisions about every aspect of their business. If they do not choose to innovate, they may stagnate. Considering how digital innovation can improve mining productivity, McKinsey & Company remarked that declining commodity prices are placing pressure on mining companies' cash flow in the short term. In the long term, many existing mines are maturing, resulting in lower ore grades, increasing hauling distances, declining ore-body replacement rates and increasing new project development times. Furthermore, worldwide mining operations are approximately 28% less productive today than they were ten years ago.

In recent years, innovation in the mining industry has shifted from being a non-essential business activity to a necessity. If the mining industry does not initiate step changes in conducting its business, it will continue on the current downwards slump. Key challenges in the last decade have forced companies to focus on business improvement initiatives, mostly in the form of innovating to gain incremental cost and productivity improvements. These key challenges have placed the mining industry at a crossroad.

The challenges currently facing the industry are substantial. Due to their highly complex nature, they cannot easily be solved. The optimisation of traditional practices, technologies and methods has provided some relief in the tough times, but the ability to gain value through incremental improvements has run out. Improving productivity by "sweating" existing assets will only go so far. Achieving breakthroughs in productivity performance demands rethinking how mining works. Incremental improvements have run their course in attempting to mitigate these challenges. In order to ultimately solve (and not merely mitigate) these challenges, fundamental step changes are required.

The impact that these challenges have had on the global mining industry, as well as the South African mining industry, is evident when one looks at the performance of the industry in terms of the global equities market and the all share index. Over the last five years, the all share index and the global equities market have had annualised returns of 15.5% and 12.1% respectively, while the South African and global mining industries have seen returns of -2.6% and -8.5%. When considering the past year, although the all share index and the equities market underperformed at 6.1% and

9.7% annualised returns, the South African and global mining industries recorded annualised returns of -20.8% and -12.6%. These alarming figures highlight the financial impact that these challenges have had on the mining industry.

A number of paradigm shifts are required to solve these challenges – and these solutions need to be sustainable. Innovation across the mining value chain has become a necessity. Without major changes and interventions, the industry will not overcome these challenges. Innovation has the power to not only overcome these challenges, but can also lead to a more sustainable and economically thriving industry. According to Deloitte, companies that innovate perform better financially in terms of stock price returns.

In Australia, out of the top 50 companies who spent the most on research and development (R&D), 30 spent more than four times the national average on R&D per revenue. In turn, these companies' average return on shareholder investment was 17.1%. Australia's top 1 000 enterprises returned an average of 7.7%. What this financial performance shows is that innovation in the mining industry could lead to long-term sustainable benefits.

Apart from the role it plays in overcoming the current survival challenges, innovation will continue to reward benefits once the challenges have been resolved. The mining industry is currently unfavourable in the eyes of investors. Innovation has the potential to make it attractive once more. Among the numerous benefits of innovation are employment creation and the stimulation of economic growth, which leads to technological progression and can have a significant socio-economic impact.

In comparison to the petroleum sector, the global mining industry greatly lags behind in terms of innovation and business improvement. On a revenue-to-revenue basis, the global mining industry spends 80% less on

The barriers to successful modernisation are uniform across the globe.

technology and innovation than the petroleum sector. Yet, operating costs on mines are increasing three times faster than consumer inflation rates, and are set to double in less than five years.

Given the substantial, ongoing cost increases, it makes sense to spend more on innovation and business improvement initiatives. The relatively small amount spent by the mining industry on R&D is not necessarily due to an unwillingness to innovate. The core business of mining is based on a number of uncertainties and constraints. These constraints are both inherent (such as declining ore grades) and imposed (such as political and regulatory issues). In many cases, the need for innovation is there, but the constraints prevent an idea from turning into a reality.

When one looks at the South African mining industry, one of the key themes is that of modernisation. In essence, modernisation refers to a paradigm shift towards next-generation mining. This presents the biggest challenge for the South African mining industry. It needs to modernise in order to survive (from a financial point of view), and needs to keep its stakeholders satisfied throughout the process.

The barriers to the successful modernisation of the mining industry are uniform across the globe.

Apart from these challenges, the South African mining industry has unique barriers to modernisation that may not be present in other countries. Thus, from the perspective of the South African mining industry, it is an even bigger challenge. It requires rapid innovation in order to make modernisation a reality. However, this innovation needs to be meticulous and disciplined. The challenges facing innovation in the mining industry are not that obvious. Innovation is traditionally an expensive endeavour, and success rates are generally low, even in a stable environment (unlike the highly unstable and volatile mining environment).

The main aim would be to seek the maximum return on investment. Research on new product development suggests that the overall success rate of new product introductions is relatively low at 60% (across global industries). This figure does not refer to viable products – it merely refers to the success rates of turning ideas into some form of a value offering. Success rates decline as the cost and risk of developing new products increases. Approximately 46% of all resources spent on new product development is essentially wasted.

Considering the innovation challenge in the mining industry, the key to unlocking the potential value of innovation is to do it at the lowest cost, in the least amount of time, and with the least amount of wasted effort. The success rate of innovation can be increased dramatically if an engineering-based approach is followed. A sound innovation foundation is required to foster innovation in the mining industry. An organisational innovation or process innovation is required in terms of the approach to innovation. This means that one type of innovation, such as process innovation, is needed first, in order to more successfully achieve other types of innovation, such as product innovation.

The use of an innovative R&D process in the South African mining industry could therefore lead to significant value gains.

Collaborative research benefits the local heavy industry

The capital-intensive steelmaking, power generation and oil and gas sectors of the South African economy have a common challenge: that of remaining competitive in the global market using existing and often ageing production plants.

Industry's collaboration with the Department of Materials Science and Metallurgical Engineering's Physical Metallurgy Research Group demonstrates breakthroughs where innovative research has facilitated advances in the local heavy industry to stave off global competition.

The South African stainless and carbon alloy steel industries are facing fierce commercial competition from the Far East. One such example is where high-strength micro-alloyed plate steels that combine the alloying elements titanium and niobium are produced with modern equipment, for export to the entire global market. These steels cannot be successfully produced at the Arcelor-Mittal South Africa (AMSA) plate mill in Vanderbijlpark, due to the high hot rolling forces and difficult shape control associated with these steels.

Through its research collaboration with the Physical Metallurgy Research Group, AMSA has countered this threat by using a locally abundant alloying element, vanadium, in conjunction with nitrogen.

Key to this development was the research that uses precipitation strengthening during the transformation of the steel microstructure. Furthermore, by using vanadium (instead of titanium and niobium), and by following hot rolling strategies researched at UP, high roll forces and poor shape could be avoided. The studies modelled the extent of recrystallisation during hot rolling and the impact of recrystallisation on flow stress at elevated temperature.

Research synergy:
Smart Cities and Transportation

Developing smart, sustainable cities

A key priority of this research focus area is the establishment of a Building Sciences Living Laboratory to provide a multidisciplinary platform for research in energy efficiency, smart buildings, smart grids, smart transportation, green retrofitting, social learning spaces and occupant behaviour, specifically related to the African continent. Another key priority is the development of the facilities on the University's Experimental Farm for research into future transportation systems for rail, road and autonomous vehicles as a collaborative effort between the University, Transnet, the Railway Safety Regulator and the South African Roads Agency SOC Limited (SANRAL).

This research focus area calls for input from a wide range of departments within the Faculty, as well as other faculties, to achieve optimal results. Endeavours to strengthen the Faculty's research profile include collaborating on research projects with the Council for Scientific and Industrial Research (CSIR), as well as a range of international partners, such as the Delft University of Technology.

The Faculty plans to improve the impact of its research by publishing in top high-impact, relevant journals, networking and delivering presentations at top international conferences. It also aims to establish productive research collaborations with leading institutions and researchers, and continuing current collaborations with international universities.

Plans to strengthen its socio-economic impact in South Africa and Africa include increasing its engagement with industry, and providing a better understanding of the factors that enhance the success of interventions, such as a building management system that reduces energy usage and increases environmentally friendly behaviour. It intends establishing a cohort of young professionals who have the necessary modelling capabilities and experiential understanding to produce more resource-efficient buildings and thus contribute to the development of more case studies, as well as to improve an understanding of the relationship between spatial design, and human wellbeing and productivity.

The Building Sciences Living Laboratory and its international networks and research programmes are intended to attract students who plan to practice as a professional after graduation, and to encourage them to consider research as an alternative or additional career path. Further activities to grow the next generation of researchers, as well as the number of postgraduate students, include the development of funded research programmes that provide scholarships. A pipeline of undergraduate students will be developed for research positions in a combined UP-CSIR Built Environment approach, based on the availability of the SANRAL laboratories. A 10% growth in PhD students is expected annually.

Smart cities are connected cities

Johnny Coetzee

The research focus on smart cities and transportation in the Faculty of Engineering, Built Environment and Information Technology provides the opportunity for collaboration within various departments in the Faculty's four schools. The multidisciplinary nature of research conducted to ensure that the urban space, with its associated infrastructure, is smart and sustainable, encompasses civil engineering, computer science, architecture, construction economics, and town and regional planning, to mention but a few.

In the Department of Town and Regional Planning, PhD candidate Jennifer Mirembe evaluated the features of a smart city, and reached the conclusion that information and communication technology (ICT) plays an important part in this concept. According to Mirembe, ICT and related e-technologies have had an enormous impact on the urban space.

What is a smart city?

During the course of her study, Mirembe found that the idea to make cities smarter and more beautiful dates back to the late 1800s when reference was made to the City Beautiful Movement of Daniel Burnham. This concept was later respected by planners and architects all over the world. The development of normative planning theories and philosophies that unpack the imperatives that are needed to transform a city into a good, smart and liveable city are largely underscored by the popular writings of the late Jane Jacobs in *The death and life of great American cities*, as well Kevin Lynch's *Good City Form*.

By definition, a city is defined as being "smart" when technologies, especially ICTs, are used to address urban problems. Several examples can be cited. In Amsterdam, The Netherlands, an intelligent street lighting system has been implemented, which entails sensors, wireless lighting controls and connected lighting management software. The use of this system allows Amsterdam to achieve energy savings of up to 80%, reduce infrastructure maintenance costs and lower lighting pollution. New York City's City24/7 programme is an interactive platform that integrates information from open government programmes, local businesses and citizens to provide meaningful and powerful knowledge anytime, anywhere, on any device. It therefore delivers the information people need where and when it helps them most. This information is displayed on durable, easy-to-use smart screens that replaced outdated public furniture, such as pay phones, located at bus stops, train stations, major entrances, shopping malls and sports facilities. Locally, the i-traffic system of the South African National Roads Agency SOC Limited (SANRAL) provides a web-based platform to provide real-time traffic information, including incident alerts, traffic speeds, construction updates and closed-circuit television (CCTV) images that are to the benefit of road users. It provides email or SMS alerts about road works and road conditions along a user's route, as well as changes in travel time along the route.

Smart cities demand digital connectivity between people. In addition, there is a prevalence of computer hardware, computer operating systems and software. According to the City of Tshwane's Integrated Development Plan, a smart city refers to integrating people with capital and infrastructure through technology. As such, the City envisions improving quality of life through the smart approach, focusing on "economy, mobility, environment, people, living and governance" by 2055.

Smart cities have a number of benefits for society and the economy, as well as for individuals in terms of the liveability and beauty of cities. In addition to creating numerous opportunities for job creation, tourism and education, a smart city is also better able to compete in the demanding global nexus.

Smart cities are typically concerned with the environment, carbon emissions and environmental change, managing population densities, safety, sanitation and the general needs and priorities of people. Monetarily, a smart city is also connected to employment creation and poverty alleviation. Some authors argue that smart cities are about satisfying the needs of

the wealthy, while others argue that little thought is given to how smart cities are actually changing the lives of the poor living in the informal enclaves of urban spaces.

Smart cities and smart technologies can result in smarter communities, spaces and networks, and smarter cities in general. However, smart cities and ICT in smart cities can have a major negative impact on communities, spaces and networks and can actually result in communities, spaces and opportunities (outside the smart city) becoming isolated or divorced from the real smart spaces. Again, it is the poor and destitute who will be most affected.

There seems to be an impression that the principle of a smart city is only visible in big cities, such as London, New York and Amsterdam, and that it is associated with the wealthy, but not for poor, developing countries such as those in Africa or South America. However, smart cities and smart e-technologies are evenly applicable in poor areas and developing countries. In fact, it has been specifically argued that more could be done to apply the smart city principle in impoverished areas in an attempt to create smart rural areas.

Smart cities in South Africa

In her research study, Mirembe discovered that, during the 21st century, South African cities increasingly shifted from an industrial mode to an informational mode of operation. Digital technology became an important aspect of urban life, with some urban cultures attempting to understand the potential of ICTs. Evidence of this lies in the fact that South Africa is the fourth-fastest growing mobile communication market in the world, with 80% of the population connected to digital communication networks.

In her study of the spatial planning policies of the City of Tshwane prior to the 1990s, Mirembe found little evidence of the use ICTs other than the use of transport technologies, which were acknowledged as the driver of urban structure expansion.

A city is defined as being "smart" when technologies, especially ICTs, are used to address urban problems. Examples include the intelligent street lighting system in Amsterdam and New York City's City24/7 programme.

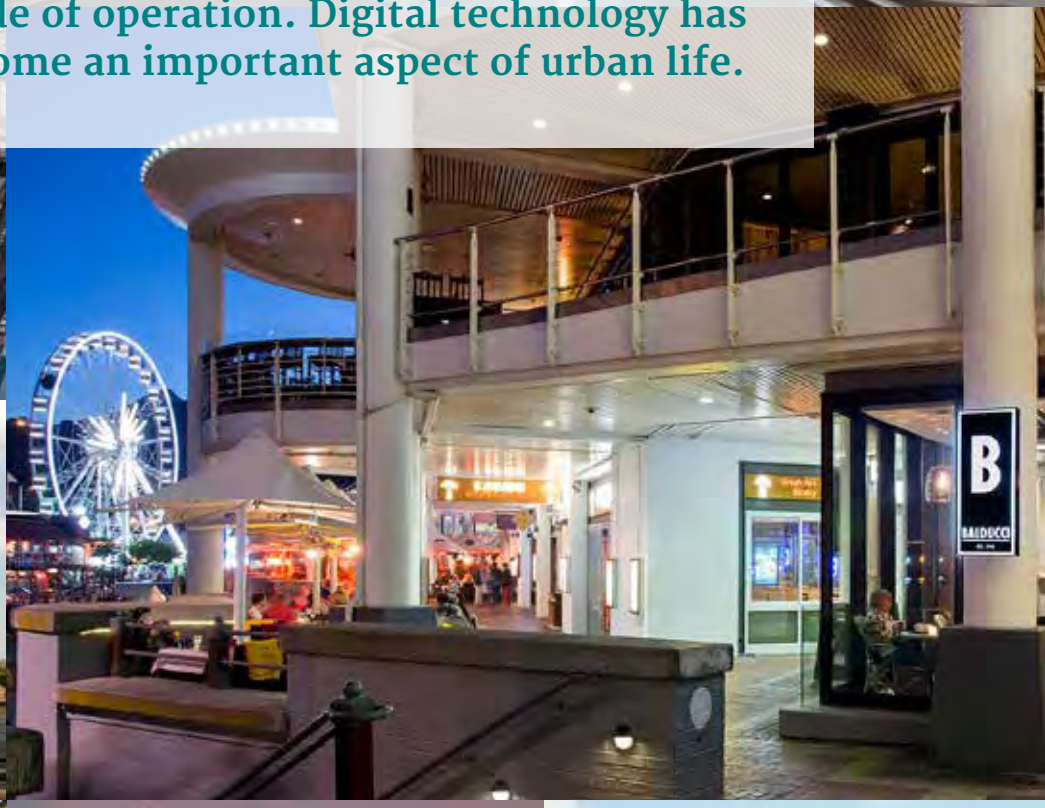
However, in the goals of the revised 1993 Pretoria Structure Plan, it was acknowledged that the influence of telecommunications, radio and television would play an increasingly important role in the city of the future. The argument was that communication technologies had increased personal communication, and that the manner in which people commuted from residence to work would play a role in informing future planning.

However, during the 1990s, South Africa started to show a new interest in ICTs. By 1995, approximately 10% of people in South Africa had access to a telephone through a landline network. Cellphone connectivity grew exponentially from 14 people per 1 000 in 1995 to 252 per 1 000 by 2002. By 2002, 11.2 million cellular phone users were reported and by 2006 the figure was 21 million. From 2002, there was deliberate investment in the installation of a digital network infrastructure in many parts of South Africa, especially the larger metropolitan municipalities. In an attempt to provide capacity for ICT to function effectively, both in South Africa and elsewhere in the world, Intelsat Company established a commercial satellite communication network with 22 geo-stationary satellites, and the undersea SAT-2 cable digital network infrastructure was installed to connect Africa, Europe and Asia.

The City of Tshwane also embarked on strategies to become a computerised city that would engage its population and promote a green economy. The City also developed initiatives to enhance integration, expand its economic competitive edge, bridge the digital divide, advance agribusiness and develop its social capital through online training. In short, the City of Tshwane Metropolitan Municipality made various efforts to become a smart city.

Other major metropolitan municipalities in South Africa, such as Johannesburg, Cape Town, Ethekwini and Ekurhuleni, also attempted to show the distinction between a traditional city and a smart city. In 2015, the City of Johannesburg was reported to have introduced smart meters, smart transportation, open web access focuses and affordable broadband. Similarly, the City of Tshwane introduced free Wi-Fi in public spaces throughout the city, and the City of Cape Town, through Smart Cape, introduced smart PCs in public libraries, notwithstanding the utilisation of mobile applications (apps) for security. It is somewhat ironic to note that so much attention was given to the development of ICTs in urban areas in an attempt to create a smart city, yet so little attention was given to this and no investment was made in the impoverished and poor areas. A brief analysis of various

During the 21st century, South African cities have increasingly shifted from an industrial mode to an informational mode of operation. Digital technology has become an important aspect of urban life.



spatial development frameworks in South Africa also revealed the overall neglect of planning and investment in the rural areas.

