Innovate:

Issue 13 2018

Inspiring the Innovation Generation

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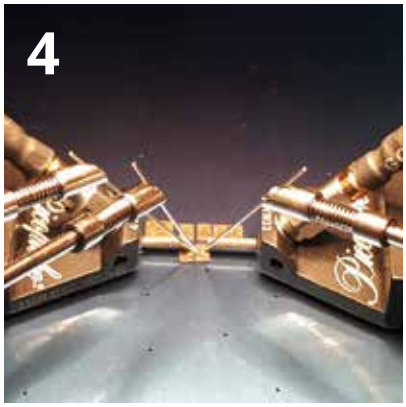
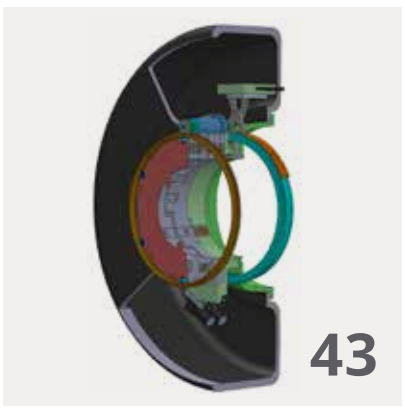
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

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:

Every day, global technology is evolving on an exponential scale. In answer to this, the Faculty of Engineering, Built Environment and Information Technology of the University of Pretoria is eager to embrace the challenges of the Fourth Industrial Revolution.

We are ready.

Technology development and unemployment – the skills debate

The impact of technological development on our society has been the theme of numerous research projects. In discussions on the topic there are typically two opposing views. On the one hand, it is globally accepted that technological development is necessary for economic growth and the improvement of quality of life. Some people are cautious, and sometimes even skeptical, about issues such as the negative impact of technology on the social behaviour of people or the negative impact of technology on employment. With the Fourth Industrial Revolution (4IR) dominating many business and political agendas, the issue of job destruction and unemployment raises many questions and it seems that few answers or solutions to this obstacle are available at this stage.

The first obvious question is if 4IR technologies will indeed lead to job destruction and unemployment. Technology platforms that support and integrate complex technology domains, such as Robotics, the Internet of Things, Big Data Science and Artificial Intelligence, will certainly lead to levels of automation that have not been known before. The argument that high levels of automation will destroy jobs thus seems to make sense. At a recent conference, a representative of the Global Manufacturing Forum did not agree at all. He based his argument on the fact that Germany and Japan are the leaders in the implementation of Industry 4.0 technology systems. In both these countries, the unemployment rates are very low. In my view, we cannot generalise the examples of Germany and Japan to say that it is true for all other countries, taking the numerous differences between developed and underdeveloped countries into consideration. However, this is not an excuse to merely accept that unemployment will increase and that governments will have to introduce socialistic policies to "remunerate" unemployed people.

The answer to this contradiction certainly lies in skills development. After all, this is what happened with technological changes over many centuries. With the 4IR, however, the rate of change makes several demands. In the first place, one needs to identify the right types of skills. In the second place, a much higher rate of skills development is needed. Institutions all over the world are conducting research in this regard. The World Economic Forum recently published the results of such a research project in which it compared the top ten skills required in 2015 to the top ten skills that will be required in 2020. Due to the future high levels of automation, skills such as complex problem solving, critical thinking and coordination dominate the list, while skills such as quality control and active listening no longer feature.

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria is very aware of all these changes, both in terms of the rate of change and the types of skills and technological capabilities that will be needed in future. In this edition of *Innovate,* you will find interesting articles on how our academics and researchers embrace the Fourth Industrial Revolution through their cutting-edge research to make a valuable contribution to improve our country's economic competitiveness and the quality of life of its people.

I trust that you will enjoy this issue of *Innovate*.

Editor
Tinus Pretorius

Message from the Dean

Prof Sunil Maharaj

As South Africa prepares for the Fourth Industrial Revolution (4IR), the Faculty of Engineering, Built Environment and Information Technology (EBIT) focuses its research, teaching and learning activities on bringing competitive knowledge to industry, education and society. We strive for research excellence and actively pursue international collaboration.

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

The Faculty is organised into four Schools:

- The School of Engineering
- The School for the Built Environment
- The School of Information Technology
- The Graduate School of Technology Management

Through its teaching, learning and research activities, EBIT enjoys high global rankings. According to the latest QS rankings of universities worldwide, the University of Pretoria is one of only two universities in South Africa, and one of only five universities in Africa to be ranked in the Top 400 universities globally for engineering and technology. In 2018, it appeared in five QS World University Rankings by Subject for architecture and the built environment (Top 200), chemical engineering, computer science and information systems, electrical and electronic engineering, and mechanical, aeronautical and manufacturing engineering, all of which are presented in EBIT's academic departments.

The Web of Science ISI Essential Science Indicators for citations also ranked EBIT's School of Engineering in the Top 0.5% of engineering schools in the world in 2018. In the local engineering market, the South African Department of Higher Education and Training determined in 2017 that almost 25% of all professional engineering graduates at South African universities graduate from the University of Pretoria.

Global technology is evolving on an exponential scale and EBIT is eager to embrace the challenges that future technology brings. We are armed with exceptional researchers and we have superb laboratory facilities. For our teaching and learning activities, we follow a hybrid teaching model in accordance with the changing landscape of higher education. Teaching is delivered by a team of motivated, competent and dedicated academics, who are supported by highly motivated administrative and support staff. Together, they serve our student community.

Global technology is evolving on an exponential scale and EBIT is eager to embrace the challenges that future technology holds for the teaching, learning and research landscape.

EBIT offers 23 undergraduate degree programmes that are locally relevant and internationally competitive. Where available and applicable, the programmes are accredited by statutory and professional bodies at national and international level. We ensure that our graduates are work-ready and able to address and overcome future challenges. Our graduates enter ever-changing job markets – some of which were not even in existence when they commenced their studies.