In the same way, according to planning strategies such as the Municipal Spatial Development Framework, the City of Tshwane even created a Consolidated Infrastructure Fund to support new transport infrastructure that would be linked to modern ICTs, for example, the Bus Rapid Transport (BRT) system and activity spines.

According to the City's 2013/14 Built Environment Performance Plan, it was mentioned that, for the past five years (2007/08–2012/13), most of the City's capital budget expenditure was invested in network development and the upgrading of infrastructure. In addition, in a separate planning-related framework, the Medium-term Revenue and Expenditure Framework 2013–2014, the City intentionally put in place the Movement System Programme, which invested in corridor developments. It was also noted that lines or paths that promote the use of motorised and non-motorised transport were prioritised for development, which included extension, expansion and maintenance. Another example was the City-wide Densification Programme, which ensured that the City of Tshwane would be geared towards the growth of urban nodes and increase the quality of infrastructure lines.

The impact of ICT on planning in the City Tshwane was also visible on 5 February 2014 when the Tshwane Rapid Transit (TRT) Spatial Development Policy was developed with an emphasis on densification and intensification around the transport corridors and TRT stations. The intention was to improve connectivity, residential densification, suburban densification, transit/transport-oriented developments, building orientation and infrastructure for non-motorised transport (pedestrians and bicycles).

However, the Metropolitan Spatial Development Framework, which is the foremost spatial planning document of the City of Tshwane, only highlighted ICT under the Blue IQ initiatives in the Rosslyn Automotive Cluster (industrial estate), Innovation Hub (research, innovation and technology) and Dinokeng Nature Reserve (tourism node). The framework made very little reference to "infostructure" (intrastructure based on data and information produced by ICTs).

ICT and city development

From the abovementioned attempt to define what is meant by a "smart city", it is evident that technology has become a very strong determinant of the urban space network.

According to some authors, technology actually triggers the emergence of new patterns and formations in urban space. For example, technology can differentiate between mechanical transport, such as a train, and natural transport, such as pedestrian movement. Other authors argue that technology is indeed one of the many tools that human beings have used to solve problems. The application of technology increasingly improves and directs the functionalities of the network structure of cities.

During the last three decades, technology (as we knew it in the 1900s and even prior to that) has transformed into a new construct, mainly shaped and informed by the evolution of computers and the informational revolution. The construct of ICT became so powerful that, in many ways, it started to control urban space activities, businesses, economies, industries, institutions, people, the aerospace industry and satellites, among other things. It actually became so powerful that it now controls and powers the whole world economy. Imagine a global shut down or "power failure" and the impact this would have on society.

Apart from the inherent power of ICTs, the computer, smart phones and the internet also spawned new communication powers, which enabled people to communicate anywhere in the world, anytime, with anyone – at a relatively cheap rate. This communication and information-sharing power is enhanced by apps, images, video footage, music and internet information.

ICTs and related e-technologies produce information at high speeds. In addition, technological change takes place very quickly, which results in the circulation of information also taking place at a high speed. In short, the way information moves in space, as well as the pace and speed at which it moves, has had a major impact on people and their social spaces.

These technologies can shape and control cities and the urban form. The nature of e-tools, such as computers, smart phones and the internet, has made ICT very powerful. Smart phones and the internet have created opportunities such as linking people globally to the urban space. ICT has become an integral part of people's lives and spaces. When considering the role of ICT in sustainable development, one would consider how ICT connects people to new knowledge, entertainment, relationships and capital.

It is clear that ICT has had and will continue to have a major impact on people, human conduct and emotions, as well as on the way in which people communicate. ICT has also become associated with the City Beautiful Movement, and in particular the Smart City Movement. ICT and related e-economies have also influenced the larger urban space economy. Furthermore, in recent years, ICT has started to have a major impact on urban planning and planners, as well as the way in which cities are planned and managed.

Upon conclusion of her study, Mirembe realised that the urban space is changing. There is an emergence of dialogues happening between people, time, power, culture, identity, governance, economy, urban space and ICT. Consequently, there is a need for cities to become smarter and to find new ways of accommodating r apid changes in ICTs and their impact on space, people, the economy and urban planning.

Collaborative research is the key to building smart, resilient, sustainable cities

The Department of Architecture is a key role-player in enhancing the University's international research profile in the field of smart cities and transportation. A number of research projects have been conducted recently in collaboration with the Council of Scientific and Industrial Research (CSIR) and the Delft University of Technology, The Netherlands. This research was showcased at the Smart Sustainable Cities and Transport Seminar, held at the CSIR from 12 to 14 July 2017.

This seminar was the result of recent formal cooperation agreements between Delft University of Technology, UP and the CSIR. The seminar was attended by built environment researchers and professionals, as well as government, business and non-governmental organisations that had an interest in smart and sustainable built environments. The main purpose of the seminar was to further boost the collaboration between South African and Dutch parties working on similar themes of the sustainable (re)development of cities. In particular, the aim of the seminar was to help the cities of Tshwane and Amsterdam, and their respective knowledge institutes, to collaborate and learn from each other in their endeavours to become smart, resilient and sustainable.

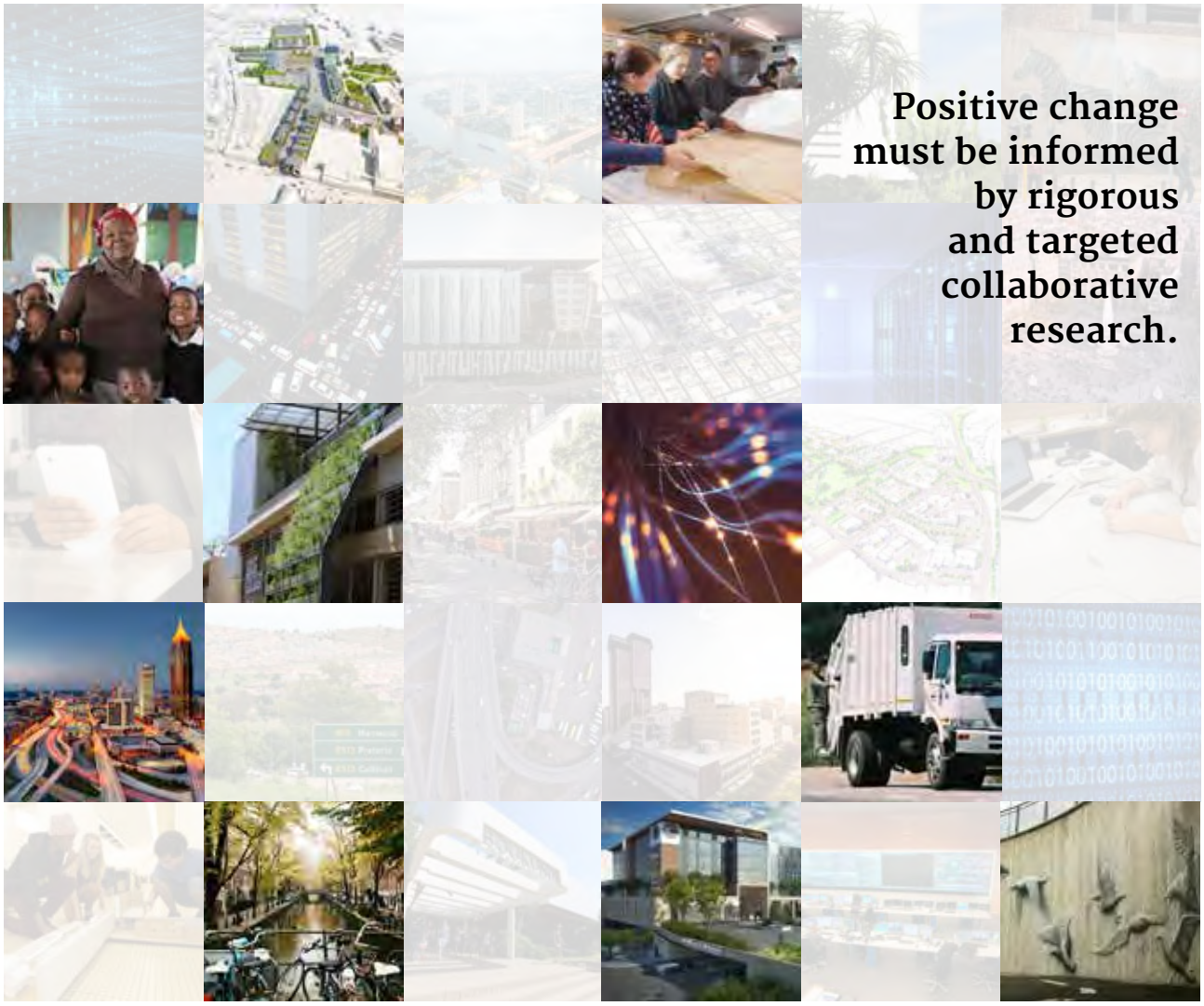
According to Prof Chrisna du Plessis, Head of the University's Department of Architecture, we are living in a rapidly changing world. The effects of climate change and the weakening of critical ecosystem services are beginning to impact on every aspect of our lives. Big Data, the Internet of Things and artificial intelligence are creating new opportunities for the more effective management of cities, as well as new challenges and threats. A range of new economic and governance models are emerging that make use of distributed networks for effective stakeholder engagement. All of these changes come together in our cities, which themselves are rapidly changing in form, nature and extent.

Given this situation, it is not only valuable to understand these changes and their impact on the physical and cultural heritage of our cities and the standard practices of producing our built environment. It is equally important that high-impact, positive change also occurs. Positive change must be informed by rigorous and targeted collaborative research that can be readily and rapidly applied to counter climate change and develop more sustainable built environments.

The papers at the seminar characterised this positive approach from different spheres of interest and perspectives. They covered a wide range of subjects reflecting the various research interests and pressing topics of the day, and introduced the id eas, tools and plans needed for smarter and more resilient and regenerative urban environments.

The papers presented at the conference included the work of several of the researchers in the Department of Architecture, including Gert van der Merwe, Carin Combrinck, Johan Swart and Jan Hugo.

The seminar boosted further collaboration between the South African and Dutch researchers.



Positive change must be informed by rigorous and targeted collaborative research.

Participant action research

Van der Merwe's paper dealt with research on participant action research: developing a framework for inner-city regeneration through the arts and creative cultures. In an attempt to stimulate urban renewal, South African cities have increasingly turned to private sector developments, which attract artists and other creatives to the urban core. He discussed the relative success of these strategies and outlined several issues surrounding gentrification through literature and precedent. These considerations then informed the ongoing theoretical and organisational developments of the Tshwane Arts Union (TAU), an artist-established civil organisation aimed at working with the various institutions housed in Tshwane.

His investigation set out a guiding framework for urban renewal strategies through art that seek to unlock underutilised land and drive urban regeneration. His research was extracted directly from engagement with the TAU, and many of the theories underpinned the conceptual foundation of the TAU. It thus served as an example of the broad considerations when investigating the relationship between a real-world project and the gentrification impacts it might have.

Embedding a culture of participation

Combrinck's paper reflected on the value of embedding a culture of participation across various disciplines towards collaborative urban citizenship. The question underpinning this investigation was how the integration and coordination of engagement modules in academic curricula could contribute towards the establishment of an urban citizenship in university graduates, as well as participating interest groups. Local and international literature points to the pitfalls of university-led initiatives that are lacking in critical scholarship and are resistant to deep transformation.

At the same time, discourse concerned with urbanism in the Global South points to a dire need to redefine the way professionals interact with communities facing the challenges of contested spatial legacies. The work presented was situated in the honours programme of the University's Department of Architecture and included contributions by the Entrepreneurship section of the Department of Business Management in the Faculty of Economic and Management Sciences, as well as the Department of Family Medicine in the Faculty of Health Sciences.

Building on an institutional history of community engagement, a pilot

study was initiated in partnership with a network of five early childhood development centres (ECDCs) in Mamelodi East in the City of Tshwane. Participatory action research informed the development of business models for the ECDCs as well as urban visions for the study area. Critical reflection on the work provided insight into the difficulties and opportunities experienced, eventually proposing an argument for the vertical curricular streaming of sustained participatory processes, as well as horizontal collaboration across disciplinary boundaries.

Smart design in the complex city

Swart's paper elaborated on smart design in the complex city: critical engagements with context and history. Cities are continuously evolving cultural systems, and the elements that make up the city can be seen as cultural residue continuously manifested by historical processes. The present layers of the city, both tangible and intangible, contain a field of residual elements that can be read as data, interpreted culturally and altered through intervention. This view of the city implicates a multitude of disciplines bound together by their attempts to understand the complexities of the city, to engage in critical discussion about its past and future and to develop strategies for meaningful change.

The basis of this paper was that architecture and its content was based on the development and outcomes of an ongoing postgraduate design studio focused on urban conservation. From this perspective, the contribution towards a broader discussion of smart and sustainable urbanism was twofold. Firstly, visual and conceptual reasoning was utilised in an attempt to provide schematic descriptions of the city where aspects of the evolving urban environment could be read as interrelated informants within a spatio-temporal matrix. Secondly, spatial design intervention was used as a platform to discuss how strategies of urban transformation on various scales could benefit from a critical engagement with the complexity of cultural history.

The aim of the paper was to prove the benefits of reading urban data culturally and contextually in relation to complex and context-specific scenarios, and as a reflection of diverse and ongoing urban narratives.

Furthermore, case studies illustrated how engaging data within such a critical framework could lead to more sustainable urban development proposals where change was considered in response to underlying urban tensions (solving problems inclusively), with reference to culturally specific dialogues (ensuring synergy and ownership), and cognisant of ongoing appropriation of resources (to ensure long-term benefit).

Improving the urban climate resilience of cities

Hugo's paper (presented together with Du Plessis) described a process framework to improve the urban climate resilience of cities through the collective retrofitting of their interstitial spaces. Globally, the rapid urbanisation that we are experiencing has caused extensive negative impacts on already vulnerable regions. While many people have highlighted the adaptation and mitigation potential of cities, the need to realign the developmental trajectory of cities is crucial in curbing its contribution to climate change.

Premised on ecological resilience thinking, this study explored the potential of architecture to improve the climate change resilience of cities. It explored the use of interstitial spaces within existing urban environments, and used urban acupuncture methods to radically transform these cities. Highlighting various ecological and climate change resilience theories, along with a discussion on the use of green infrastructure and ecosystem services within the Gauteng Cities Region, the study synthesised those considerations into a preliminary framework to enable the revisioning and adaptive use of the various undervalued spaces within the urban environment.

As outcome, the study hoped to highlight the adaptation and mitigation potential within South African cities, and proposed a novel process framework to retrofitting these spaces.

Overcoming data challenges for waste management

Elias Willemse of the University's Department of Industrial Engineering also presented a paper at the seminar. He considered the topic of overcoming data challenges for waste management in developing cities.

The safe disposal of waste is one of the primary services that cities provide to their citizens. The service is also transport-intensive, making it the most expensive component of waste management in developing countries. Waste collection also has ill side-effects for cities, such as contributing to road congestion and vehicle emission pollution. It is therefore crucial to optimise collection operations to minimise their negative side-effects and make the service more sustainable.

Much research has been devoted to optimising this function, but a key assumption is that the data needed for better collection planning is readily available. This assumption rarely holds in developing countries. The key challenge is then for developing cities to inexpensively source waste collection data to improve their planning. To address this challenge, he showed how existing data sources could be combined to create detailed waste collection statistics on a sub-suburban scale. The data sources used were GPS records of waste collection vehicles, regional census data, collection service areas and schedules, and the locations of landfills and intermediate facilities. The presentation focused on how the combined data could be used to generate collection statistics, including the cost and time required to service sub-suburban areas. Finally, the presentation illustrated how the information could be used to improve waste collection planning.

New engineering facilities increase research capacity

In the current scenario in South Africa, where there is a shortage of civil engineering and other transport engineering skills, it is vital to ensure that critical mass in these areas is developed and maintained. This can be achieved by optimising the utilisation of current facilities and staff available at the University of Pretoria and the Council for Industrial and Scientific Research (CSIR) through a managed partnership with the South African National Roads Agency SOC Limited (SANRAL).

On 28 June 2016, Prof Cheryl de la Rey, Vice-Chancellor and Principal of UP, Mr Nazir Alli, CEO of SANRAL and Dr Rachel Chikwamba, Executive Director of the CSIR, signed a collaborative agreement. This agreement will lead to the establishment of an Integrated Education, National Certification, National Reference and Research Laboratories Facility, as well as SANRAL national test tracks. New laboratories and equipment, together with existing facilities, will conduct academic and industry research, as well as certification functions.

UP's strategic plan for the period 2012 to 2025 focuses on problems of national and/or regional concern in order to simultaneously maximise local impact, while enhancing its academic stature and visibility in a highly competitive international world. To this end, UP has been fostering relationships with SANRAL, the CSIR and other research entities in the interest of producing quality engineers and research. In terms of the private sector, there has also been good cooperation with industry associations such as South African Bitumen Association (SABITA), which has funded several research projects and has been actively pursuing innovation, knowledge transfer and training activities.

The new facility's vision is to provide an internationally renowned platform for academic and vocational training support in transport infrastructure materials testing, a national transport materials reference testing platform, as well as high-quality research facilities and skilled staff. This will enhance the quality and quantity of the outputs and avoid the costly duplication of laboratory facilities.

Not only will the new facility benefit the three partner institutions, but it will also contribute to the South African pavement engineering landscape in general. More engineers who are skilled in transport engineering will qualify and the qualification standard of transport engineers, technologists and technicians will be improved. These skilled professionals will contribute to cost savings through improvements in design, construction, maintenance and transport infrastructure management. The country will also benefit from better-performing transport infrastructure and the associated reduction in user operating costs. Transport infrastructure construction will also have a reduced impact on the environment.

Envisaged new facilities

The new laboratories will be constructed on the University's Experimental Farm in Hatfield. This location was selected as it lies in a buffer zone adjacent to the N1/N4 highway. A multi-storey building will be constructed to which access can be gained from the south, while the

The vision of the new facility is to provide an internationally renowned platform for academic and vocational training support.

→ *Overall layout of the Experimental Farm indicating the space to be utilised.*

northern façade will be designed to be aesthetically pleasing when viewed from the highway, while playing a noise-abating role.

The development will comprise facilities to host the Department of Civil Engineering's academic and technical staff, as well as practical and discussion teaching facilities for senior undergraduate and postgraduate students in the Department, and visiting scholars. The building will also house a collection of laboratories for other departments at UP.

The University will be responsible for the design, construction and operation of the new facilities. The CSIR will procure equipment and operate the existing facilities on its premises, which forms part of the agreement, while SANRAL will fund the project and coordinate the facilities.

Academic and Training Laboratory

The Academic and Training Laboratory will provide materials testing training courses and independent certification. UP will be responsible for the laboratory's day-to-day management. The staff complement will consist of individuals from UP, CSIR and the Gauteng Department of Roads and Transport (Gautrans).

This new laboratory will host a standard suite of transport infrastructure materials testing equipment for the training of large groups of UP students, students from universities of technology and industry.

SABITA developed a curriculum for materials testers that is endorsed by the Roads Pavement Forum (RPF). This is proposed as the official curriculum for materials testers in South Africa and requires such testers to be trained in the full complement of transport infrastructure materials tests, in accordance with relevant South African National Standard (SANS) and industry test methods. In order for the facility to play an independent and vital role in the training and monitoring of materials testers in South Africa, it is important to align activities to this curriculum.

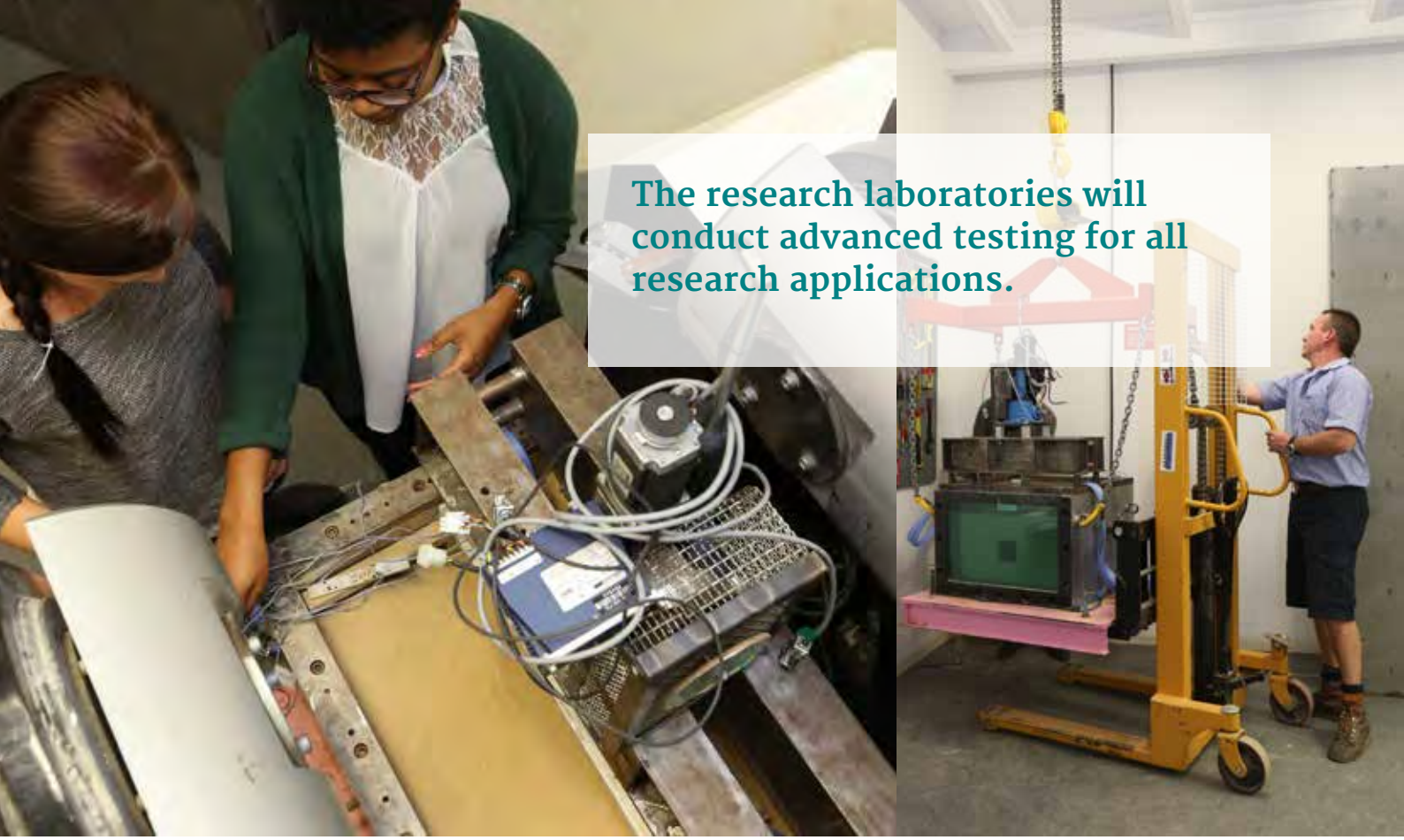
As part of the activities of the Academic and Training Laboratory, the facility will play the role of an independent facility for the certification of material testers. This will enable an environment where such testers can conduct an independent trade test to verify their competency in the required tests and enable industry to trust the certification process, as it is being done independently. As an outcome of the independent verification of materials testers' competency, the facility will also maintain a national register of certified materials testers for reference purposes.

In addition, there is a need for the national training and certification of road and bridge visual inspectors. This certification consists of a one-week theoretical and practical course with an associated examination. Each authority independently administers these examinations, which results in a duplication of effort. A facility like this will be able to ensure better data consistency and reduce duplication.

National Reference Laboratory

The National Reference Laboratory aims to participate in international proficiency schemes and conduct standard reference testing for SANRAL and other authorities in the northern parts of South Africa. This laboratory will be fully accredited by the South African National Accreditation System (SANAS). It will be responsible for operating the National Laboratory Proficiency Scheme. As with the Academic and Training Laboratory, UP will be responsible for the day-to-day management. CSIR laboratory staff and possibly staff from Gautrans will also be part of the team. This laboratory will focus on industry's needs. SANRAL will purchase the initial equipment, and reference testing on projects will recover costs. The CSIR, UP and SANRAL will be responsible for the laboratory's planning and scheduling. Existing equipment from the CSIR will also be used.

A national proficiency scheme for laboratories allows the accreditation of competent laboratories and staff to ensure the formal recognition of



The research laboratories will conduct advanced testing for all research applications.

such laboratories, and that staff are competent to carry out specific tasks in terms of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, Act No. 19 of 2006. The intention is that the facility will be involved in the management of this scheme to ensure that all relevant aspects of quality control and certification are managed by a central facility.

Proficiency testing refers to any activity undertaken by a laboratory in order to provide objective evidence that it is proficient or competent to perform measurements. The term applies to all laboratories, whether they perform measurements for calibrating instruments or for the purpose of testing products. Proficiency testing is a requirement of a SANAS-accredited laboratory. The National Laboratory Association of South Africa (NLA-SA) has embarked on a project to make proficiency testing schemes that meet all the ISO/IEC 17025 requirements available to the laboratory community.

A further role of the laboratory is to perform independent testing of duplicate samples from road construction projects in the northern parts of South Africa. It is important to ensure that test results obtained from commercial and site laboratories that are all connected to the major road construction consultants and/or contractors can be continually verified and that the quality of all public infrastructure can be guaranteed. It serves a major auditing role in ensuring that all test data from road construction, maintenance and rehabilitation projects in the country are independently audited and verified.

The laboratory will also be responsible for the annual national certification of road surface profilers and falling weight deflectometers that are used for asset data collection. These certifications are currently being conducted by several separate authorities, which results in a duplication of effort. Such a facility will also be able to ensure better data consistency and reduce unnecessary duplication.

Research facilities

The research laboratories aim to conduct advanced testing for all research applications. The aim is to use the current facilities available at the CSIR and UP, and to complement these with new facilities and/or equipment where necessary. UP will manage the concrete laboratory and the new laboratories, while the CSIR will manage the existing bitumen and asphalt laboratory. These laboratories are to be used by postgraduate students and researchers. The laboratories will be funded by SANRAL, the CSIR and industry.

A research laboratory steering committee will conduct the planning and scheduling, with the primary focus on approved academic and bona fide research plans. UP's existing specialised concrete test equipment, the CSIR's existing specialised soil, bitumen and asphalt test equipment and new international specialised test equipment that is not currently available at UP or the CSIR will be used in these laboratories.

The new concrete laboratory will host current specialised concrete test equipment from UP for postgraduate and industry research. Competent technicians will be available to train and support students.

A new, separate UP civil engineering laboratory is also being planned for the Experimental Farm site, although it will function separately from the envisaged integrated laboratories. This includes current UP laboratories, as well as structural, timber, water and railway research facilities. The site will also house UP's geotechnical centrifuge. Research in some of these laboratories will support and complement the research being conducted in the concrete and asphalt laboratories, where applicable. A dedicated transport laboratory space will be provided to enable undergraduate thesis students to conduct experiments that do not fit into the available CSIR research laboratory due to the large number of final-year undergraduate students.

It is envisaged that the laboratories will be supported by metal and electronic workshops to support the construction of equipment and models, as well as general sensor and instrumentation development. Existing facilities on both the CSIR and UP campuses will be used where applicable.

Test tracks and full-scale accelerated pavement testing (APT) facilities are traditionally used to scale up the research findings that were obtained in laboratory testing to real-world scale and conditions. This is a requirement for implementation of the research, as the majority of laboratory-based research focuses on material-specific properties and behaviour, and real road infrastructure consists of a combination of materials and layers to which stresses and strains are applied that are sometimes magnitudes larger than that which can be simulated in a normal laboratory environment.

South Africa is a leader in the development and use of full-scale APT, with the two major systems currently available internationally both being developed locally. Over the past 25 years, this type of technology has proved itself to be vital for the final link between the laboratory-based results and full-scale implementation of research findings, often highlighting limitations in research that would not be visible in a laboratory environment.

→ *The potential location of real traffic test tracks.*

Test tracks are a more recent development, where actual traffic is allowed to use a test section that is instrumented and monitored for various performance and behavioural parameters. Currently, there are approximately five well-known international test tracks used for the evaluation of road infrastructure, and again, the results from such tests are vital to show the response of road infrastructure to real high-speed traffic. Conceptually, test tracks and APT facilities fill the gap between the single material testing of small samples in a laboratory environment and the full-scale implementation of the research results.

As part of the new developments, an APT track will be used for the in situ testing of experimental pavements at an accelerated pace using an APT device. The facility will be used to support the SANRAL research programme. A real traffic diversion track from the current N1/N4 located adjacent to the Experimental Farm is planned as part of a future full-scale real traffic test area. This is similar to current developments in Virginia, Minnesota and Texas in the USA, where actual traffic is allowed access to the test track at designated times. The intention is to split road sections using New Jersey concrete barriers into a traffic and test lane with test sections constructed in the road reserve.

In addition to the APT tracks, a 30-meter-long PY Slab Track was recently constructed next to two existing rail track structures. The PY Slab Track borrows its name from the heavy haul concrete sleeper, as it has the same cross-sectional profile as that of the PY sleeper.

It is a ballastless track structure that the Passenger Rail Agency of South Africa (PRASA) currently uses on the Metrorail lines that carry passengers.

The railway engineering research will be conducted on this structure to evaluate the performance of the track structure components, which will include three different types of rails, rail pads and concrete slab, as well as the constructed formation layers below the track slab. The PY Slab Track is a South African design by Henry de Wet of RCE Consultants, a former Transnet employee. Stefanutti Stocks Civils, Aveng and iKusasa Rail sponsored the track's construction.

Conclusion

Given the shortage of transport engineering skills, UP, the CSIR and SANRAL aim to address the national need for education and the development of new technological solutions for the transport industry in South Africa.

These three institutions will be jointly responsible for the new engineering development at UP's Experimental Farm, which will go a long way in ensuring that competent graduates and meaningful research outputs are produced.

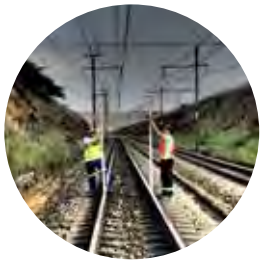
Collaborating towards railway safety

The importance of rail safety in South Africa has never been more prominent than today. Transnet's objectives and government infrastructure investment support this notion. Skills transfer, teaching and continuing education are the keys to unlocking the potential required to achieve short- and long-term goals in the rail industry. It is a fact that investment in research and development will increase the competitive edge that rail has over other modes of transport. To this end, the University of Pretoria has entered into two partnerships.

UP partners with the Railway Safety Regulator

Safety on rail, like all other public services and infrastructure development, is the number-one priority, and railway engineers have much work to do to ensure that the users of rail transport in South Africa arrive safely at their destinations. To achieve this goal, Prof Cheryl de la Rey, Vice-Chancellor and Principal of the University of Pretoria, Nkululeko Poya, Chief Executive Officer of the Railway Safety Regulator (RSR) and Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, signed a Memorandum of Understanding (MoU) for the RSR Chair in Railway Safety on 14 November 2016. This agreement was signed for a period of five years from 2016 to 2021.

This collaborative effort between UP and the RSR is an example of how academics and industry can partner to meet the greater needs of society. The benefit for both parties has far-reaching consequences. The RSR will have the opportunity to articulate its training, research and development needs to the University, while the University will gain first-hand knowledge on what skills are needed in the railway industry to fully equip its students and ensure that they are ready to make a difference in the world as soon as they graduate. The MoU includes the development of a Railway Safety Inspector Qualification, which will be a combination of formal training and practical workplace experience with a multi-disciplined focus. Development courses to address deficiencies in the training of technical staff will also be implemented. A further two courses, Technical Auditing and Report Writing and Train Movement Authorisation Systems, will also be developed and presented.



Railway safety is an important priority in the development of rail infrastructure.

Prof Hannes Gräbe, the incumbent of the Chair in Railway Safety in the Department of Civil Engineering, believes that the cost associated with rail incidents warrants investment into the training of rail safety inspectors. "We are excited about the opportunities that this partnership will create. In addition to the training, research projects will be initiated to address burning issues in the field of railway safety. We trust that this partnership will last for many years and that the fruit of our efforts will notably benefit railways in South Africa," he says.

In addition to the Chair in Railway Safety, the Department of Civil Engineering also holds the Transnet Freight Rail Chair in Railway Engineering, which was established more than 20 years ago. The Chair, of which Prof Gräbe is also the incumbent, annually presents more than 20 short courses to industry and is responsible for technical support and problem-solving, as well as research and development in the different railway disciplines. The Chair's activities feed into the University of Pretoria's numerous postgraduate programmes in railway engineering.

Postgraduate students are involved in a number of programmes in railway engineering.

Railway Occurrence Investigation Programme

Transnet Freight Rail (TFR) and the Department of Civil Engineering at the University of Pretoria have jointly developed the Railway Occurrence Investigation Programme (ROIP) to address the escalating, repetitive nature of incidents through proper investigation.

Railway incidents, such as derailments and collisions, annually cost the operators approximately R570 million in addition to the unquantifiable loss of life. According to the State of Safety Report of 2015/16, some 665 people were injured and a further 20 lost their lives as a result of derailments and collisions.

The aim of the programme is to provide TFR rail occurrence investigators a detailed understanding of all the major aspects of railways (infrastructure, operations and rolling stock), as well as their interrelationships and interdependencies in the railway undertaking.

The ROIP was developed as eight individual modules that are presented as short courses over a 12-month period. At the end of the formal training, occurrence investigators will be subjected to a summative assessment on the content of the programme.

The curriculum content of the ROIP is aligned with the theoretical and practical course content of the Railway Safety Inspector Qualification that is currently being developed by Enterprises UP, the RSR and other stakeholders. The Engineering Council of South Africa (ECSA) accredits all modules, which are therefore eligible for continued professional development (CPD) points.

The ROIP is just one of many ways to achieve a state of "no occurrences" in the railway industry. By reducing incidents, starting with derailments and collisions, the industry can save millions of rands and ensure the safety of its users and operators.

In collaboration with all rail stakeholders, the University of Pretoria has the technical expertise and facilities to be a leader in railway safety in Africa.

Real-time monitoring of the extended road network by utilising telematics technology

Illeze Wessels and Prof Wynand Steyn

Continuous, real-time monitoring of the road network can assist in prioritising when roads should be maintained or rehabilitated. The timeous maintenance or rehabilitation of roads improves road safety and comfort. This type of monitoring can be used to assist in investing the available funds and resources more intelligently. A study conducted by the Department of Civil Engineering explores the practicality of adopting telematics technology to monitor the condition of the extended road network on a continuous, real-time basis.

Telematics technology continuously evolves and is currently used in the market to monitor and manage vehicle fleets, retrieve hijacked or stolen vehicles and monitor driver behaviour for insurance companies. Most telematics units incorporate a global positioning system (GPS), acceleration and gyroscope sensors. Leading telematics companies generally have large databases and complex algorithms to store this type of information.

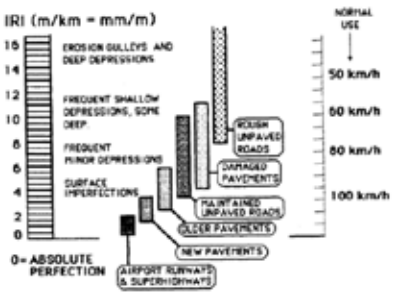
In this study, different statistical analysis techniques were applied to the existing telematics data and the most promising outcome was utilised to show that this technology contains additional potential in terms of monitoring the condition of the extended road network on a continuous, real-time basis. Although road roughness is currently measured with dedicated Class 1 profilometers, when effective calibration techniques are applied to the data harvested from telematics units, a reasonably accurate representation of the road condition can be produced. This is shown by sampling data from a few local passenger vehicles fitted with telematics devices and doing the necessary analysis and calibration techniques on the vertical (up/down) acceleration to produce data that can provide a cost-effective indication of the condition of the extended road network in real time.