The Faculty also hosts 141 postgraduate study programmes across honours, master's and doctoral degree levels, as well as 30 research chairs and entities. These help us to actively contribute to the knowledge economy. We have crafted a progressive research strategy to exploit the research of our world-class experts, who engage in multidisciplinary research and innovation. Our 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.

Through its wide range of initiatives, EBIT attracts high-quality students and staff, and it is well equipped in terms of research and teaching activities.

In order to ensure that the Faculty remains relevant, we maintain close ties with industry partners. This allows us to continually search for opportunities for collaboration. Such collaboration is essential to our efforts to enhance the relevance of our academic programmes, which, in turn, enables our students to acquire scarce and highly specialised skills. As a result, our graduates are in high demand in South Africa and across the globe. Data shows that 90% of our graduates become employed within six months of their graduation.

EBIT is home to a generation that embraces the "Thuma Mina" ethos, and who serve as leaders and innovators dedicated to improving their lives, the lives of their families, their country and the world.

EBIT technology advances the telecommunications industry

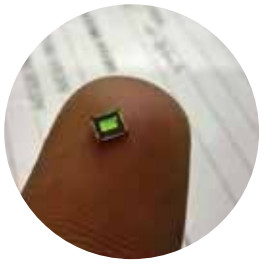
Research conducted in the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Faculty of Engineering, Built Environment and Information Technology (EBIT) has led to innovation that contributes to the development of fifth-generation (5G) technology. Two postgraduate students, Nishant Singh and Piotr Osuch, have developed novel on-chip bandpass filters and analogue signal processing blocks, as necessitated by future 5G technologies. 5G is the fifth generation of cellular networking – the next step in mobile technology that the phones and tablets of the future will use.

The first generation of mobile networks (1G) was introduced in 1982. It was a fully analogue system until the launch of second-generation (2G) networks, which made the jump to digital in 1991. This second-generation technology added cellular data in the forms of general packet radio service (GPRS) and enhanced data rates for global system for mobile communications (GSM) and evolution (EDGE) technologies. Some 10 years later, 3G networks were launched, offering an even faster data rate than 2G. About 10 years after that, current long-term evolution (LTE) networks developed as the fourth generation of networking (4G). In retrospect, it seems that a new generation of networking technology is rolled out every decade or so. The 5G networks will offer a similar leap forward when it comes to things like data speed.

Cellular technology transmits data over radio waves. Depending on the type of electromagnetic signal, this is measured as a different frequency – the higher the frequency, the smaller the wavelength. Millimetre wave (mm-wave) technology therefore refers to signals with a wavelength that is measured in millimetres, and is generally defined as between 30 GHz and 300 GHz.

What is the significance of mm-wave technology? It promises higher data capacity and lower latency than is currently available. The higher the frequency, the more data it can transmit. Another advantage of the shorter wavelengths is that the antenna used to transmit and receive the signals can be made comparably smaller. This means that phones that use mm-wave technology will take advantage of multiple antennas for massive multiple-input, multiple output (MIMO).

Singh and Osuch's technology solves some of the problems that have plagued the telecommunications industry for more than 30 years. These inventors have developed tunable mm-wave on-chip bandpass filters, with characteristics similar to those that can be achieved in traditional soft substrates, as well as on-chip analogue signal pre-



5G is set to enable the Internet of Things – the industrial revolution of the 21st century. Unprecedented volumes of data will connect every aspect of life.

Commercialisation

Multifractal Semiconductors SA, the company that licenses this intellectual property (IP) on behalf of the University of Pretoria, was established as a result of the development of the tuneable mm-wave on-chip bandpass filters.

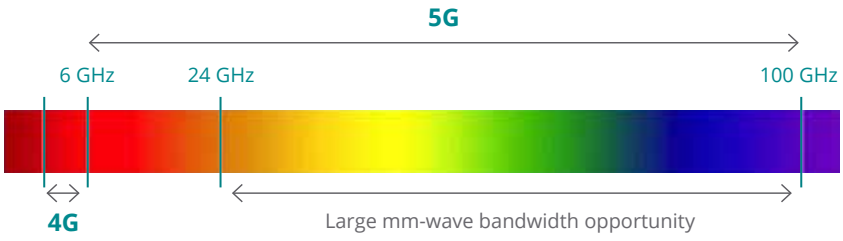
It was conceptualised in the mm-wave research group of Dr Tinus Stander at CEFIM. The Institute has been active in the field of microelectronics research and specialist training since 1981. The research and postgraduate programme is mainly concerned with the field of integrated circuit design, especially the design of analogue signal processors, radio frequency (RF) circuits and optical receivers in complementary metal-oxide-semiconductor (CMOS) technology.

The application of semiconductors as opto-electronic devices plays an important role in the activities of CEFIM. International contact in microelectronics is vital. CEFIM lecturers and students often participate at international conferences, and international experts regularly visit the Institute.

The development of Multifractal Semiconductors SA's tuneable mm-wave on-chip bandpass filters.

processors for ultra-wideband signal processing. This technology eliminates waveguide, as well as surface acoustic wave (SAW) filters that prevent a true low-cost single-chip solution with high dynamic ranges, while maintaining best-in-class noise figures (NF) and low-phase noise (PN), and spurious performance. It furthermore provides the ability to process high bandwidth signals for 5G in real time, presenting a viable solution to the Big Data problem.

The invention boasts a Technology Readiness Level (TRL) of 4. Following successful proof of concept work, the technology will be developed further for commercialisation in the form of physical hardware, as well as microelectronic IP blocks for use by system designers. It is an exciting time for the microelectronics industry, which will make the giant leap to 5G a reality. This industry will form the backbone to 5G, which will in turn enable the Internet of Things – the industrial revolution of the 21st century. Unprecedented volumes of data will connect every aspect of the life of the future "connected person".