Road roughness and condition monitoring

Road roughness describes the relative degree of comfort or discomfort road users experience. Monitoring road roughness is vital, since it has a direct influence on the user experience of a specific road. An uncomfortable ride is generally associated with variations in the surface elevation along the wheelpaths of a road. Measuring the road surface profile is one of the most direct methods of quantifying the variations in surface elevation. The International Roughness Index (IRI) roughness parameter is determined from the road profile measured in a specific wheelpath. Most modern profilometers have the capability of measuring the profile of the road in both wheelpaths simultaneously. A more theoretically accurate assessment of roughness can be attained if the roughness index is calculated in both wheelpaths, using the Halfcar Roughness Index (HRI).

The IRI produces a controlled measurement for a number of roads under numerous conditions from a variety of instruments and methods. It is defined as the ratio of the accumulated suspension motion of a vehicle, divided by the total distance travelled by the vehicle, and has units of slope (m/km). An IRI interpretation scale was developed by Sayers, Gillespie and Paterson (Sayers et al., 1986), and generally indicates the IRI ranges for different paved and unpaved road sections, as well as recommended safe operating speeds.

Various instruments monitor road roughness and can be broadly divided into two main categories: the profilometric methods and the response-type road roughness measuring system (RTRRMS).



→ *The IRI interpretation scale.*

Road section used for analysis.

Measuring a road profile allows a continuous representation of a road to be evaluated to identify local defects, or to be processed to yield a roughness numeric. Profilometric methods include manual, quasi-static and high-speed profilometers.

For an RTRRMS, a vehicle is fitted with an instrument such as a road meter. The road meter produces a roughness measurement that results from the motion of the vehicle as it traverses the road at a constant speed. The RTRRMS depends on the vehicle type and the dynamics of its ride tuning. The performance of the RTRRMS is therefore not consistent with time and may change abruptly with a turnover in fleet vehicles or due to travelling at different speeds. Primary calibration of the RTRRMS includes obtaining standard roughness measurements for actual roads by simulating the reference RTRRMS on the profiles that were measured by the profilometer.

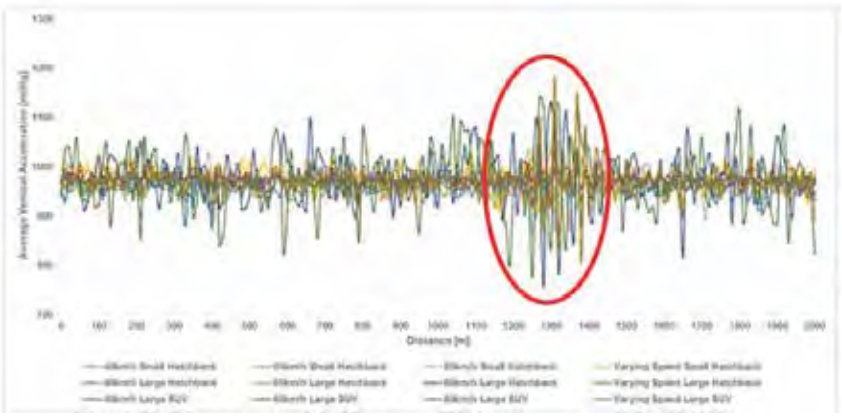
If calibrated correctly, an RTRRMS is capable of producing measurements in standard units to an accuracy of approximately 10% for individual measurements. Most RTRRMSs are affected by variations in the physical properties of vehicles. Many of these variations originate either due to the initial design or due to the degradation or replacement of various components.

Numerous smartphone applications have recently been developed to evaluate and detect road conditions. These applications use different sensors of mobile smartphones. Although smartphones have several advantages of measuring the road condition, limitations include the manual orientation of the smartphones, placing and keeping them in a fixed position in a vehicle and physically exercising human effort to understand and run the applications correctly.

Modern telematics devices in vehicles adopt GPS technology, which is capable of locating a vehicle within a circular error probability (CEP) of approximately 2.5 m. The position of the vehicle is thus communicated to a monitoring centre via Global System for Mobile (GSM) technology. Telematics companies are able to continuously communicate with the monitoring centre to increase frequency in the event of an emergency.

If the road pavement roughness decreases, road users tend to drive faster. An increase in speed might offset the benefits to be gained from reduced rolling resistance, which is associated with reduced pavement roughness. A linear regression model was generated to estimate the free-flow speed on freeways in California. The variables considered included lane number, total number of lanes, day of the week, region, fuel price and pavement roughness.

The data used to create the model was obtained from the freeway network of California in the USA between 2000 and 2011. Results confirmed that roughness has a very small impact on free-flow speed with regard to wider and smoother road sections. However, a strong relationship was produced between riding quality and the speeds attained for narrower and rougher road sections.



→ *Average vertical acceleration for 10 m segments, indicating an area of high road roughness.*

Statistical analysis

The study investigated different statistical techniques to find a method that could be used to link the data harvested from the telematics devices in the field to a road condition index that could be used and distributed to road users on a continuous, real-time basis throughout the road network.

A road section with various defects and different degrees of roughness was identified in the development of a model that could be used to estimate the road condition by utilising the data harvested from telematics devices. To generate a preliminary model, three passenger vehicles (a small hatchback, a large hatchback, and a large sports utility vehicle (SUV)) were driven at 40 km/h, 60 km/h, 80 km/h and varying speed over a continuous road section 2 km long. The constant speeds were achieved with the vehicles' cruise control systems. The varying speed was achieved when the driver randomly varied the speed over the length of road. To ensure that the data was calibrated for all the different variabilities, the telematics devices were also installed in different locations on each vehicle. Calibration by correlation involved calibrating the telematics device's profile data with the actual road profile as measured with a Class 1 profilometer. The latest-generation telematics devices manufactured by the tracking company were used in this study. These telematics devices have various built-in components, such as a three-axis accelerometer, three-axis gyroscope and data storage facilities. The devices also have a GPS that is capable of locating a vehicle within a CEP of approximately 2.5 m.

The section length selected for analysis depended on the storage capacity of the telematics devices. The calibration by correlation occurred over segments of 10 m. The overall length of the section used to generate the linear regression model was 2 km. The average vertical acceleration generated for the different vehicles that travelled at the different speeds for 10-m segments of the 2-km road section were calculated and plotted.

In order to produce a road profile from the raw data generated, different statistical analysis techniques were investigated.

Results

The ultimate purpose of the analysis was to generate reliable data that could be visually portrayed to all road users so that they were aware of the road condition and could drive accordingly if they knew the condition beforehand. This would assist with the awareness factors of road users and improve road safety.

The continuous, real-time road roughness of the extended road network can be computed, displayed and distributed to all road users via portable navigation devices (PNDs) or smartphone applications. The roughness of the road section will be continuously calculated as identified consenting customers travel on different roads on the network. The deterioration rate of the road can also be monitored by comparing the estimated road roughness, which was calculated previously, with the estimated road roughness after a specific period has elapsed. This can provide an indication of rapid road deterioration and the resultant need for more in-depth investigation of the road structure. The actual measured HRI from the Class 1 profilometer and the estimated HRI from the telematics device data were plotted to illustrate the means of visual portrayal and correlation.

Conclusion

Telematics technology can potentially be utilised to estimate the road condition. With appropriate calibration techniques and continuous progress, the data harvested from a large sample of telematics devices installed in the field can produce information. This information can be valuable to all road users, as it improves road safety and assists with the implementation of better road maintenance prioritisation. Telematics technology holds the potential of various prospective future applications, such as the following:

- Calibrating the sensors to detect road anomalies such as potholes, speed bumps and untrue bridge deck joints on a larger network level through pattern recognition algorithms.
- Deterioration rate monitoring of roads on a network level.
- Proposals for safe operating speeds in relation to road roughness.
- Vehicle operating cost models, which link the fuel cost to the estimated calculated road roughness.

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The effects of road conditions and packaging types on transported tomatoes

Prof Wynand Steyn and CJ Pretorius

A study conducted in the University of Pretoria's Department of Civil Engineering looked at two crucial aspects of transport logistics in the tomato-farming industry. It considered the influence of road conditions and different packing types on the shelf-life of tomatoes.

Tomatoes is one of the most popular crops in the world. Unfortunately, a considerable amount of freshly harvested tomatoes never reaches the consumer due to bruising during transportation and handling. When considering the quality of fresh tomatoes, consumers are primarily concerned with the firmness and appearance of the product, which includes colour and freedom from imperfections. Tomato quality also deteriorates as the tomato matures during its shelf life. The effect of temperature and humidity on the ripening time of tomatoes cannot be underestimated. Other factors such as road conditions, acceleration and packaging all have an effect on the cargo.

Road transport is one of the most efficient ways of moving produce from origin to destination because of shorter travel times and the ability for it to reach more inland destinations than any other mode of transport. Although the flexibility of road transport is an advantage, previous studies have indicated that fruit and vegetables suffer mechanical damage due to in-transit vibrations.

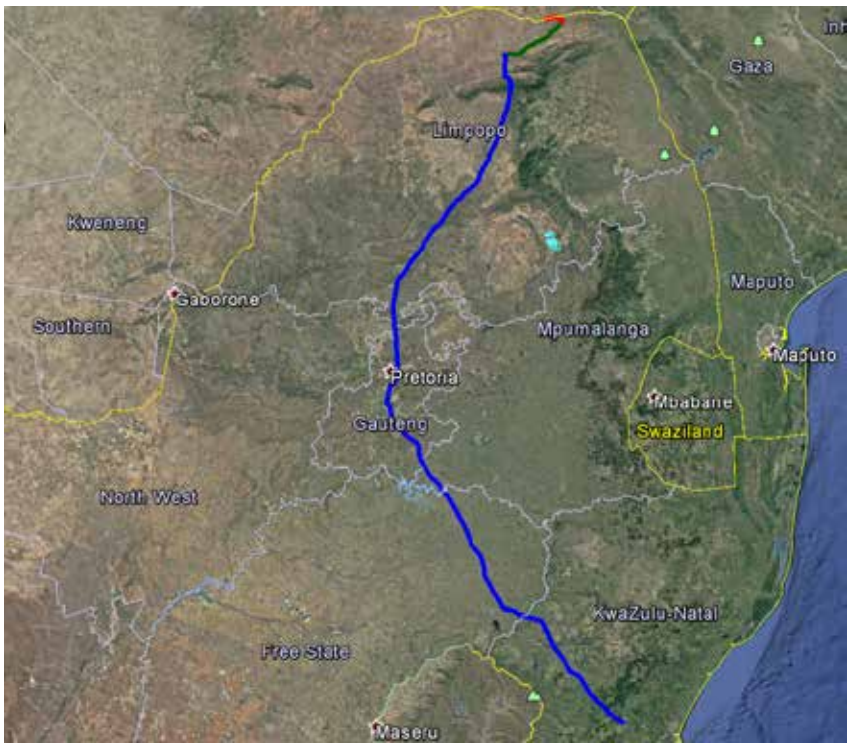
The condition of roads in South Africa varies significantly depending on the responsible authorities. The national road network is under the jurisdiction of the South African National Roads Agency SOC Limited (SANRAL) and each road in this network is paved. The provincial road networks are 25% paved and under the jurisdiction of the provincial authorities. Municipalities maintain the remainder of the roads, but approximately 140 000 km of gravel road is not maintained by any authorities. The primary network is mostly in an acceptable condition, but the secondary and tertiary networks have deteriorated in condition.

According to the sixth State of Logistics Survey, conducted by the CSIR in 2009, which focused specifically on the cost of bad roads to the economy, there is a strong relationship between road condition and the vibrations that a truck experiences when travelling on the road. This affects the transported cargo, and vibration-induced damage could be a result of poor road conditions.

It is expected that roads with higher roughness values could cause premature deterioration in the quality of tomatoes. To evaluate this theory, a study was conducted at three tomato farms in Limpopo, which are owned by ZZ2. Trucks travel from the farms via a gravel road, after which they travel on a provincial road and a section of the national road to the central packaging house at Mooketsi. Trucks also travel from this packaging house on the national road via Gauteng until they reach the market in Pietermaritzburg.

The roads travelled on are shown in Figure 1. The average distance travelled from the farms to the fresh produce market is roughly 1 000 km. The maximum speed that the trucks are allowed to travel is 80 km/h. It therefore takes them between 12 and 15 hours to complete the trip. Trucks leave the central packaging house in the afternoon at around 17:00 and reach the market at around 06:30 the next morning. These trucks drive on a variety of roads, including unsurfaced roads, where higher roughness values are probable, along with more produce damage.

The trucks travelled on three different road sections, which consisted of a gravel or unsurfaced road, the provincial road and the national highway (red, green and blue respectively in Figure 1).



→ *Figure 1: Road sections travelled during field experiment.*

There is a fundamental link between sustainable economic growth and the logistics costs of a country. Transport is one of the largest components of logistics costs and cost-saving in this regard has a huge impact on overall logistics costs. Vehicle-pavement interaction (V-PI) is an important factor to consider during logistical cost optimisation for the agricultural sector. Fresh produce, such as tomatoes, are susceptible to mechanical damage during transport, lowering the profit margin for the grower and the retailer. The amount of damage to produce is directly influenced by the road condition. With deteriorating road conditions, the vibrations increase and so does the damage to tomatoes. By considering the roughness values of roads used and the speed of the vehicle during the transport of tomatoes, the estimated damage to the tomatoes can be calculated.

The study aimed to investigate the relationship between road roughness and tomato damage. It comprised two phases. The first phase included the measurement of road roughness, vertical accelerations to which the system components are exposed and in-transit pressures applied to the tomatoes. The PaveProf profilometer monitored and collected road roughness measurements every 10 metres. The road roughness, location and cumulative distance were recorded, and this information was used to determine the locations of good, average and poor road sections. The effect the maturity of tomatoes has on the amount of damage and the role that two different packaging types played as a method to contain produce during shipment were also considered.

In order to assess the effect of road roughness, accelerometers were positioned on the truck, half-bins and small boxes containing tomatoes. The measured accelerations can thus be compared for different locations with different degrees of road roughness. One-kilometre road sections of good, average and poor quality were selected for the gravel and provincial roads. A Fast Fourier Transform (FFT) analysis was done for each of the accelerometers that were placed on the truck, boxes and half-bins for the one-kilometre section to determine the dominant frequencies. The dominant frequencies of the different sections and container types were compared. Parameters such as the temperature and humidity were also monitored during the experiment. Food technologists will use these in a complementary study to evaluate the specific effect of these parameters on the tomato deterioration.

Accelerometers were installed on the truck and tomato packaging for data collection. Two different types of packaging were considered. The first type was a half-bin, which was used for the shipment of the tomatoes between the farms and the central packaging house. A half-bin can have eight to ten layers of tomatoes. The second packaging type considered was the standard boxes that can hold up to three layers of tomatoes. As a control measure, accelerometers were installed on the body of the truck. To determine the forces that act on the tomatoes during transport, pressure sensors were installed in between the layers of fruit.

The second phase of the project involved an experimental set-up in the laboratory. The frequencies at which the testing had to be conducted was determined from field experiment accelerometer analysis. A vibration table was used to simulate and monitor the in-transit conditions to which the tomatoes are subjected. The locations of impact were monitored for colour changes. Different situations were assessed, including the effect of the number of layers of tomatoes, as well as tomato maturity.

To ensure that the tomatoes for laboratory testing do not get damaged during transportation, layers of bubble wrap were placed in between the tomatoes, and each tomato was inspected for damage prior to testing.

To simulate the in-transit conditions of the boxes and half-bins, three experimental containers with two, four and six layers of tomatoes were tested. The pressure sensors were installed between the bottom two layers.

Installation of accelerometers on the half-bins.

Installation of accelerometers on the small boxes.

Installation of the pressure sensors in the half-bins.

Installation of the pressure sensors in the small boxes.

Boxes with the two- and four-layer set-ups.

A colour and condition monitoring process was used to determine the marketability and shelf life of the tomatoes. There are only two methods for consumers to assess whether they would be willing to purchase tomatoes from a retail shelf. These are the physical appearance and firmness of the tomatoes, and the presence of soft spots. Consumers' perspectives of marketability were also considered, and a focus group was asked whether they would buy the tomatoes or not.

This study indicated that, as the roughness of the road increased, so did the damage to the transported tomatoes, irrespective of the maturity of the fruit and its position within the package.

Three different stages of tomato maturity were investigated during the analysis. Tomato maturity was based on the colour of the skin (defined as red, pink and green). The effect of maturity should be considered jointly with the position in the package, which influences the contact time and pressure of loading during shipment.

On well-maintained roads with average roughness values, red tomatoes in the top layers tend to display greater damage with an increase in time, compared to tomatoes in the lower layers. Green and pink tomatoes are more resistant to damage in the top layers than red tomatoes. On all accounts, irrespective of the maturity of the fruit, the highest loss in shelf life was visible in the upper layers. For different combinations of frequencies and amplitudes, fruit can experience vibrations approaching 1.0 g. This can cause rotation, rubbing, skin discolouration and breakdown of the surface tissue.

Dominant frequencies for one-kilometre road sections with different road roughness values were calculated for accelerometers placed on the trucks used for transport, half-bins and small boxes. Two main groups of dominant frequencies were apparent from the evaluation. These are body bounce, with a frequency range between 0.1 Hz and 5.0 Hz, and axle hop, with a frequency range between 5.0 Hz and 20.0 Hz.

When considering the small boxes, it was observed that they mostly experience axle hop frequencies and absorb a large amount of energy. The half-bins, by comparison, experienced both axle hop and body bounce frequencies, but less energy is absorbed by the system because of the mass of the unit. There is, however, not conclusive evidence to imply that a half-bin is a better form of packaging for transport. The bottom layer of the half-bins has at least six to eight layers of tomatoes on top of it, whereas the small boxes only have two layers. Although the frequency of vertical acceleration is higher for the small boxes, the contact stress and time between the tomatoes are expected to be much less than the contact stress and time in the half-bins.