Visual representation of mm-wave bandwidth opportunity.

Achievements

The 5G invention won the 2017 start-up Tel Aviv-South Africa competition, administered by the Embassy of Israel. The inventors received an all-expenses-paid trip to Israel to participate in the Tel Aviv Digital Life Design (DLD) festival. They also met angel investors and learned from start-up ecosystem gurus in Israel.

Closer to home, Singh was selected as one of eight finalists in the ICT category of the sixth annual Gauteng Accelerator Programme (GAP) Awards, which were held at the Innovation Hub during Global Entrepreneurship Week in November 2017. The company, Multifractal Semiconductors SA, also walked away as one of four category winners. This competition was established by The Innovation Hub in 2011 to recognise and reward innovative ideas that have the potential to positively influence the Gauteng economy.

Multifractal Semiconductors SA has been selected to participate in the first of Si Catalyst's two-stage incubation programme, the world's only incubator focused exclusively on semiconductor solution startups. If approved, the in-kind support received will be valued at approximately $5 million over three years. It will also receive incubation support in the form of office space from TuksNovation.

Malaria research in the Institute of Applied Materials

The Institute of Applied Materials in the Faculty of Engineering, Built Environment and Information Technology (EBIT) is conducting research to address serious public health issues on an international scale. It is a major partner in the University of Pretoria Institute for Sustainable Malaria Control to combat malaria. Malaria kills hundreds of thousands of people on the African continent each year, and new tools are needed to eliminate this disease. This is precisely what the researchers are working towards.

Under the leadership of the Institute's Director, Prof Walter Focke, it has already delivered two commercialised inventions with the ability to contribute to malaria control.

The first of these was undertaken by Mthokozisi Sibanda and Prof Focke in collaboration with Dr Andreas Leuteritz and Dr Harald Brünig of the Leibniz Institute for Polymer Research in Dresden, Germany. These researchers have successfully produced personal protection clothing items. The project developed a bi-component polymer yarn with a core containing a volatile repellent active and a sheath layer that reduce the rate at which the active ingredient is released into the atmosphere. The yarn has been successfully knitted into personal protection clothing items under the NoBuzz® trademark.

The combination of cotton or wool with the insect-repellent yarn results in a high-quality, comfortable and long-lasting insect repellent textile to protect against outdoor malaria transmission from infected mosquito bites.

What makes the technology unique is that it is designed to impregnate volatile liquids directly onto the yarn during the production process in such a way that they are slowly released. The method used to control the release of the volatile actives is innovative and cost-effective compared to alternative slow-release techniques.

NoBuzz® products are manufactured by combining part cotton or wool for comfort and part insect-repellent yarn (BiKoRepellent Fabric™) to give the repellent effect. The result is a high-quality, comfortable and long-lasting insect repellent textile.

The textile can be cold washed up to 25 times or kept under room conditions for up to six months and still repel insects such as mosquitoes effectively. This textile has been used to manufacture insect-repellent hiking socks, ankle guards, slap bands and hiking shoelaces.

Until now, long-life insecticide-treated nets and indoor residual spray have been the flagship interventions recommended by the World Health Organization (WHO) for malaria vector control. Both these interventions target mosquitoes that feed indoors. However, it has been determined that a significant proportion of malaria infections in Africa may be due to exposure to vector mosquitoes during the early hours of the evening when people are still active outdoors. It has also been determined that over 90% of outdoor infective mosquito bites occur on the ankles and feet. For this reason, it is important for people to protect their ankles and feet while they are outdoors in a malaria endemic area.

The NoBuzz® products are specifically designed to protect the user's ankles and feet from ankle-biting mosquitoes outdoors. The products are also effective against ticks and fleas.

→ *The malaria research team in the Institute of Applied Materials.*

Malaria is a silent emergency. It has been estimated to cost Africa more than US$ 12 billion every year in lost gross domestic product (GDP).

– United Nations Children's Fund (UNICEF)

The second invention was developed by researchers Homa Izadi, Prof Focke and Leo Braack. They have discovered a synergistic mixture of approved mosquito repellents that could provide a faster route to the public use of replacement repellents with fewer negative consumer perceptions like high cost, odour, a high absorption rate, an oily feel or skin irritation. Through their research, Izadi, Focke and Braack have discovered a special blend of two repellents that exhibit pseudo-azeotrope behaviour with improved repellent efficacy and persistence. This approach will open the way for the development of better mosquito repellent formulations based on azeotropic blends, which are sorely needed to fight mosquito-borne diseases such as malaria.

What makes the technology unique is that this formulation takes longer to evaporate, resulting in the repellent effects lasting longer. The blend has also proven to be toxic to mosquitoes.

→ *NoBuzz® repellent hiking sock, ankle guard, slap band and hiking shoelaces.*

Alkali-activated cements can form the foundation of environmentally friendly construction

Concrete is one of the most widely used construction materials. In civil engineering works, Portland cement is generally used as a binder component and basic ingredient of concrete, mortar, stucco and non-speciality grout as it is the most common type of cement in general use around the world.

The production of cement requires high-energy efforts that have a significant impact on the global emission of greenhouse gases. Research conducted in the Department of Civil Engineering by Prof Elsabé Kearsley, Dr Julia Shekhovtsova and Dr Maxim Kovtun has focused on the development of alkaline-activated compositions by exploring the use of both fly ash and furnace slag for alkaline activation.

This research has not only resulted in the development of alkali-activated fly ash, which is better known as geopolymer, but has also resulted in an improved alkaline-activated slag composition as an alternative to conventional cement. This invention contributes to the health of the planet in three ways: by reducing the emission of greenhouse gases; by reducing waste in the form of furnace slag or fly ash that inevitably ends up in ash dams and landfills; and by preventing the toxic elements that are present in fly ash from polluting our soil and ground water.

The researchers determined that South African fly ash can be used in alkaline-activated cement formulations to produce a concrete with good mechanical properties.