Fruit with different maturities has different factors that affect bruise susceptibility. When developing a holistic damage model, these factors should also be considered. In the latest research, models have been developed relating road roughness to tomato shelf-life, and these models are currently being evaluated in field studies.

This study could serve as the basis for the development of damage models for other fruits and vegetables. With this knowledge, growers can consider different route options to optimise and balance financial and time inputs for the best solution.

Sustaining world-class teaching and learning outcomes

Prof Alta van der Merwe, Deputy Dean: Teaching and Learning, has developed a progressive strategy for the Faculty of Engineering, Built Environment and Information Technology with the objective of enabling it to rank among the world leaders with respect to the University's five identified strategic goals. Through research excellence, innovation and resilience, the Faculty aims to sustain its progress within the context of the current South African higher education landscape and, as an outcome, improve its international rankings.

The University's five strategic goals are as follows:

- Enhance access and successful student learning through excellent teaching and relevant curricula.
- Strengthen the University's research and international profile.
- Strengthen the University's social responsiveness and impact on society.
- Foster and sustain a diverse, inclusive and equitable University community.
- Optimise the University's resources and enhance institutional sustainability.

Enhancing access and successful student learning

A Teaching and Learning Committee has been constituted in the Faculty, which aims to address a number of key priorities over the next five years. These priorities include the following:

Increasing overall module success rates and significantly decreasing modules with low success rates

A number of modules in the Faculty have been identified as high-impact modules, where student numbers are high and throughput is low. Interventions to improve student success in these modules include focusing on success factors and putting strategies in place, in consultation with heads of department and course coordinators, to increase throughput to above 70%. It is imperative that tutor and assistant lecturer support should be adequate to support students with content-related problems during their studies.

Special interventions will be developed for seven modules that have been identified as being particularly problematic. These include inviting students for a meeting with the head of department if they are enrolled for the second time and fail the semester test. Such students will also be directed to additional help, such as the Faculty Student Advisors (FSAs), as needed.

All high-risk first-year students will be invited to attend a workshop presented by the FSAs, which will focus on student-related matters such as time management and study methods.

Increasing minimum-time-completion rates

A significant increase in throughput after four years has been identified from the 2001 cohort (first-year enrolments) to the 2012 cohort. However, the University strives to increase this throughput even more, and is therefore committed to introducing interventions to assist students to complete their studies in the prescribed period of time.

Several priority areas have been identified. The FSAs constitute an important component of the FLY@UP project (launched to encourage students to complete their programmes in the minimum time). Furthermore, the entry requirements for programmes in the Faculty will be revisited. An audit of the Faculty's summer and winter schools will also be conducted to determine the success rate of students who are

involved in these opportunities. The Department for Education Innovation will use a cluster analysis tool to determine higher-level success factors and investigate interventions to support students.

The Data Science Institute in the Department of Computer Science will develop an institutional analytics research group to study student progress. Topics of interest might include student management analytics, learning analytics, faculty performance analytics and degree completion analytics. It is envisaged that patterns might emerge from the data sets gathered across the student life cycle (from the moment the student applies at the University until the student graduates), which can provide information that can be applied to develop strategies to improve student success.

Transformation of and through the curriculum

The extent to which the Faculty's programmes contribute to or serve as an obstacle to transformation will be assessed, and curriculum transformation plans developed accordingly.

Several priority areas have been identified. A transformation plan will be finalised and tools identified to support the audit process of all the modules. The focus will be on an audit that investigates the current state, the future state, and action plans to reach the future state. As part of the Faculty's transformation awareness with lecturers, it will involve students in annual teaching and learning dialogue sessions. The purpose of these sessions will be to create an awareness of the circumstances faced by students when studying at UP.

As part of the Brown Bag series of lectures that will be launched in the Faculty, it is investigating ways to interact with staff on topics related to transformation, such as opportunities for dialogue. The possibility of translating course material into Sepedi is also being investigated, as well as a research project to measure the impact of the use of a Sepedi assistant lecturer. Finally, the

Through research excellence, innovation and resilience, the Faculty aims to sustain its progress in the higher education landscape.

Faculty plans to develop a strategy on specific transformation aspects that can contribute to entering more successful undergraduate students into postgraduate programmes, such as black female students.

Systematic monitoring of the implementation of the hybrid model of teaching and learning, and providing support where needed

The Faculty has a very high uptake in the use of the University's learning management system, ClickUP, with 95% of the modules using some form of web-based support. The Faculty's focus is to retain and improve this uptake, and ensure that all undergraduate modules have a presence on ClickUP.

Staff members in the Faculty are continuously experimenting with the use of electronic support. Some of these projects include enhancing the use of video material and discussion forums as interactive tools, the integration of online content using additional electronic material through Wiley Plus, the use of gamification and virtual reality to enhance student engagement, and including projects using 3D printing to visualise designs.

Improving the Faculty's international ranking through teaching and learning practices, innovation and success

The University is evaluated every year not only on its research outputs, but also on the high quality of the graduates it produces. It is therefore imperative that the Faculty should continuously improve on its teaching and learning practices. The establishment of a Teaching and Learning Committee in accordance with guidelines set by Senate to monitor the relevance and academic standard of the Faculty's programmes is an important initiative in this regard. The purpose of such a committee is to consider, on behalf of the Faculty Board, the relevance and standard of academic programmes, to exercise quality control over teaching and learning, and to have an oversight of teaching and learning initiatives.

The Faculty will also seek opportunities to use TuksNovation as an incubator of new ideas by organising innovation competitions focusing on mobile applications, presenting the Mad Challenge, a series of workshops to high school learners where mobile application development is taught and where the activities of the School of Information Technology are marketed, and engaging with industry on collaborative projects where students might benefit from the innovation by taking their ideas to market.

A learning environment will be established in the Faculty for students with innovative projects, which will keep students' degrees relevant and internationally competitive. Such initiatives include the Building Sciences Living Laboratory in the Department of Architecture, which will enable the Department to shift into a digital space and create a community design hub as part of its strategic initiatives, and the development by the Department of Informatics of a multidisciplinary undergraduate Information Systems (Data Analytics) programme, as part of the Data Science Institute, in collaboration with the departments of Computer Science, Statistics and Financial Management.

Developing a hybrid learning model

Prof Alta van der Merwe

One of the University's priorities to increase the desired speed of change to meet and exceed its teaching and learning targets is to transform the current teaching model into a more hybrid model, with a focus on online and blended learning methodologies.

According to its Implementation Plan of 2015, one of the key interventions that focus on hybrid learning states that the University will be involved in implementing a system-wide hybrid delivery model that includes face-to-face teaching, learning and assessment in a blended mode, traditional distance education and online programmes.

This will be done by means of the following interventions:

- Piloting and further developing, based on rigorous, ongoing research, the various components of a system-wide hybrid system.
- Strengthening initiatives to transform the teaching and learning approach towards an inquiry-based orientation.
- Extending its suite of fully online postgraduate courses (professional master's programmes will be prioritised).
- Extending the online educational resources programme that is already implemented in the Faculty of Veterinary Science to other faculties, as applicable.
- Extending in-class technologies to enhance students' engagement in class, including the expanded use of clickers within a flipped classroom paradigm.

A hybrid delivery model includes face-to-face teaching, learning and assessment in a blended mode, traditional distance education and online programmes.

What is hybrid learning?

A hybrid teaching model is characterised by different modes of delivery in combination or separately. Blended learning involves face-to-face teaching and learning enhanced by appropriate technology to support student engagement outside the contact sessions. Some programmes use a combination of block contact and distance education (paper-based or online). Fully online programmes would be part of the hybrid model, as would be full distance education using a paper-based approach where it could be motivated in terms of national need. Distance education could also be a blend of paper-based, limited contact and some online communication.

The replacement of more than 25% to 30% of in-class time with online and out-of-class work differentiates "hybrid courses" from "web-enhanced courses", which continue to meet during the normal class hours and use the online component to supplement face-to-face time.

The changing higher education landscape

Over the past decade, the country has seen increased tuition costs, new technologies, a struggling job market and economy, online degree options, massive open online courses, funding model changes, flipped classrooms, an increased focus on learning analytics and the more frequent admission of non-traditional learners. These elements have played a role in the changing face of the higher education landscape.

Today's students expect technology to help them with nearly everything in their day-to-day lives. They expect to receive a push notification if a class becomes available. They expect to get a text or email if there is a problem with their account. They expect to

The Faculty's Mining Industry Study Centre is equipped to support students in the hybrid learning environment through its provision of workstations and computers for all engineering students.

learn about campus events through notifications on their handheld devices.

In addition to these technology expectations, students are not as prepared for University as they once were. Study and time management skills are low and many lack the degree of "university knowledge" that institutions traditionally expect – like knowing the financial and academic consequences of withdrawing from a class, knowing what credit hours versus credits completed or attempted are, or knowing that they should appreciate a professor's feedback, even in the face of a low grade.

A hybrid learning strategy for a technologically advanced faculty

In a faculty such as the University's Faculty of Engineering, Built Environment and Information Technology, certain elements need to be considered when developing a strategy for hybrid learning.

Lecturers in this Faculty are pragmatic by nature and mostly need a pragmatic approach when they are introduced to concepts such as hybrid learning. This approach comprises the following elements:

- Create awareness: Lecturers need to realise the benefits of hybrid learning, as well as the necessity of adopting a hybrid approach to learning.
- Show the benefits: Lecturers need to perceive the benefits of hybrid learning by hearing success stories.
- Provide assistance in specific targeted modules: Such assistance is provided by specialist education consultants in the Department for Education Innovation.
- Monitor progress and measure success: It is only possible to monitor and measure success if one has clear goals. A situation analysis is therefore necessary to clearly define the intervention to be introduced. An ideal measurement structure should include more than one measurement of success, such as interviews and focus groups in addition to student feedback forms.

By systematically monitoring the implementation of the hybrid model of teaching and learning, and providing support where needed, the Faculty can make optimal use of this learning intervention to improve student success.

Empowering the innovation generation

A number of modules in the Faculty of Engineering, Built Environment and Information Technology (EBIT) have been identified as high-impact modules, where student numbers are high and throughput is low. One of the interventions to support the students who experience problems academically is the EBIT Faculty Student Advisor Hub, where three Faculty Student Advisors (FSAs) provide ongoing assistance with study and examination skills, time management and other co-curricular issues.

The EBIT Faculty Student Advisors in front of Loeloeraai. From left: Caitlin Barford, Madeleine van Meyeren and Rumaine Naidoo.

The EBIT FSA Hub is situated in the Loeloeraai Building at the Prospect/ Festival Street entrance to the Hatfield Campus. The academic support rendered at these dedicated facilities aims to equip students to make the correct career choices, handle academic stress better and be equipped to succeed academically. It has an open-door policy.

Students who struggle academically due to various reasons, be they emotional problems or trauma, or even problems with time management and study methods, can make an appointment to consult an FSA. Even students who are doing well, but want to optimise their performance, find these services useful. The aim of the EBIT FSA Hub is to empower students by teaching them life skills through powerful interventions that develop them holistically and empower them to be successful, well-rounded individuals, employers or employees, and responsible citizens.

Each student's case is unique and is treated as such. Some students might only need a little guidance on time management, while others might need a few follow-up sessions to address all their academic needs. When extensive emotional counselling is required, students are referred to UP's student counsellors, while the FSAs continue the academic support.

The FSAs guide students through the various challenges they might experience and show them how these factors influence their academic performance. Students see the benefit of addressing emotional factors once they understand the detrimental influence emotional distress can have on their academic performance. Because the FSAs have a professional qualification in counselling and psychology, they can identify any issues and refer the students to the correct support structures where necessary.

FSAs assess the situation to see why students' stress responses might be activated. Common causes of stress include studying for too many hours at a time, using the wrong study method or emotional factors that come into play. Students who are overwhelmed might not be able to implement the advice they are

Rumaine Naidoo in consultation with a student.

given immediately, and need a few accademic support consultations to succeed. Students are mainly assisted through face-to-face sessions. Depending on the need, the hub presents 50-minute seminars several times a week to address topics such as time management, study methods and exam preparation. Separate seminars on life skills and how to cultivate lifelong resilience are also offered. These will give a prospective candidate the edge when applying for employment, as emotional intelligence is highly beneficial for them to overcome current challenges, and to negotiate the transition and challenges they face in the workplace. According to Madeleine van Meyeren, Senior FSA, problems specifically relating to course content mostly arise as a result of the student's approach to the material. Some students do not understand the underlying theory of a specific concept and thus struggle to apply it to specific scenarios. With some guidance on the correct way to approach the academic material, most of these students see improved results. Only a few students end up requiring more extensive tutoring or consultations with lecturers.

The support provided by the Department for Education Innovation (EI) goes hand in hand with the academic support given at the Hub. The FSAs are in a unique position to identify teaching and learning problems within the Faculty and to make suggestions. This includes problems with the way lecturers engage with the module content or the way in which information is communicated via ClickUP, the University's official learning management system.

Adriana Botha, the Faculty's Education Consultant, advises the EBIT FSAs where required for ClickUP and ensures that the content, format and standards of all the seminars are in alignment with the outcomes to be achieved. Among other things, Botha is responsible for tutor training in the Faculty. She and her colleague, instructional designer Alastair Smart, are designing an e-Tutor training programme for tutors and teaching assistants to meet the growing demand for support to assist students in the online environment.

Smart also provides just-in-time ClickUP support to all the FSAs. The EI team engages with students during focus groups for high-impact modules, performs class visits and has follow-up meetings with lecturers to support them with interventions to improve teaching practice.

The significance of working as a multi-disciplinary team can be witnessed during their monthly meetings with Prof Alta van der Merwe, Deputy Dean: Teaching and Learning.

At these meetings, feedback is provided on progress made with their activities, any challenges they are experiencing are discussed and they plan their actions for the next month.

The impact and results of this working culture, which was created by Prof van der Merwe, eliminates any unnecessary duplication of work, and enables the early identification of gaps in critical high-impact practices.

The true power of innovation lies in the partnership these professionals portray, each being individually responsible for their own contribution to student success. As a team, they strive towards providing a holistic support service to students and lecturers in the Faculty.

The change to higher education can be a challenging experience for students. Some may only experience challenges later on in their studies. Regardless of the level of support required, the EBIT FSA Hub provides students with the best possible guidance in their respective situations.

Preparing software engineering students for industry

Vreda Pieterse, Fritz Solms and Stacey Omeleze

A software engineering course should not only provide students with a theoretical knowledge of software engineering practices and tools, but also equip them to apply these in the industry. Creating multiple opportunities for students to develop a range of employability skills is therefore an essential component of a software engineering course that seeks to produce industry-ready graduates.

The Department of Computer Science in the Faculty of Engineering, Built Environment and Information Technology focuses on teaching its software engineering students both the technical and workplace skills required to thrive in the software engineering industry. Its third-year software engineering module focuses on teaching students the essentials of software engineering processes and their complexities, exposes them to a variety of methodologies for tackling different stages of the software life cycle, creates awareness of the latest trends in software engineering and support tools to assist in the implementation and control of projects under development, and facilitates the execution of a team project in order to introduce students to the responsibilities associated with a variety of roles in a teamwork scenario. The motivation behind this approach is that students will benefit largely from the practical skills that they have developed when entering the workplace.

To succeed in its goal, the software engineering module partners with industry role-players to give students the opportunity to experience the intricacies of working on a real project.

During the first eight to ten weeks of the module, the students work on a class project consisting of a series of micro-projects in which different teams work collaboratively to design and implement a modular system. The students are assigned to new teams for each micro-project to create maximal opportunities for them to develop their employability skills of communication, management and planning, teamwork and collaboration, interpersonal relations and problem solving. To avoid free-riding, much effort is devoted to ensuring that the lecturers in the module understand the working patterns of each team, as well as the individual team members, throughout the semester's projects. This helps to ensure that each member of the team is prepared for the challenges that await them in the work environment.

Following the class project, the remainder of the module is dedicated to industry-based capstone projects, where students participate in self-selected teams of five members. Each team has to develop a large, authentic, open-ended software system for a client in industry. They are required to liaise with this client and present progress reports of their work at regular intervals. The main goal of this project is to deliver a high-quality, cost-effective software project to the client, while simultaneously mastering technical software engineering skills and applying cutting-edge technologies to a practical problem.

The technical skills that students enrolled for the software engineering module need to master through their projects include the following:

Configuration management and issue tracking

Students are required to manage documents and code that are collectively owned by the members of the team through configuration management tools that track code changes, and to facilitate a team of people to work concurrently on the same artefacts, resolving conflicts as needed. These tools support base-lining, rolling back to previous versions and branching. Branching enables developers to develop new features and fix bugs in a separate branch that is merged back into the main trunk only after having passed both unit and integration testing.

Buisman and Van Eekelen (2014) observe that students are reluctant to perform atomic commits with short clear commit messages and to create branches rather than pushing to master. This degrades the quality of the work and diminishes the depth of the learning that takes place. For this reason, the lecturers of the software engineering module evaluate how the students use their configuration management tools on a regular basis. When forced to comply with the criteria for the proper use of these tools, students get acquainted with them and gradually grow into appreciating their value.

Unit and integration testing

The module emphasises the need for formal software testing throughout the development process. Through unit testing, the students learn that, although the different modules developed by the different teams are dependent upon one another, each sub-system can be tested in isolation. Thereafter, integration testing ensures that each component works within its actual deployment environment.

Component-based design and decoupling

The module requires technology-neutral component-based modelling, facilitating the mapping of component contract specifications into interfaces and unit tests, as well as data structure specifications into entities and activity diagrams into method bodies. This introduces students to component-based development based on interface control diagrams, but does not require component contract specifications and full decoupling via dependency injection. In contracts-based developing, one codes against contracts for the dependencies and not against the concrete components. Contracts include the specification of the required functionality with the pre- and post-conditions for each method, service or function. Dependency injection is an implementation of the Inversion of Control (IoC)

Through participation in the industry-based project, students acquire valuable technical, as well as employability skills.

pattern, which is widely used in industry to achieve loose coupling by having concrete components for required dependencies injected into the dependent component. This facilitates unit testing against mock objects, integration testing against actual components, as well as deployment into different environments where different concrete components may be available to provide the required functionality. Modern reference architectures and frameworks like Java-EE, Spring, Django, node-js and Microsoft.Net all provide IoC containers to implement this software engineering technique.