Dr Kovtun's invention involves the development of a composition that includes slag, alkali metal carbonate, silicon dioxide and alkaline metal hydroxide.

Fly ash is the fine particles that are carried in the output of a furnace at a power station. It has a number of uses and is seriously underutilised in South Africa. Consider the fact that energy production relies mostly on coal. Sasol and Eskom are the largest coal-processing companies in South Africa. Sasol, as a petrochemical manufacturer, annually consumes more than 30 million tons of coal and produces about 8 million tons of gasification ash. Eskom, as a power utility, consumes more than 100 million tons of coal per annum. More than 35 million tons of ash was produced in 2011, and almost 90% of the ash produced by Eskom is fly ash.

The morphological features of fly ash result in the improved workability of

Prof Kearsley and Dr Shekhovtsova used classified low-calcium fly ash from the Lethabo power station to study the preparation of alkaline-activated fly ash cement pastes.

cement systems. However, in South Africa, only 7% of all fly ash produced by Eskom is beneficially used and millions of tons are disposed of annually.

Developing an alternative application for fly ash as a raw material to produce an environmentally friendly construction material contributes to finding a solution for fly ash utilisation. This would expand the raw material base of the building industry without using natural mineral resources.

Although there is a considerable amount of literature on the alkaline-activation of fly ash, little is known about the activation of South African coal fly ashes in particular. Prof Kearsley and Dr Shekhovtsova therefore used classified low-calcium fly ash from the Lethabo power station to study the preparation of alkaline-activated fly ash cement pastes.

During the course of their research, they determined that Lethabo fly ash can be used in alkaline-activated cement formulations to produce a concrete with good mechanical properties. This is of great importance in the long-term performance of these materials in order to give them a real chance to be adopted at an industrial scale.

The improved alkaline-activated slag composition contributes to the health of the planet by reducing the emission of greenhouse gases.

The use of alkali-activated cements has been hampered by the corrosive nature of the activators required to activate the waste materials. The large-scale use of alkali-activated cements will only be possible if these cements can be manufactured pre-mixed and bagged in dry format before distribution.

The invention of Dr Kovtun involves the development of a composition that includes slag, alkali metal carbonate, silicon dioxide and alkaline metal hydroxide. It furthermore involves a process for the preparation of a dry, mixed alkaline-activated slag composition that is ready-to-use by just adding water. This invention has been patented and the University's Technology Transfer Office is seeking potential investors who would be interested in licensing the product.

Prof Elsabé Kearsley.

Smart mobile wireless health system ensures miner safety

South Africa has the world's deepest mines (as deep as 4 000 m below the earth's surface in some cases). In the last couple of decades, there has been a sustained reduction in the number of fatalities and fall-of-ground incidents. Since 1994, the number of fatalities in the industry has declined by around 88%, while fatalities as a result of fall-of-ground incidents have declined by 92%.

Significant strides have been taken over the last few years to improve the health and safety of mine workers. However, mining is still a highly hazardous occupation. Most recently, this has been shown by the Kusasalethu Mine incident, in which five miners were trapped underground in August 2017 after a fall of ground at the gold mine. Environmental factors such as rock falls and flooding, as well as physical factors like fatigue, heat stress and even falling, can pose risks to mine workers. With improving communication capabilities in underground mines and the advent of sensor technologies, real-time and unobtrusive measurements of these factors are becoming a reality.

In light of this, Prof Reza Malekian and his research team in the Advanced Sensor Networks Research Group of the Faculty of Engineering, Built Environment and Information Technology's Department of Electrical, Electronic and Computer Engineering will utilise sensors to determine mine workers' activity status by measuring their physiological parameters, such as heart rate, body temperature, blood pressure and respiratory rate. Sensors are also used to measure the mine's environmental parameters, such as air flow, temperature, humidity and carbon dioxide level.

The data generated from these sensors is analysed over a wireless Internet of Things (IoT)-based framework in a remote monitoring centre. Diagnostic and predictive algorithms at the remote centre will help to monitor and determine whether a mine worker is in danger, and if action needs to be taken.

The team's approach consists of three subsystems: the sensor subsystem, the communication subsystem and the remote monitoring subsystem (see Figure 1).

The sensor subsystem is where measurements are taken from various sensors. This data is transmitted over a wireless IoT framework to a remote station for further analysis. The development of wireless, low-powered, non-invasive devices has paved the way for the unobtrusive, ongoing monitoring of miners' health. This is done by means of wearable sensors that are used to sense the miners' physiological parameters. It is important that the wearable device does not hinder the user and that it operates ubiquitously and accurately. This is especially important in mining, since the miner should be free to carry on with work-related tasks. In order to guarantee successful smart health monitoring, decisions