Build tools and integration

Modern software systems are commonly complex, and require sourcing dependencies, configuration, compiling, testing, linking and packaging, distribution and the deployment of a variety of components, which may themselves be developed in different technologies. It is standard practice in industry to use platform-independent build tools that automate this process. There are many examples of these tools. The integration of such modules into a cohesive system is often subject to a range of unforeseen complexities and challenges, and students must learn to deal with these.

Because the capstone projects are sourced from industry partners, their authenticity increases. This typically increases the student's motivation. It also enables the Department to monitor changing trends and technologies in the industry, as well as assess any gaps between the skills developed through the software engineering course and those required by industry.

Industry projects are vetted for appropriate scope and complexity, as well as the potential to capture the interest of the students before they are presented to the industry client. The teams are then required to submit tenders for the three projects in which they are most interested. Industry clients express their preference for the teams based on the strength of their tenders, after which partnerships are established. The teaching team assigns projects to teams giving first preference to the choice of client and second preference to the choice of team, thereby rewarding teams that formulated strong tenders. Through this process, industry clients become educational partners in the training of the students and receive the opportunity to work with potential future employees.

The course culminates in an end-of-year project exhibition, through which the students have to contend with the prospect that their efforts will be laid bare for public exposure, as would be the case in a real-world scenario. The exhibits are judged by staff members, as well as industry representatives, who contribute towards prizes in various categories. These can include innovation, software engineering excellence, algorithmic innovation, architectural awareness, user experience and environmental impact.

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Producing well-rounded graduates one project at a time

The ability of students in the Faculty of Engineering, Built Environment and Information Technology 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.

The aim of this eight-credit module is the implementation of a community service project to make a positive impact on a chosen section of society. The ideal scenario is where students engage with a section of society that is different from the students' own social background. This module also aims to develop an awareness of personal social and cultural values, as well as multidisciplinary and life skills, such as communication, interpersonal and leadership skills. The module requires the students to dedicate 40 hours of their time to a project that they plan and execute, after which they make a YouTube video of the project.

Keep that Gold Shining

A recent project was the collaboration between Keep That Gold Shining, a student society that supports school learners, and JCP students. The project involved tutoring learners in Mathematics during the July 2017 school holidays. The students offered lessons structured as a Mathematics competition. The learners write a pre- and post-test and are tutored between the tests. The schools that received tutoring include Grade 10 and Grade 11 learners from Soshanguve (eMakhosini Combined Secondary School, Botse-Botse Secondary School and Soshanguve Secondary School), Bela Bela (Raeleng Secondary School, Moape Secondary School and Bela Bela Secondary School). A community-based project in Bela Bela, #100KidsToVarsity, helped Keep That Gold Shining to facilitate the mathematics competition in some of these schools.

Some 37 JCP students and 10 volunteers tutored 239 learners in Soshanguve. In Polokwane, one JCP student and five volunteers facilitated the mathematics competition for 39 Grade 12 leaners of Sehlaku Technical High School. At eMakhosini Secondary School, eight JCP students helped approximately 13 Grade 12 learners who required assistance.

The project concluded with an award ceremony for the top achievers. The awards, catering and transport for the event were sponsored by JuniorTukkie, EBIT Faculty House, Investec and Metal Bad.

Collaboration with University Illinois Urbana-Champaign

During the July recess in 2016, six engineering students from the University of Illinois Urbana-Champaign collaborated with JCP students on projects in Pretoria. They spent the first week at Bester Birds and Animal Zoo Park and the Susan Strydom Retirement Home. During the second week, they assisted with a brick-making course at Stanza Bopape Community Centre in Mamelodi. They also renovated various parts of His Grace and Mercy Day Care in Sunnyside and assisted with the vegetable garden at Bekekayo Farm School.

The July recess in 2017 also saw three engineering students from the University of Illinois Urbana-Champaign working with some of the JCP students. During the first week, students built various platforms for visitors to sit on in the dog enclosures at Wollies Animal Shelter in Pretoria North and upgraded the area where visitors can walk the dogs. One of the students assisted with the Faculty's career guidance project.

During the following week, three students worked with a group of JCP students at Lory Park Animal Zoo Park in Midrand. The students created a herb garden in the zoo and helped with other maintenance projects.

Opkyk Pathways

Another project took place in August 2017 at Opkyk Pathways near Hartbeespoortdam, where one of the learners suffers from drop attacks and cannot walk. This means that he could faint at any given moment. He has the ability to crawl. However, this type of movement exposes his face and causes severe injuries to his facial area when he suffers a drop attack. He can also use a kicking bike, but his plastic kicking bike, which was actually designed for younger children, was not durable enough to support his weight. The JCP students, Danielle Coetzee (chemical engineering), Cherise Horn (metallurgical engineering), Franco Janse van Rensburg (mechanical engineering), and Handri Steenkamp (metallurgical engineering) decided to design and build a tricycle for him.

The students reflected afterwards on how one small thing could make a difference in someone's life and how enriching and fulfilling this experience was. The JCP students always learn and benefit from teaching community members basic skills.

One of the students said, "JCP was a great learning experience for us. The key skills we learnt from doing the project were time management, teaching, teamwork, working with people, problem-solving, critical thinking and communication. The community project gave us an opportunity to apply our academic knowledge and teach it to other people. We now believe that doing community work is of utmost importance to a young demographic, as it increases a sense of responsibility and Ubuntu."

→ *Dr Martina Jordaan.*

→ *Manchala Sithole.*

→ *Altus Bisschoff.*

JCP in Mexico

Dr Martina Jordaan and two JCP alumni attended the Talloires Network Leadership Conference (TNLC) at the Universidad Veracruzana in Mexico from 21 to 23 June 2017. The TNLC called for institutions to nominate two students who show exceptional leadership qualities to attend. Altus Bisschoff managed three JCP projects in 2016 and Manchala Sithole mentored 55 students in 2015, as well as 70 students in 2017. Their attendance resulted in international exposure for the JCP module, the Faculty and the University. The Talloires Network is an international association of institutions committed to strengthening the civic roles and social responsibilities of higher education.

The theme of this year's conference was "Social responsibility and human dignity in higher education engagement". During the TNLC, Dr Jordaan reflected on what the JCP module had accomplished as a result of its University Education for Transformative Leadership in Africa (UETLA) Faculty Support Grant. The module used the grant to launch several projects at the Stanza Bopape Community Centre in Mamelodi.

Involving students in community service gives them the opportunity to learn social responsibility as critical citizens and encourages them to use their knowledge and skills to improve the communities they serve.

Engineers Without Borders

→ *Paul Ssali at the Gradstar Awards Ceremony.*

The UP Chapter of Engineers Without Borders (EWB-UP) won the first Empowering Communities through Engineering Excellence Award, presented by EWB-SA in 2015, for its projects at Kutumela Molefi Farm School. EWB-UP is headed by Paul Ssali, a JCP alumnus and mechanical engineering student in the Faculty, who serves as chairperson and project coordinator and was ranked among the top ten students in South Africa during the Gradstar Awards Ceremony. The Gradstar competition recognises students who show potential as South Africa's future leaders. One of the special projects that Paul initiated was the Litre of Light project. This is the design of a lamp made through the use of recycled two-litre bottles and zinc to create a solar bulb for shacks in an informal settlement in Mamelodi.

The JCP module is an essential part of the curriculum of all undergraduate programmes in the Faculty, as it accommodates the need for community service and service-learning projects in a higher education environment.

Honouring exceptional achievement

The UP Academic Achiever Awards has become an annual gala event to pay tribute to academic staff members who have excelled in their contribution to the University's mission. This year's awards have a special significance as 2016 was a particularly challenging year for South African universities. Student protests across the higher education sector meant that academics had to show exceptional resilience and innovation to ensure that students could complete their academic year, while continuity in research and community service was maintained. A number of researchers in the Faculty of Engineering, Built Environment and Information Technology were recognised at the annual Academic Achiever Awards on 10 May 2017.

Exceptional Academic Achiever Award

The Exceptional Academic Achiever Award is made annually to senior academics who have already achieved the status of professor, are regarded highly by their peers and have consistently excelled in the areas of undergraduate and postgraduate teaching and learning, research, community service and administration over a period of time. Any academic who has been awarded an A-rating by the National Research Foundation (NRF) in the year under consideration automatically qualifies as an Exceptional Academic Achiever for as long as he or she remains an A-rated researcher.

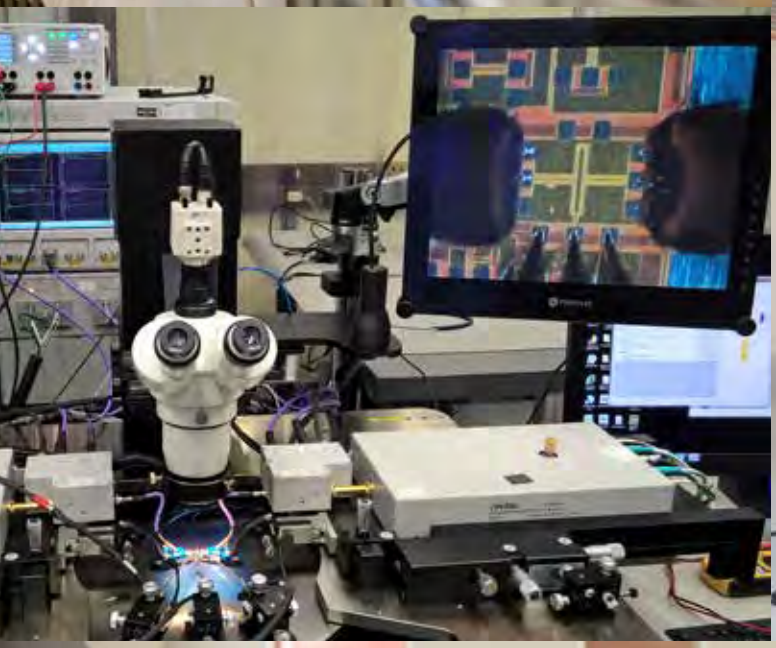
Prof Ian Craig is a professor and Section Head: Control Systems in the Department of Electrical, Electronic and Computer Engineering, a position that he has held since 1995. His research interests include the modelling and control of process systems, with a particular focus on mineral and metal processing and utilities in the petrochemical industry, the economic performance assessment of process control and automation, and the modelling and control of disease networks.

Prof Josua Meyer is a professor, Head of the Department of Mechanical and Aeronautical Engineering and Chairperson of the School of Engineering. He established and leads the Clean Energy Research Unit, which has a broad focus on thermal sciences and fluid flow, and a narrower focus on heat exchangers. His heat exchanger research focuses on the fundamental work of flow in the transitional flow regime, nanofluids and condensation.

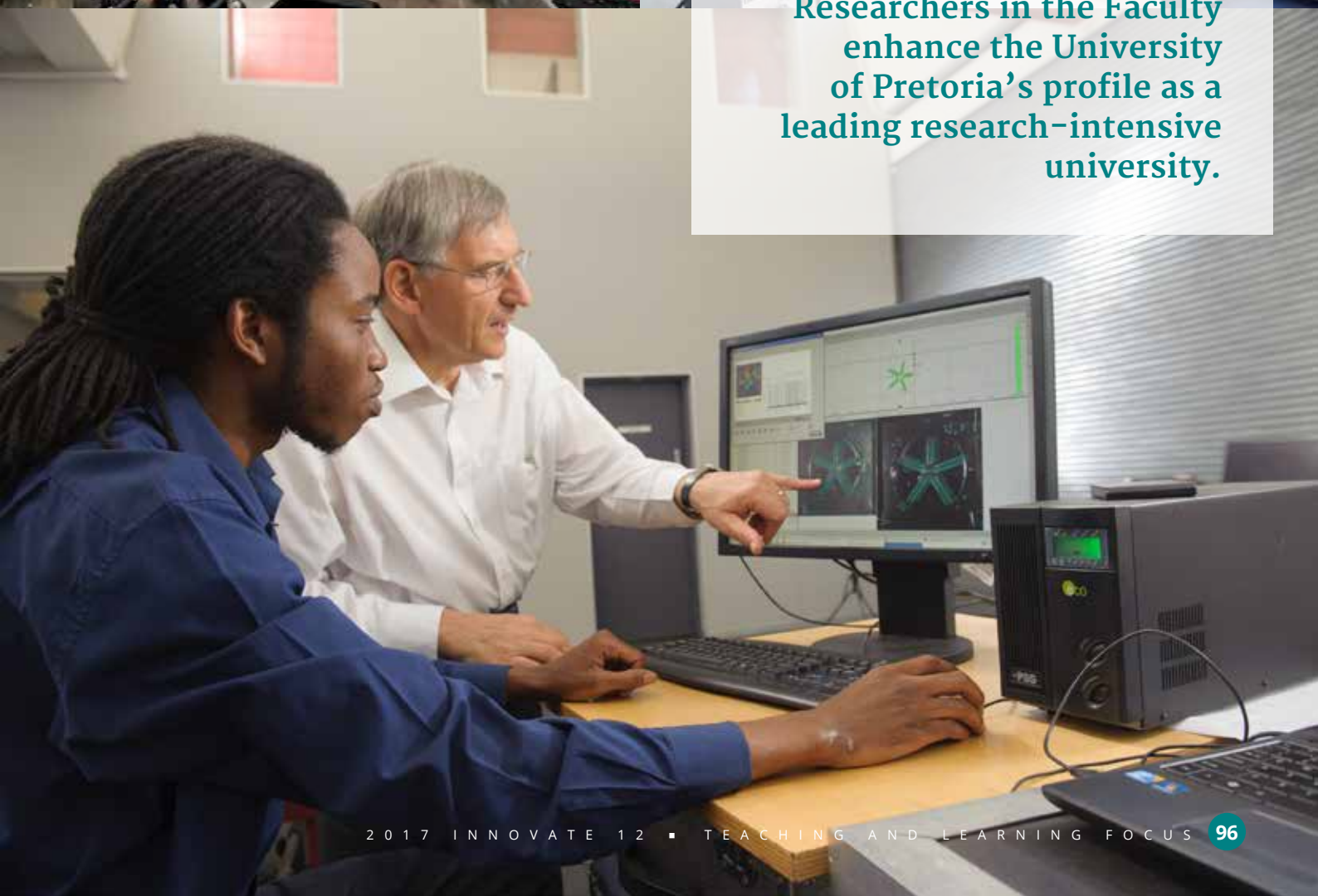
Exceptional Young Achiever Award

The Exceptional Young Achiever Award is given to exceptional young achievers in the field of research, as seen against the University's strategic goals of achieving academic excellence, international competitiveness and local relevance. Any person who has been evaluated by the NRF as a P-rated researcher automatically enjoys Exceptional Young Researcher status.

Prof Reza Malekian is an associate professor in the Department of Electrical, Electronic and Computer Engineering. Having 12 years' experience in teaching and research in both the university and industry sectors, he has maintained an active research programme and provided supervision and mentorship to several master's and doctoral students, as well as postdoctoral fellows, under industry and government funding. Prof Malekian's research focuses on the Internet of Things, sensors and smart cities.



Researchers in the Faculty enhance the University of Pretoria's profile as a leading research-intensive university.



NRF-rated researchers

B-rating

A B-rating is awarded to a researcher who enjoys considerable international recognition by his or her peers for the high quality and impact of his or her recent research outputs.

Prof Attahiru Alfa is the incumbent of the South African Research Chairs Initiative (SARChI) Chair in Advanced Sensor Networks in the Department of Electrical, Electronic and Computer Engineering. His main area of research is the mathematical modelling of communication systems, with specific emphasis on wireless sensor networks, cognitive radio networks and the Internet of Things. He received a B2-rating from the NRF.

Prof Stephan Heyns is a professor and Director of the Centre for Asset Integrity Management (C-AIM) in the Department of Mechanical and Aeronautical Engineering. C-AIM focuses on the structural integrity of critical physical assets. Prof Heyns's personal research focuses on machine and structural health monitoring using vibration measurement and analysis, and the use of machine learning and statistical analysis techniques. He received a B3-rating from the NRF.

C-rating

A C-rating is awarded to a researcher with a sustained recent record of productivity in the field, and who is recognised by his or her peers as having produced a body of quality work, the core of which has coherence and attests to ongoing engagement with the field, and has demonstrated the ability to conceptualise problems and apply research methods to investigating them.

Dr Ida Breed is a senior lecturer in the Department of Architecture. Her research is concerned with open space design and how it relates to natural and cultural contextual issues and identity. Her research demonstrates the importance of landscape design as part of green infrastructure, urban ecology and social-ecological resilience. Dr Breed is one of only two landscape architects in South Africa with an NRF-rating and has a C3-rating.

Prof Carina de Villiers is a professor and Head of the Department of Informatics. Her main research area is the teaching of information systems, particularly the use of different theories in pure information systems research that can be applied in research on the teaching of information systems. Her second area of research is information and communication technology (ICT) for development. She has been an NRF-rated researcher since 2000, and has received her third C2 re-rating.

Prof Johan W Joubert is an associate professor heading the Optimisation Group in the Department of Industrial and Systems Engineering. He is also affiliated with the Centre for Transport Development. His research focuses on the development of models that support government and industry decision-making under uncertainty, especially related to inequality of access and spending on transport infrastructure. He received a C2-rating from the NRF.

Prof Andrie Garbers-Craig is a professor in the Department of Materials Science and Metallurgical Engineering. She holds the Anglo American Chair in Pyrometallurgy. Her research covers the fields of pyrometallurgy, refractory materials and iron ore agglomeration, where she focuses on industry-related questions and process developments. She received a C1-rating from the NRF.

Prof Jan Malherbe received a C3-rating from the NRF. Since his retirement in 2005 as Emeritus Vice-Principal of the University of Pretoria, Prof Malherbe has been a professor in the Department of Electrical, Electronic and Computer Engineering.