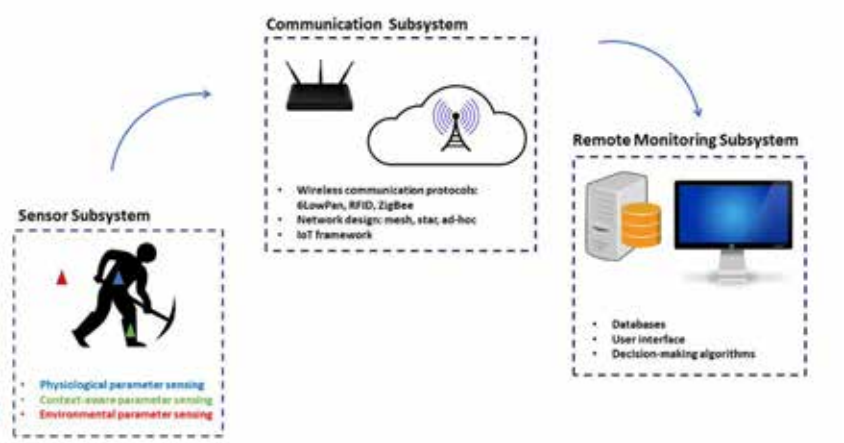
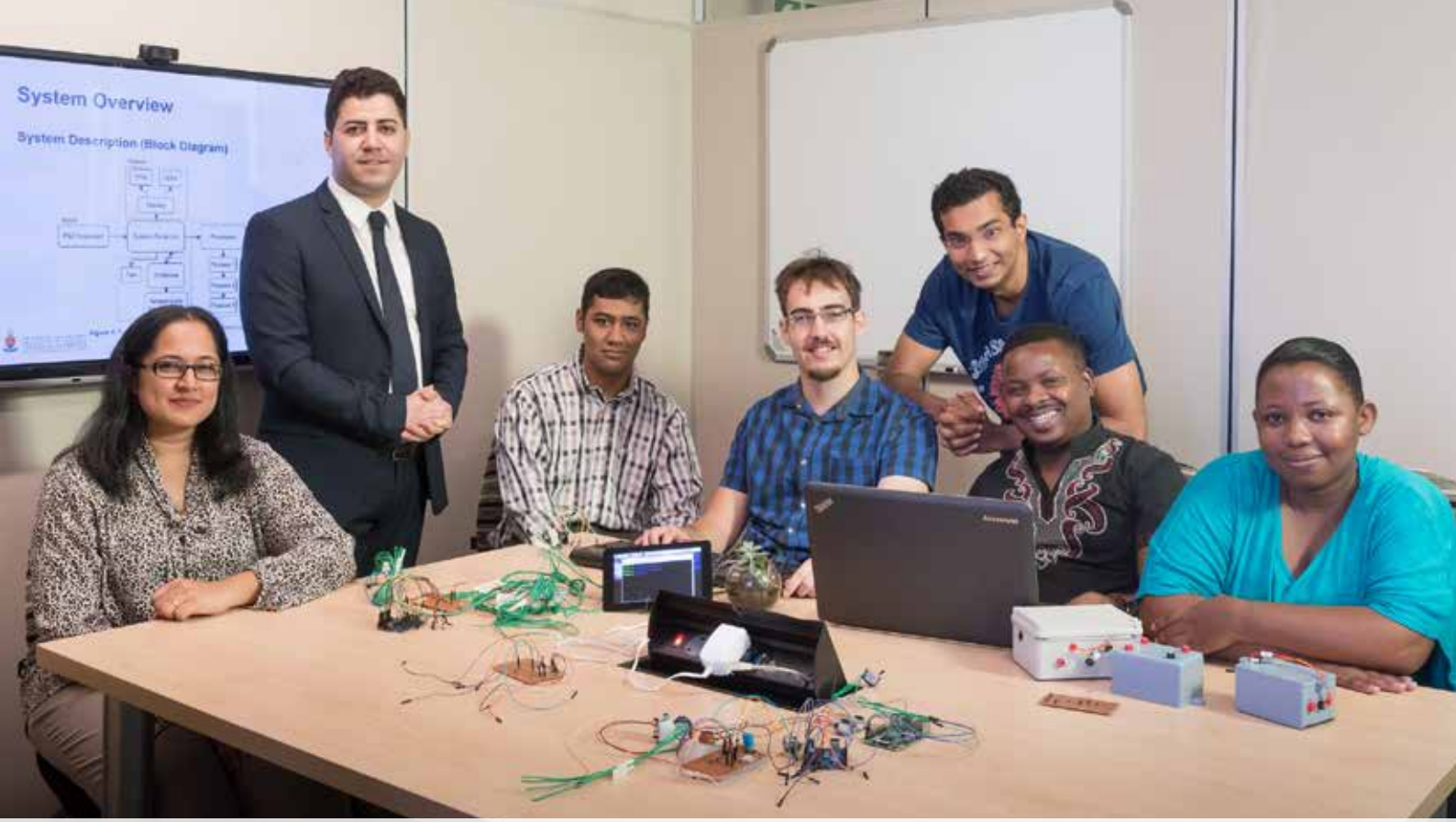


Figure 1: Systems for monitoring the mining environment.



Prof Reza Malekian, Head of the Advanced Sensor Networks Research Group (standing second from left), with the members of the research group in the Department of Electrical, Electronic and Computer Engineering.

should not only be based on the measurement and interpretation of physiological parameters, but also on contextual information of the miner and possibly the surrounding environment. User context in the form of activity can give crucial information to the decision-making process when monitoring a miner's vital statistics.

The communication subsystem provides the IoT communication framework for transferring data from the sensors to the remote station. Underground mining networks consist of main tunnels and branches, where the branches are rather limited and their directions are completely dynamic, making it difficult to find a standard communication solution. A very promising solution that could standardise and alter the current implementation of wireless communication in industry is 6LoWPAN, which is a somewhat contorted acronym that combines the latest version (version 6) of the Internet Protocol (IPv6) and low-power wireless personal area networks (LoWPAN). Therefore, 6LoWPAN makes provision for the smallest devices with limited processing ability to transmit information wirelessly using an internet protocol. The 6LoWPAN is a communication protocol that utilises IP-based communication and is built on the IEEE 802.15.4 standard. It is also a key enabler in the revolutionary IoT concept (Yu et al., 2017; Henriques & Malekian, 2016). IoT refers to physical embedded devices that can collect data from their environment with sensors and actuators, and then wirelessly exchange this information with other devices over the internet. According to Lourie (2017), the mining industry has a lot to gain from the connectivity that IoT provides. Mining operations around the world are applying technologies to automate their key functions to gain efficiencies in production. However, these initiatives are often focused on and restricted within production silos.

The result is a remote monitoring subsystem that is developed with the goal of creating an enhanced decision-making system that enables early warning and predictions to be made with high accuracy and precision.

Sensor node in a testbed environment.

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Upscaling a device for the electrolytic production of metal

The prototype of a device that has been developed to achieve the continuous production of metal in powder form by means of electrolysis has reached the pilot phase. This invention, which has been developed by Ryno Pretorius, a PhD candidate in the Department of Chemical Engineering, has already sparked the commercial interest of large mining companies locally and internationally.

The manufacture of metal for industrial electrochemical purposes has always relied on two main production methods: electrowinning and electrorefining. Electrowinning is an electrometallurgical production technique that uses an electric current to deposit metal on the cathode of an electrolytic cell. Electrorefining uses a similar process to remove impurities from a metal. Both use electroplating on a large scale. These techniques are important for the economic beneficiation of non-ferrous metals.

The first prototype of this invention was developed in 2016. It transformed the standard batch or semi-batch electrowinning process into a continuous process. This was shown to work well for the production of copper, but could also be used to produce metals from aqueous solutions of cobalt, nickel and zinc. The advantage of this technique, which could also be used for electrorefining with minor modifications, is its long-term continuous operation.

The process on which this invention is based was first demonstrated in 1907, and has since been developed into a widely used technique to extract metals from acid leach solutions. An example of this technique would be the extraction of copper from oxide- or sulphide-bearing ore.

Commercial electrolytic cells have not developed much since the early 20th century, and batch or semi-batch processes are still used to produce metals. The plated cathodes have to be removed and replaced after a designated period, which requires specialised labour and hoisting equipment. This leads to production losses. Furthermore, traditional electrolysis devices make use of parallel electrodes, which leads to unwanted high current concentrations on the edges of the electrodes, which results in unwanted electro-depositions and other process inefficiencies.

During the course of the development of the invention, Pretorius conducted an extensive study of electrolysis, which revealed the abovementioned flaws. He sought to address these issues from both a theoretical and a practical viewpoint, which resulted in three prototypes that were able to continuously produce copper.

After rigorously evaluating and testing the prototype, seed funding was secured from the Technology Innovation Agency (TIA) to build a pilot plant. He is currently applying for a development grant from TIA to build a demonstration plant so that he can illustrate the benefits of continuous metal production to potential investors.

Pretorius's new device has the benefit of low-labour, hands-off processes that are incorporated into a modular design. This will not only reduce the cost of production due to a decrease in production downtime and bring about an increased production rate, but will also improve worker safety and reduce the risks associated with operators working with heavy machinery.

→ *A demonstration model of the cylindrical device for the continuous production of copper.*

The device has the benefit of low-labour, hands-off processes that are incorporated into a cylindrical design, which brings about savings on a range of fronts.

In addition to savings resulting from continuous production and reduced labour costs, the device also has a smaller footprint than previous devices of this nature, implying reduced civil and operational costs. This feature makes it attractive to mines and industries on a smaller scale. It also has the potential to minimise process inefficiencies associated with high current densities.

This novel invention is able to continuously produce copper as a fine powder, which is scraped from the electrode and collected for further processing.

It has also demonstrated the ability to alter product parameters such as the size and shape of the metal particles, deposition rate of the produced particles, degree of electrolyte (leacheate) depletion and the operating cost associated with electricity use. A further advantage is that "sludge" from the valuable platinum group metals (PGMs) can continuously be extracted. This is of particular interest in South Africa, where copper is commonly produced during the purification of PGMs. These include palladium, platinum and rhodium.

The invention boasts a Technology Readiness Level (TRL) of 5, which means that it needs to be demonstrated in a real-world environment. The invention was a runner-up at the SA Innovation Summit 2017.

Inspiring the Innovation Generation

The University of Pretoria (UP) is considered a leader in the region and is a recognised international player in the innovation space. The Faculty of Engineering, Built Environment and Information Technology (EBIT), in particular, has established unique capacity and expertise in this domain.

The University's Graduate School of Technology Management (GSTM) was the first of its kind in the country to offer programmes in engineering and technology management, and its Institute for Technological Innovation (ITI) was similarly the first of its kind to conduct research into the management of innovation. Furthermore, Enterprises University of Pretoria (E at UP) traces its roots to the Laboratory for Advanced Engineering, a consulting company that was established in the former Faculty of Engineering.

In addition to the formal technology and innovation management programmes that are offered, "innovation is spoken" throughout the Faculty, including in the innovative curricula of the respective departments, and the supporting world-class research activities. This is one of the reasons why EBIT's graduates are so sought after.

Innovation champion

In its efforts to encourage innovation and excellence in research, EBIT is proud to associate itself with remarkable alumni of the Faculty. One such alumnus is Prof Calie Pistorius, currently Director and Principal Consultant at DeltaHedron in the United Kingdom, which specialises in the management of innovation.

At UP, Prof Pistorius is well known for his role as Vice-Chancellor and Principal of the institution between 2001 and 2009, and for his significant contribution to the success of the University during this period.

Prof Calie Pistorius.

He is also a former Dean of EBIT, a former Head of its Department of Electrical, Electronic and Computer Engineering, and Director of the ITI. He served as Chair of the National Advisory Council on Innovation (NACI), a statutory body advising the Minister of Science and Technology (and through the Minister, the Cabinet) on policy issues pertaining to national science, technology and innovation strategies and policies.

Defining innovation

According to Prof Pistorius, "innovation" is one of those terms that has become a bit of a cliché. It is generally understood to describe what is new, novel and "out of the box" – perhaps somewhat extraordinary.

"From a serious innovation management point of view, I like to think of innovation as having two components: both of which need to be present for a successful innovation," he says.

EBIT is home to exceptional members of the Innovation Generation.

The first component is invention. This involves the creation of a new product, process or service. It very often combines existing ideas with new ones. The second component is market acceptance. This is where the market decides whether it is going to adopt the invention. This results in the diffusion of the innovation into the market. "Technology does not adopt itself," explains Prof Pistorius. "It is people who make the decisions. If there is no market adoption, then the innovation remains an invention".