Prof Mohsen Sharifpur is an associate professor in the Department of Mechanical and Aeronautical Engineering. His research area includes thermal fluid behaviour and the stability of nanofluids, the improvement of heat transfer by nanofluids, convective multiphase flow and computational fluid dynamics. He received a C2-rating from the NRF.

Prof Waldo Stumpf is a professor of physical metallurgy in the Department of Materials Science and Metallurgical Engineering. He has spent the 16 years since his appointment pursuing his passion for postgraduate teaching and research on microstructural development and phase changes in hot working and heat treatments of carbon steels, low-alloy steels and stainless steels, and how these relate to their physical and mechanical properties. Prof Stumpf holds a C2-rating from the NRF.

Prof Joe Amadi-Echendu is a professor of Engineering and Technology Management. His teaching and research activities focus on engineering asset management and the commercialisation of technology. His involvement in community development, as well as his professional and scholarly activities, has been recognised through various local, national and international awards for best paper, distinguished service, excellence and leadership. He received a C2-rating from the NRF.

Prof Evans Chirwa is a professor in the Department of Chemical Engineering. Since 2014, he has been the holder of the Sedibeng Water Chair in Water Utilisation Engineering. His most recent work on the characterisation of biosurfactants produced by polycyclic aromatic hydrocarbons (PAH)-degrading bacteria produced 12 articles in high-impact journals in 2016. He received a C2 rating from the NRF.

Y-rating

Young researchers (normally younger than 35 years of age) who have held the doctorate or equivalent qualification for less than five years at the time of application, and who are recognised as having the potential to establish themselves as researchers within a five-year period after evaluation, based on their performance and productivity as researchers during their doctoral studies and/or early postdoctoral careers, are awarded a Y-rating.

Dr Heinrich Badenhorst is a senior lecturer in the Department of Chemical Engineering. His work focuses on developing novel materials for energy applications. This includes the development of high thermal conductivity graphite nanoplatelets and aerogels. These materials allow rapid energy storage and retrieval from phase change materials that hold promise for continuous energy supply from solar resources. He received a Y2-rating from the NRF.

Dr Jacomine Grobler is a senior lecturer in the Department of Industrial and Systems Engineering. Her main fields of expertise are multi-method optimisation algorithms, multi-objective and supply chain optimisation, swarm intelligence and scheduling. She received a Y2-rating from the NRF.

Dr Willem le Roux is a senior lecturer in the Department of Mechanical and Aeronautical Engineering. His research focuses on solar energy conversion where the subjects of thermodynamics and thermal engineering are mostly applied. He received a Y2-rating from the NRF.

Lecturer recognised for excellence in teaching and learning

Prof Tania Hanekom is a professor in the Department of Electrical, Electronic and Computer Engineering. She received the Chancellor's Award for Teaching and Learning at the University of Pretoria's Academic Achiever Awards on 10 May 2017.

Her journey in teaching and learning started when she was appointed at UP in 1999. In 2005, she was put in charge of the third-year Microcontrollers module.

With the explosive growth in embedded technology over the past decades, she recognised the need to equip students with more than just a theoretical knowledge of microcontroller systems.

She developed a teaching and learning strategy that cultivates a hands-on practical knowledge of microcontroller systems, supported by a firm theoretical foundation. Innovations include, among others, the development of a unique programmatic electronic grading system to support the teaching and learning of assembly language, a computerised tutoring system based on this e-grading system, the introduction, development and presentation of the annual Robot Car Race Day, which is both an academic extension of the microcontrollers teaching and learning strategy and a widely published marketing event that promotes engineering as a career option. The event is strongly supported by local and international industry partners.

Her efforts in teaching and learning culminated in several awards in 2015,

Participants at this year's Robot Car Race Day preparing to demonstrate what their cars can do.

such as a Laureate Award as part of the UP Excellence and Innovation in Teaching Awards, the EBIT Faculty Teaching Award and the Council on Higher Education (CHE)/ Higher Education Learning and Teaching Association of South Africa (HELTASA) National Teaching Award. She was appointed as the function head for undergraduate studies in the Department in February 2015.

She is a member of the Faculty's Teaching and Learning Committee and served on the UP2025 task team for teaching and learning.
Prof Hanekom is also an internationally recognised researcher in biomedical engineering, specifically the computational physiology of peripheral auditory neural excitation in cochlear implants. Her work focuses on the translation of computational models of cochlear implants to clinical tools, such as model-based diagnostics to address complications such as facial nerve stimulation, and high-resolution, model-based visualisation of the cochleae of specific users based on low-resolution clinical computed tomography images.

She has supervised and co-supervised numerous postgraduate students on master's and doctoral degree level. She is the author or co-author of more than 25 international journal and conference publications in biomedical engineering.

She is registered as a professional engineer with the Engineering Council of South Africa (ECSA) and holds a C2-rating from the National Research Foundation (NRF). She is also a member of the Institute of Electrical en Electronic Engineers (IEEE), a senior member of the South African Institute of Electrical Engineers (SAIEE) and a member of the South African Cochlear Implant Group (SACIG).

Enhancing research excellence, innovation and resilience

With the appointment of Prof Alta van der Merwe as Deputy Dean: Teaching and Learning in the Faculty of Engineering, Built Environment and Information Technology on 1 August 2016, the Faculty embarked on a journey to enhance research excellence, innovation and resilience with the objective of enabling the Faculty to be ranked among the world leaders in higher education. In this position, she will endeavour to enhance access and successful student learning in the Faculty.

Deputy Dean: Teaching and Learning, Prof Alta van der Merwe.

Prof Van der Merwe is the former head of the Department of Informatics in the School of Information Technology at the University of Pretoria. She had previously held leadership positions as professor at the University of South Africa (Unisa) and was a principal researcher at the Meraka Institute of the Council for Scientific and Industrial Research (CSIR).

She obtained a bachelor's degree in Computer Science at the University of Johannesburg and completed her honours and master's degrees in Computer Science at North-West University. She obtained her PhD in Computer Science at Unisa. She has been involved in teaching and research for the past 29 years, including the design of an Enterprise Architecture (EA) course for honours students at Unisa.
She is co-chair of the Institute of Electrical and Electronics Engineers (IEEE) Enterprise Architecture Technical Committee and is acting in her second term as president of the South African Institute of Computer Scientists and Information Technologists (SAICSIT).

She holds a C3-rating from the National Research Foundation (NRF), and has supervised a number of master's and doctoral degree students. She has published articles in peer-reviewed journals, conferences and several book chapters.

Elevating research and innovation to a new level in the Faculty

The new strategic plan of the Faculty of Engineering, Built Environment and Information Technology included the development of the position of Deputy Dean: Research and Postgraduate Studies. Prof Jan Eloff was appointed to this position on 1 August 2016, and has since developed a progressive research strategy for the Faculty.

Deputy Dean: Research and Postgraduate Studies, Prof Jan Eloff.

Prof Eloff is a professor of Computer Science (Cyber-security) in the School of Information Science at the University. His main career focus is on leading research and innovation projects in cyber-security.

His expertise focuses on cyber-security, innovation leadership and management, research leadership and management in industry, the academic environment and education.

He enjoys working in a multidisciplinary environment, supported by cross-cutting application domains. Most of the projects in which he engages are focused on the improvement of economic and social conditions in the developing world and, in particular, South Africa.

Under his research and leadership, a number of innovative software prototypes have been developed for industry. He is the co-inventor of a number of patents registered in the USA, and holds a B-rating from the National Research Foundation (NRF).

Prior to his appointment to this position, he had held leadership positions as Research Director for SAP Research in Africa (until June 2015), Chairperson of the School for Information Technology and Head of the Department of Computer Science at the University of Pretoria (from 2002 to 2009). He was also a member of the Steering Committee of the IT CoachLab at The Innovation Hub.

He obtained a BSc in Computer Science and Mathematics, and completed his honours, master's and doctoral degrees in Computer Science at the Rand Afrikaans University (now the University of Johannesburg).

His main focus is on research, innovation and productisation. He is associate editor of *Computers & Security* and serves on the editorial panel for the *Computer Fraud & Security Bulletin*.

He has supervised a number of master's and doctoral degree students.

He has published extensively, producing both book chapters and articles in peer-reviewed journals, nationally and internationally.

Celebrating 10 years of information ethics in Africa

Rachel Fischer

Many academics, especially in library and information sciences, have been involved in information ethics since the 1990s. Their dedication to the field culminated in the first local African Network of Information Ethics (ANIE) Conference, which took place in Pretoria in 2007.

The 5th ANIE International Conference on Information Ethics took place in Pretoria, South Africa from 21 to 23 February 2017. This event hosted 45 participants from Australia, Canada, Germany, Ghana, Kenya, Malawi, Nigeria, South Africa, Sudan, Tanzania, The Netherlands, Uganda, the USA and Zimbabwe, and coincided with the tenth anniversary of formal structures and research projects in the field of information ethics in Africa. The event was also known as the ANIEversary.

Establishment of ANIE

Since 2007, the Department Information Science has been actively involved in the creation and growth of the ANIE through a partnership established with the South African Department of Telecommunications and Postal Services. This was achieved in 2012 when the African Centre of Excellence for Information Ethics (ACEIE) was established in the Department.

ANIE's partnership with government has resulted in a renewed commitment to cyber-safety, cyber-security and digital literacy from all role-players in the context of information ethics.

In terms of a Memorandum of Agreement signed in 2012, its objectives were to conduct research on information ethics, design a tertiary curriculum on information ethics to be implemented at universities across Africa, and present workshops across South Africa and Africa targeted at government officials, academics and community members.

Since then, 24 African countries have joined the network, which now comprises over 700 participants at more than 130 institutions. A second Memorandum of Agreement was signed in 2015, which builds on the achievements of the ACEIE through ongoing research on digital wellness, cultural diversity and the Fourth Industrial Revolution.

The ACEIE ensures regular communication with network members from all over the globe. Subsequently, the ACEIE has organised ANIE conferences in Botswana (2010), South Africa (2012) and Uganda (2014), as well as workshops across the Southern and Eastern African regions. The initial target of 12 African countries and institutions was met.

Due to the success of the ACEIE and the ANIE, further collaboration has taken place with Intel Education, the South African Department of Basic Education, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and its Information for All Programme, as

24 African countries have joined the network ACEIE, which now comprises over 700 participants at more than 130 institutions.

well as representative offices of the Brazil, Russia, India, China and South Africa (BRICS) collaboration.

In addition to the 5th ANIE International Conference on Information Ethics, highlights for 2017 included the National Cultural Diversity Conference in Mthatha and the eLearning Africa Conference, during which International Day on Universal Access to Information (IDUAI) was celebrated. Both these events were held in September.

ANIEversary

The ANIEversary expresses the South African government's commitment to cyber-safety, cyber-security and digital literacy. The Minister of Telecommunications and Postal Services, Dr Siyabonga Cyprian Cwele, and former Deputy Minister of Telecommunications and Postal Services, Prof Hlengiwe Buhle Mkhize, who addressed the delegates during the international conference and gala dinner, attested to this commitment, and showed their support for the projects of both the ACEIE and ANIE.

The ANIEversary also illuminated the global and African endeavours towards emphasising the importance of research relating to the knowledge society and information ethics. Platforms were created where the academic community highlighted research. During the gala dinner, Jared Bielby and Matthew Kelly launched *Information cultures in the Digital Age: a Festschrift* in honour of Rafael Capurro. They were the editors of this publication.

This seminal work brings together original research from both the pioneers and the younger generation of information ethics academics in a joint effort to express and promote Rafael Capurro's contributions to information research.

The Festschrift addressed the crossroads of information and communication technologies, intercultural dialogue and philosophy, bringing to light new directions in information culture that inspire a wider consideration of issues than those first introduced by Capurro in the 1970s.

The ACEIE is also the only African representative working on *Ethically aligned design: a vision for prioritising human wellbeing with artificial intelligence and autonomous systems*, which is published by the Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems of the Institute of Electrical and Electronics Engineers (IEEE). This project brings together technologists, ethicists, philosophers and computer scientists who seek to prioritise ethical considerations in light of artificial intelligence and autonomous systems.

The ACEIE and ANIE will continue to conduct research and collaborate on projects relating to information ethics and digital wellness.

The ANIE will retain its core objectives of research, developing partnerships and raising awareness in facilitating the World Summit on the Information Society (WSIS) Action Line C10, which deals with the ethical dimension of information societies.

A new era for the Department of Architecture

The Boukunde Building has been home to the Department of Architecture at the University of Pretoria since 1951. In July 2017, the building was evacuated for renovations for the first time since the major renovations of 1973. Thomashoff + Partner Architects are behind the design of the renovations.

Some of the items under construction include the addition of a lift in order to make the building accessible to disabled persons, gender-neutral bathrooms, a new air-conditioning system, as well smoke detection and ventilation systems.

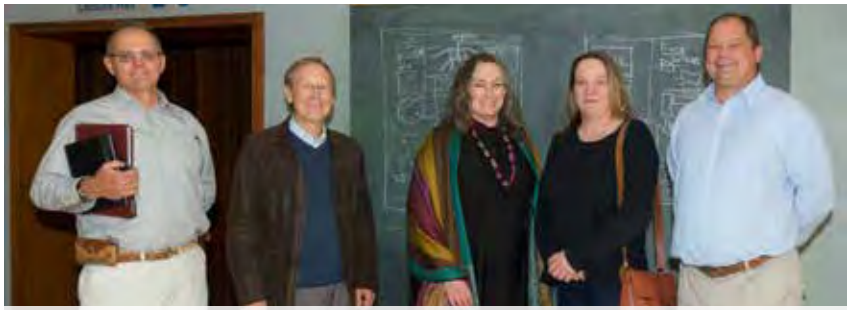
The aim is to use the planned upgrade of the Boukunde Building to establish a living laboratory and pedagogical space that will inspire research-led design and enable international collaboration within the research theme of Smart Cities and Transportation. The building provides an excellent case study of a green retrofit of academic buildings that also provides opportunity for ongoing research on occupant wellbeing, including indoor air quality, lighting and acoustics. Because the building includes both naturally ventilated spaces and a range of mechanically ventilated and conditioned spaces that mimic open-plan office environments, it provides an excellent test bed for interventions that do not require transformation of the building envelope. The renovations are scheduled for completion by mid-2018.

Anniversary celebrations

The completion of the new building will coincide with the Department's 75th anniversary. To kickstart the preparations for its birthday celebrations, the Department hosted a fundraising event and alumni open day in the newly evacuated building on 22 July 2017. The vertical studio programme for 2017 was integrated into the celebratory event, with students across various years and programmes collaborating to contribute to the exhibition.

Guests were treated to a typical day of architectural play, including a timeline of the Department of Architecture's past, present and future, a digital exhibition entitled "Graphic residues", a story collection of the Department's interesting past, present and future characters, the story of the "new" Boukunde Building, the traditional Kitsch Cake competition and other wonderful installations by current students.

The Department strives to build a great future, but it does so in acknowledgement of its proud past. After the Transvaal University College became the University of Pretoria in 1930, a course in Architecture was instituted in 1931, taught in collaboration with the University of the Witwatersrand. The Department of Architecture at the University of Pretoria became an independent institution in 1943 when a young (at the time), dynamic staff complement was appointed.



The project team responsible for building a better Boukunde: Wim Joubert, Radon Projects (contractor), Prof Schalk Claassen, Project Manager, Prof Chrisna du Plessis, Head of the Department of Architecture, Karlien Thomashoff (architect) and Ferdie van der Merwe, GROZ Consulting (quantity surveyor).

Creating a learning space that inspires discovery through design.

Lecturer elected as SANIRE president

Jannie Maritz, a senior lecturer in the Department of Mining Engineering, was elected as the president of the South African Institute of Rock Engineering (SANIRE) for the term 1 July 2017 to 31 June 2019. He had served as vice-president from 2015 to 2017.

Jannie Maritz, president of the South African Institute of Rock Engineering.

After graduating from the Department of Mining Engineering at the University of Pretoria, Maritz joined a major gold-producing company where he obtained all his industry certificates in mining and rock engineering before joining a consulting firm where he acted as a mining engineering consultant on various national and international projects. He then established his own rock engineering consulting firm, which he still owns. He subsequently joined the University as a senior lecturer in rock engineering and mine design. He is particularly interested in numerical modelling and pillar design as a technical expert. However, through his involvement at the University, he also developed an interest in the career development of individuals.

On the SANIRE Council, he is actively involved in the Future Education portfolio and was an examiner for the Chamber of Mines Certificate in Rock Engineering: Paper 1. As the Chamber certificates are being phased out, he serves as part of the community of expert practitioners, which was tasked to develop a new replacement qualification for the current Rock Engineering competency certificates, which is being developed under the Mine Health and Safety Act, Act No. 29 of 1996, a legal requirement for practicing rock mechanics and strata control on mines. This new qualification will be a full Quality Council for Trades and Occupations (QCTO) Level 6 National Qualifications Framework (NQF) qualification and will align the South African rock engineering training to the international market. It will be rolled out in the near future.

Under Maritz's presidency, SANIRE will largely focus on membership growth and development. The focus will be on an individual level, as well as the number of members associated with the body. This means that SANIRE will build confidence in the next generation through coaching and mentoring, while learning from past mistakes. SANIRE also aims to build on its good relationships with current role players.

At its recent strategy meeting for the incoming council under Maritz's tenure, the SANIRE Council identified the need for transformation. It will put strategies in place to address this issue with the much-needed attention it deserves.

In short, Maritz's leadership will drive SANIRE's vision to actively promote the South African rock engineering profession in all mining and geotechnical areas.

Two new textbooks from the pen of Prof Ramesh Bansal

Prof Ramesh Bansal, Head of the Power and Energy Systems Research Group at the Department of Electrical, Electronic and Computer Engineering, has published two new books.

Prof RameshBansal with his new titles.