According to Prof Pistorius, it has been said that inventions create new knowledge, but innovations create new wealth. In this context, the term "wealth" should be interpreted widely. It may mean economic wealth, but it can also mean social, cultural or environmental wealth. "What is important," he says, "is that there is impact, and a difference is being made".

Surveys of business leaders more often than not indicate that "innovation" is one of their top priorities. There is a general recognition in business that innovation is important for growth and survival. However, at the same time, while these surveys acknowledge the importance of innovation, many business leaders are not overly confident of the ability of their companies to fully understand the notion of innovation and how to innovate. "There is a dire need for those individuals who understand the process of innovation to share their expertise," he observes.

Prof Pistorius goes on to explain that innovation is not restricted to the technological field: it can take place across the board. There are many examples of innovations in social and political systems, finance and insurance, marketing and fashion.

Inventions create new knowledge, but innovations create new wealth.

From the viewpoint of technological innovation, however, the major issues that business leaders need to deal with are that all companies rely on technology in one way or another, and that change is a key feature of all technologies. This combination implies that the dynamics of technological change and emerging technologies have a strategic impact on businesses, and present strategic opportunities, risks and threats that business leaders need to deal with.

It is not something about which businesses really have a choice. If they choose to ignore innovation, it would be akin to "fumbling the future", as many companies that were once great have discovered. At the same time, many start-up companies that have embraced new technologies and business models of the new order have become very successful and have risen to become business leaders in industries that did not even exist a few decades ago.

How does South Africa rate in terms of innovation?

South Africans have always been very ingenious and inventive, and many innovations have originated in South Africa over a long time.

South Africans have also been very good at adapting technologies to local conditions and environments. The rapid diffusion of mobile technology and new applications that have been built on these technologies are good examples.

South African engineers and managers are generally held in high esteem across the globe when it comes to the management of technological innovation. The academic programmes in engineering, technology and innovation management at universities such as UP and the University of Stellenbosch are also considered to be top notch internationally.

Establishing an innovation generation at UP

Prof Pistorius recalls that when he was appointed as Vice-Chancellor and Principal of UP in 2001, the University's students and researchers were branded as "the Innovation Generation".

"This was also the title of the University's strategic plan at the time," says Prof Pistorius. "The thrust was to create an environment where innovation could flourish, focusing not only on the acquisition and creation of new knowledge, but also on the impact and the difference the University (its students, staff and alumni) could make." It was about achieving greater outcomes and proactively contributing towards shaping a better future.

According to Prof Pistorius, UP is known for its innovative approaches and entrepreneurial spirit; not only with regard to the nature of its research outputs and thrusts, but also the way in which it conducts its activities. It was the first university in the country to develop a large-scale e-learning programme using the internet, which benefitted both distance and residential students. It was also the first university to introduce a technology-enhanced integrated service centre for its students. "But I think it was the University's very successful structure of campus enterprises that best

It is the "wave of creative destruction" that brings renewal and growth.

illustrates its commitment to innovation," says Prof Pistorius. These are vehicles through which the University's expertise is made available to the public through continuing education, consulting and commercialisation. These enterprises are active across the world and continue to be considered by many to be a truly world-class example of how a university's knowledge exchange and transfer should be done.

Becoming a recognised global leader

When questioned about the challenges tertiary institutions face to become a leader in the management of innovation, Prof Pistorius remarks that the University of Pretoria is already a leader in the management of innovation, certainly in a national and regional context. "The challenge all universities face in this regard is to maintain and strengthen their leadership position in a global context," he says.

Universities across the world are increasingly recognising the value and impact of teaching programmes and research in the management of innovation. This is often linked to the promotion of entrepreneurship and the incubation of new businesses. In this regard, UP has a strong brand in the GSTM. "The challenge now is to become a recognised global leader," he observes.

According to Prof Pistorius, innovation drives economic growth. "It is therefore imperative that this is addressed in a national innovation strategy that should also focus on enhancing the nation's competitiveness. "Ultimately, however, it is not policies or strategies that create growth: it is people who create a better future through innovation," remarks Prof Pistorius. "It is very often a combination of innovations from different and sometimes unexpected areas that trigger the major disruptions. It is the "wave of creative destruction" that brings renewal and growth," he says.

One must be aware of the fact that the technologies and structures that may have served us well in the past, may have reached the end of their shelf life, and should be phased out. According to Prof Pistorius, the philosopher Machiavelli reminds us that innovators have always faced resistance from those who benefit from the status quo and only lukewarm support from those who are trying their best to imagine how the disruptive innovations will contribute to a better future.

It is very often not a question of "believing when they see it", but rather of "seeing it when they believe it". The task of an innovator is therefore not always an easy one, but innovators are the real heroes to be celebrated. These are the people who bring renewal and inspire growth and prosperity; sometimes against great odds.

Embracing the Fourth Industrial Revolution

The Fourth Industrial Revolution is one of the global megatrends that is shaping debate around emerging technologies in industrial production in industry and academia, as well as among policy-makers. The concept was defined in Germany as part of the formulation of a high-technology strategy and project for the future in 2012.

The Fourth Industrial Revolution entails the convergence of cyber-physical systems, building from the Third Industrial Revolution, which was inspired by automation through the use of logical controllers. Therefore, information and communication technology (ICT) is a key component of Industry 4.0.

The state of broadband in South Africa is a major focus in ICT, as broadband technologies are the enablers for the effective and efficient utilisation of ICTs. Broadband also enables universal access to ICT services. An affordable broadband connectivity further enables universal access.

The World Economic Forum initiated a study to assess the readiness of countries to respond to the changes presented by the Fourth Industrial Revolution. The preliminary results indicate that, on the four selected maturity levels (global leaders, legacy champions, followers and high potential), South Africa is classified as a follower (Campbell, 2017). Global leaders have a strong current manufacturing base and are well positioned for the future. Legacy champions have a strong current manufacturing base, but are at risk for the future. Followers have a limited current manufacturing base, but are underprepared for Industry 4.0 and are at risk for the future. High-potential countries have a limited current manufacturing base, but are well positioned for the future. To remedy this, the National Advisory Council on Innovation (NACI) reported that South Africa has been investing in emerging research areas such as robotics, artificial intelligence, nanotechnology, biotechnology and advanced manufacturing.