Thermal power plants: modelling, control and efficiency improvement explains how to solve highly complex industry problems regarding identification, control and optimisation through the integration of conventional technologies, such as modern control technology, computational intelligence-based multi-objective identification and optimisation, distributed computing, and cloud computing with computational fluid dynamics (CFD) technology. The book introduces innovative methods that are utilised in industrial applications, explored in scientific research, and taught at leading academic universities. It also discusses thermal power plant processes and process modelling, energy conservation, performance audits, efficiency improvement modelling, and efficiency optimisation, supported by high-performance computing, integrated with cloud computing. Readers can read more about stimulating power plant fossil fuel processes in real time, including boiler, turbine, and generator systems. The book provides downloadable source codes for use in CORBA C++, MATLAB®, Simulink®, VisSim, Comsol, ANSYS and ANSYS Fluent modelling software.

Handbook of distributed generation, of which Prof Bansal is the editor, features extensive coverage of all distributed energy-generation technologies, highlighting the technical, environmental and economic aspects of distributed resource integration, such as line-loss reduction, protection, control, storage, power electronics, reliability improvement and voltage profile optimisation.

Prof Bansal's research interests include reactive power control analysis, artificial intelligence techniques in power systems, the analysis and control of induction generators and renewable energy systems.

Collaboration with the Clay Brick Association of South Africa

Over the last few years, the Clay Brick Association (CBA) of South Africa and Swisscontact have commissioned a detailed analysis of the environmental impacts of clay brick production and utilisation in South Africa. The National Research Foundation (NRF) and the Department of Architecture conducted the analysis.

The study was performed under Prof Piet Vosloo's leadership using specific production data from 86 of the 102 clay brick production sites in South Africa that are members of the CBA.

The analysis was conducted in accordance with the ISO 14040 and ISO 14044 standards with an external review to achieve the highest quality standards. A second parallel study compared the thermal performance of the six most-often-used wall construction methods over three building typologies and over the six South African climatic regions. In accordance with the ISO 14040 and ISO 14044 standards, the University summarised the results in two extensive reports. These reports were tailored for environmental experts and describe the detailed methodology, data base and all the assumptions used in the study. In order to facilitate the dissemination

Prof Piet Vosloo presenting the reports to Nico Mienie, CBA CEO and Musa Shangase, Chairman of the CBA Board.

of the findings of the reports among members of the CBA and stakeholders without expertise in environmental assessment, Swisscontact contracted Quantis to extract, in collaboration with UP, the most relevant results from the main report and consolidate these in a separate document.

The project resulted in two papers presented at international conferences, the conferring of an honours and MSc degree on a research assistant, as well as three research reports.

Brickmaking entrepreneur

Elijah Djan is a third-year BEng (Industrial Engineering) student who believes that entrepreneurship is the answer to innovating our tomorrow. He feels compelled to make a positive change wherever he travels.

Elijah Djan presenting one of his bricks.

Elijah's curiosity drives him to dream big and to develop his ideas. He was keen on inventions from an early age and already made bricks from waste paper In Grade 5. He called these Nubrix. Subsequently, he has done much research around this invention and has subjected his bricks to rain and compression tests. He also built a Nubrix wall, which has been standing for a year now. Elijah wants to contribute to the innovation of sustainable and affordable housing, which is much needed in Africa. He presented his invention during the Global Entrepreneurship Congress in Sandton, the World Economic Forum in Africa, which was held in Durban and at USAID's TechCon Innovation Marketplace Competition, where he represented Africa in America through the Resilient African Network.

Female students excel in science, engineering and technology

Two of the Faculty's female students have been recognised for their contribution to science, engineering and technology. Marilize Everts is a PhD student in the Department of Mechanical and Aeronautical Engineering, who was recently honoured at the Women in Science Awards for the second time in three years. Shruti Lall is a master's student in Electronic Engineering, who received the Bronze Medal of the Southern Africa Association for the Advancement of Science (S^2A^3). The S^2A^3 Bronze Medal is awarded annually to the most outstanding master's degree research student in a scientific subject graduating at each South African university (since 1981) and university of technology (since 2001).

Marilize Everts with her award.

Marilize Everts also received the TATA Africa Scholarship for Women in Science, Engineering and Technology in recognition of her outstanding academic and research performance. She also received this award in 2015.

At the Woman in Science Awards ceremony, Minister of Science and Technology, Ms Naledi Pandor, addressed the attendees, saying: "The Women in Science Awards is a celebration of the achievements of women in science, and it is a reminder that the full scientific potential of our country will only be realised when all our young women are able to enjoy access to the best facilities and education."

Marilize's research focuses on the single-phase mixed convection of developing flow in the laminar, transitional, low-Reynolds-number end and turbulent flow regimes. This work is fundamental to addressing the gap between laminar and turbulent flow, as well as to understanding the fundamentals of mixed convection. The research will enable engineers to optimise heat transfer equipment used in the generation of energy, which is a major crisis in South Africa.

Shruti Lall (centre) with Prof Sunil Maharaj (left), Dean of the Faculty of Engineering, Built Environment and Information Technology, and Prof Stephanie Burton, Vice-Principal: Research and Postgraduate Education.

Shruti Lall received the award from Prof Walter Meyer, a representative of S^2A^3.. He noted that this prize-giving was made even more auspicious by the fact that Shruti's mother, Prof Namrita Lall, had received the same award. Shruti completed her master's degree in Electronic Engineering, specialising in wireless network security, supervised by Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology.

In her research, Shruti investigated the optimal placement and power allocation of protective jammers in wireless networks involving the development of security-comprising protective jammers, which were optimally placed to afford wireless networks protection against malicious devices seeking to obtain confidential information. Shruti, who is also a Fullbright Scholarship recipient, is currently pursuing her PhD at the Georgia Institute of Technology in the USA.

Built for speed

Jonathan Wing is a second-year Mechanical Engineering student who loves speed. Whether he is canoeing, flying or winning the World HandiKart Championship – the sky is the limit. He is driven to do well and he wants to be proud of anything he attaches his name to.

At the age of six, Jonathan lost his foot when he fell off the back of a small tractor lawnmower and the doctor advised his parents to amputate. However, setbacks do not faze him. Jonathan matriculated from Hilton College in KwaZulu-Natal and obtained his pilot's licence in his Grade 12 year. He also took up paddling in Grade 10, and received professional training from Grade 11 onwards.

As a rower, Jonathan represented South Africa at the Para World Championships in Moscow and in Milan, and also qualified for the C-final when he was 17. On national level, he is currently the only rower competing in the category for people with prosthetic limbs.

"My challenge is to stay fit and to improve my upper body strength. I have a healthy and disciplined lifestyle, which includes a lot of gym work and, on Saturday afternoons, I paddle for two hours at Roodeplaat Dam. I hope to become the second Paralympic canoeist from Africa to qualify for the Olympic Games in Tokyo in 2020. Graham Paul was the first."

Jonathan says that he is disciplined about managing his time and doing well in his studies. He says that he attends all the lectures and makes notes in every class. His motto is: "Don't leave what you can do today, for tomorrow." The Faculty is excited to be backing Jonathan when he competes in Tokyo in 2020.

UP track champion graduates from Faculty

Akani Simbine is a South African sprinter who competed in the 100 m event at the 2013 World Championships in Athletics and the 2016 Summer Olympics. He graduated with a Bachelor of Information Science on 8 September 2017. He says that completing this degree has provided him with a pathway outside of the sports arena, and that this is something he encourages all professional sportspeople to consider.

Akani Simbine at his graduation ceremony.

Akani obtained a scholarship from the University after his first year and was later assisted by the South African Sports Confederation and Olympic Committee (SASCOC). His academic journey has also enabled him to improve his performance on the track. He says that "my degree in the IT field has taught me that, due to this field constantly being in a state of change and advancement, one has to be open to change, be prepared to grow and be in the loop of these new developments in order to be on top of your game." He has also adopted this mindset in his athletics.

The roots of industrial engineering

Compiled by Paul Kruger

The Concise Oxford Dictionary defines "dynasty" as a succession of leaders in any field. History has produced several families that may claim to be a dynasty in the worlds of politics, music and business. These families include the Rothchilds, Nehru-Gandhis, Medicis, Vanderbilts, Rockefellers, and certainly the Bachs. In the field of mathematics and science, the most famous and best-known family is probably the Bernoullis, although the Curies - with five Nobel prizes to their credit - may be in the same league.

The Bernoullis

The Bernoullis were a Swiss family of remarkable achievements in Mathematics, Statistics, Physics and Science. The original family, mainly importers and traders of "dry goods", such as spices, was from Antwerp, but they moved to Frankfurt and most of them later settled in the free city of Basel. The Bernoulli clan shared the same era, namely the mid-17th to the mid-18th centuries, with some of the great mathematicians like Isaac Newton, Gottfried Wilhelm Leibniz, Blaise Pascal, Leonard Euler, Joseph-Louis Lagrange, René Descartes and Pierre de Fermat. Some of the Bernoullis were of the same mathematical calibre as these illustrious mathematicians, and with good reason.

Nicolaus (1623–1706) was the founding father of the Bernoullis and produced several famous children. The members of the remarkable Bernoulli family achieved eminence not only in mathematics, but also in several other disciplines, such as science, astronomy, law, medicine, philosophy, economics, business and administration. The family even included an artist and alderman. Nicolaus was an apothecarian, but inherited a lucrative spice-trading business and was a wealthy businessman. He expected his sons to join the family business, but only Hieronymus, who is not often mentioned, did so and managed the business very successfully. Jacob, Johann and Nicolaus refused to join the family business and, against their father's wishes, eventually gravitated to mathematics and the arts. Nicolaus tried to convince his eldest son, Jacob, to study theology, but he refused. As a businessman, Nicolaus was not pleased; after all, the salary of a priest was about double that of a professor of mathematics at the time. The refusal of his three most gifted sons to join the family business may have been the start of the acrimonious family relations.

→ *Jacob Bernoulli, eldest son of Nicolaus.*

The belligerent brothers

The strife between the brothers, Jacob and Johann, is well known and documented since much of it was conducted over many years and in public. It may have started when Johann claimed that he had coined the word "integrate" and not his brother. Johann, while at the University of Groningen, was jealous of his older brother's status at the University of Basel and coveted his brother's position, which he eventually attained after Jacob's death. The personal relationship between the brothers (Jacob and Johann) was marred by fierce public strife, consisting mainly of disputes about priority in the discovery of scientific results. The brothers would criticise each other severely in letters to each other and notably to Leibniz, l'Hôpital and Euler, often without reasonable cause. Furthermore, they would publish a spiteful and malicious attack on each other's work under the guise of a legitimate

Johann Bernoulli, brother of Jacob.

Daniel Bernoulli, son of Johann

comment, which started a new round of conflict. The brothers had different personalities and approaches to their work. Jacob was a meticulous and brilliant mathematician. On the other hand, Johann possessed a natural and instinctive talent for mathematics, but he could be impetuous and rash. However, they collectively produced some of the most significant contributions in the history of mathematics. Given their respective personalities, conflict was inevitable.

Johann considered himself a self-taught mathematician and at least the equal of his brother, while Jacob always considered his much younger brother as his inferior student. For example, after Johann launched a particular vitriolic attack on his brother, Jacob responded by calling Johann a naïve parrot that was only capable of "repeating what he has learnt from his master".

The mathematical and academic community tried on several occasions to convince the brothers to stop their bitter and public bickering, but to no avail. Both brothers had been admitted to the French Academy of Sciences, on the explicit condition that they put an end to their hostilities, but soon afterwards they continued unabatedly and with more intensity. During the much-vaunted Leibniz-Newton controversy over who should be granted precedence for the development of calculus, the two brothers took an active part, with Jacob supporting Newton and Johann supporting Leibniz. The brothers had the habit of posing a mathematical problem in one of the journals. The other brother would then provide a solution in the same journal, upon which the brother who posed the problem would criticise and ridicule the solution, often resulting in a protracted public altercation. In later years, this was the only way of communication between the brothers. Jacob was an admirer of the logarithmic spiral, to the extent that he requested that it should be depicted on his gravestone.

However, the engraver placed the much less interesting Archimedean spiral on the stone. This may have been an honest mistake, but it was rumoured that the engraver did this on the instruction of Johann in a last attempt to get even with his brother. After Jacob's death, Johann transferred his tendency to be jealous to his son Daniel.

Daniel won a prize from the French Academy of Sciences for his work on planetary orbits. Johann coveted the prize for himself and promptly threw his son out of the paternal home, never to return.

When Daniel published his famous book, *Hydrodynamica*, his father immediately claimed that it was his work and stolen by his son. Johann produced some unpublished papers, which may have been plagiarised from Daniel's book, and by predating them, endeavoured to establish precedence over his son. Jacob's attempt at fraud was exposed and it caused a rift between father and son that was never mended. Johann also suffered the effects of plagiarism when his student, l'Hôpital, published a book consisting almost entirely of Johann's lectures, including the now famous l'Hôpital's Rule.

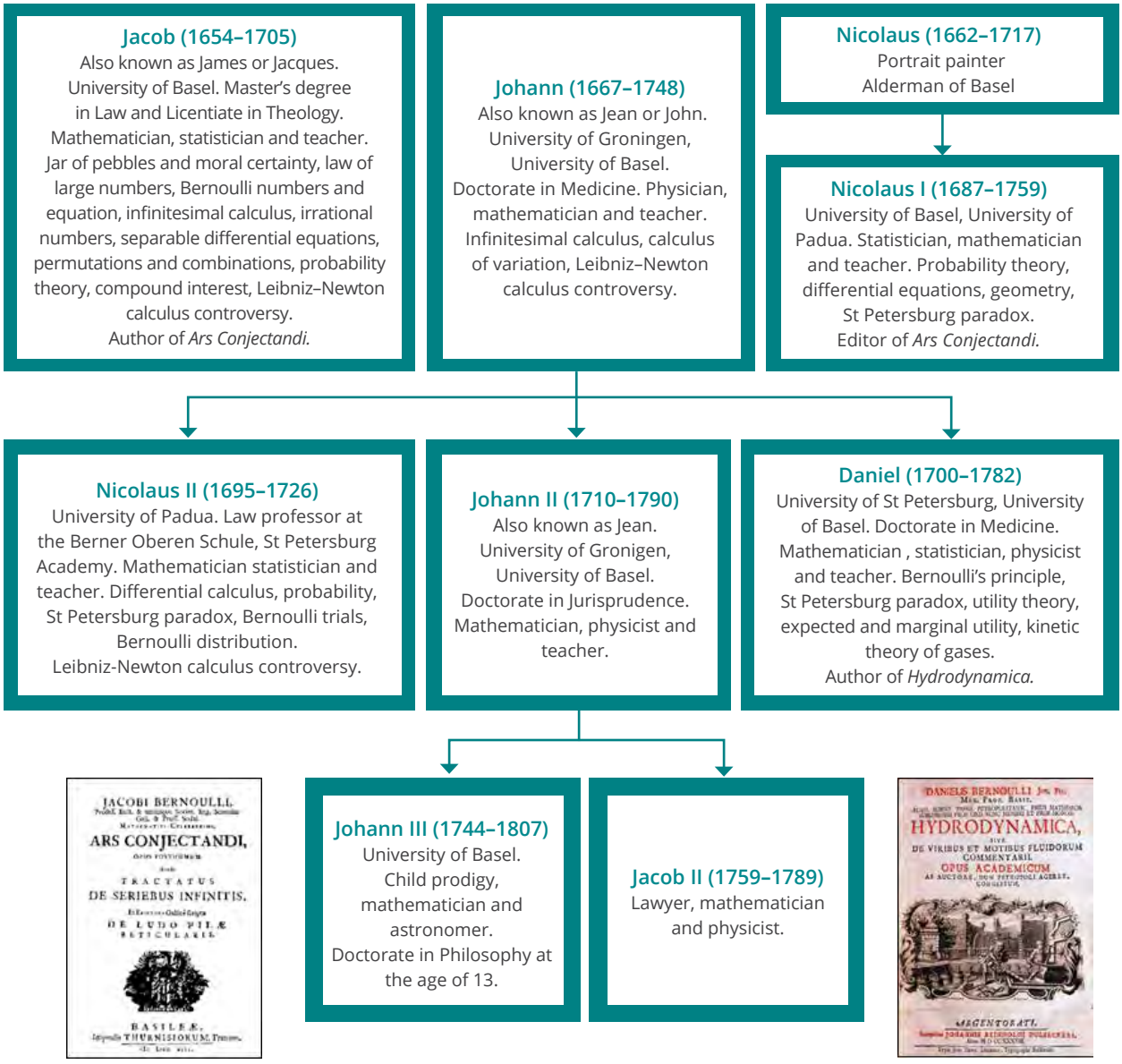
Although the personal lives and interpersonal relationships of some of the members of the Bernoulli family may remind one of a soap opera, their combined contributions and achievements are with little doubt one of the most significant experienced by the world of Mathematics and Statistics. Over the course of three generations, the Bernoullis produced eight mathematically gifted academics who, among them, contributed significantly to the foundations of Applied Mathematics, Physics and Mathematical Statistics. The abbreviated and annotated family tree in Figure 1 shows this.

Most of the worse squabbles and public confrontations in the Bernoulli family occurred between the brothers Jacob and Johann, and between Johann and his son Daniel.

"I recognise the lion by his claw."

– Johann Bernoulli

(after reading an anonymous solution to a problem that he realised was Newton's work)



→ *Figure 1: Three generations of Bernoulli mathematicians and the title pages of* Ars Conjectandi *and* Hydrodynamica.

Ironically, these three members of the Bernoulli family are at the same time often considered to be the most famous and mathematically accomplished.

Conclusion

The Bernoullis collectively changed Mathematical Statistics from a mathematical curiosity, only applicable to games of chance, to a powerful tool for analysis and decision making in almost all spheres of engineering, business, economics and finance.

It has been debated whether the jealousy and envy among the members of the family had a detrimental or positive influence on their work and the development of Mathematics. However, the resultant atmosphere of jealousy and competition may have contributed to their achievements, since they constantly challenged and spurred each other on.

It is fair to say that the Bernoulli family is to mathematics, science and engineering what the Bach family is to music. In the long history of mathematics, from Archimedes and Euclid, via Euler, Newton, Leibniz, Gauss and Fermat to John von Neumann, Andrew Wiles and all the other modern mathematicians, the Bernoullis, individually and collectively, deserved a special place in the history of mathematics.

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