The dti is contemplating developing a Fourth Industrial Revolution Strategy in conjunction with key private and public role players to address challenges and opportunities brought about by the Fourth Industrial Revolution (the dti, 2018). Furthermore, the dti is planning to develop a policy that will clarify the role of government, the private sector and labour with the hope of devising interventions required to make South Africa more competitive in the global economy.

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria finds itself in the ideal position to facilitate research opportunities for the advancement of the Fourth Industrial Revolution through future technologies. The Faculty's research has the potential to increase South Africa's competitiveness in this fast-evolving arena.

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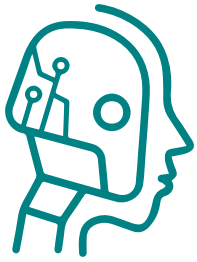
It’s the end of the world as we know it

Prof Sunil Maharaj

The Fourth Industrial Revolution (4IR) is a game-changer for the future. It is marked by breakthroughs in the fields of robotics, artificial intelligence, nanotechnology, Internet of Things (IoT), quantum computing and biotechnology, among other things. These fields are unique to the 4IR because they contribute to solutions to challenges such as food security, healthcare, education, water and energy like never before.

Both industry and academia should be vigorous about providing the right technical education and training to tackle the 4IR. Such training ranges from that at the artisan level through to the level of qualified engineers. If this does not happen, we could very easily plunge deeper into the digital divide, poverty and inequality. Nevertheless, there is no need to be nervous, because the 4IR can be seen as an opportunity that could be exploited through focused and decisive leadership. This, in turn, could help South Africa to leapfrog the digital transformation agenda and improve access to healthcare, food security and economic growth.

Canadian reports have indicated that more than 25% of jobs in that country will be disrupted by technology in the coming decade, while 50% of occupations will undergo a major skills overhaul. Lakefield University’s report on empowering Canadian youth for the jobs of tomorrow indicates that 2.4 million jobs are expected to open up in the next few years. These will require a new mix of skills that include critical thinking, social perceptiveness and complex problem solving. The report indicated that people will reskill and change jobs several times, while digital fluency will be necessary. Traditional jobs such as machinists, sheet metal workers, electricians and carpenters could shift to 21st century jobs such as drone assemblers and robotics engineer technicians. In South Africa, the 4IR brings about the potential for job losses. However, it also brings about the opportunity for people to reskill themselves for different types of work. It is particularly important for academia to train students for jobs that could only exist in 10 years time. There will be new jobs in augmented reality, coding, big or massive data science, surgery with an engineering background, unmanned flight



“You can run, but you can’t hide from the Fourth Industrial Revolution.”

– Prof Sunil Maharaj,
Dean of EBIT

controlling, robotic deep mining, as well as traffic controlling and engineering. The traditional role of many jobs will be radically disrupted, and positions such as receptionists, cleaners, farmers and traditional accountants or auditors may become redundant.

In addition, it will become essential for industry and government to embark on lifelong learning and reskilling on a continuous basis. These entities will need to help workers to become resilient in the face of the 4IR through continuous professional development. In this regard, universities could become actively involved in retraining efforts. In South Africa, the Department of Science and Technology is tackling issues around the 4IR. However, South Africa needs to invest more in research, particularly in the discipline of engineering, Areas such as smart transportation, cybersecurity, artificial intelligence (AI) and machine learning require significant investment. In order to become globally competitive, partnerships between government, industry and academia are vital.

Regardless of the challenges and opportunities of the 4IR, the human touch will still be needed for aspects such as leadership, debate, conflict resolution and ethical and moral considerations for decision making.

South Africa is ripe with opportunity. For example, the county has some of the deepest mines in the world, but safety is a major issue. The safety risk can be minimised through remote-controlled mining and inspections by robots. This has the potential to save lives and make mines more profitable. In this scenario, mine workers would have to be reskilled to occupy other positions such as mine robotic controllers and supervisors, IoT safety officers or planners. In the future, a factory could be operated through hologram technology, have driverless vehicles or automated homes. AI has the potential to bring about equity between rural and urban areas if it is backed by sufficient vision and investment. In rural areas, for example, the scarcity of good mathematics and science teachers can be augmented with a hologram of a teacher from an urban area such as Johannesburg. This can bring fifth-generation (5G) technology into the classroom in real time. With the same future technology, a highly specialised physician in the United States could instruct a robot in a rural hospital anywhere in the world to perform complicated, life-saving surgery on a patient. South Africa needs a paradigm shift in its planning and implementation, and this is what is meant by digital transformation. Regardless of the challenges and opportunities of the 4IR, the human touch will still be needed for aspects such as leadership, debate, conflict resolution and ethical and moral considerations for decision making. The fundamental skills of critical thinking, problem solving, effective communication, community building and teamwork will remain paramount. Despite great advances in technology, specifically in the field of artificial intelligence, today's most powerful 20-megawatt computer cannot come close to matching the human brain. In this new technological world, it will become essential for future, transdisciplinary research to consider all the ethical pitfalls of technology in the 4IR.

South Africa is ripe with opportunity. Partnerships between government, industry and academia are vital to become globally competitive.

The Faculty of Engineering, Built Environment and Information Technology (EBIT) is dedicated to educating its graduates in the fundamental and foundational skills of mathematics, stochastics, programming, electronics, problem solving, critical thinking and design, which can be applied in a new work environment. Its programmes include aspects pertaining to professional practice, communication skills, ethics, human values, and environmental and social responsibility.

Artificial Intelligence: myth or reality for the Fourth Industrial Revolution?

Prof Nelisha Pillay

Since the term artificial intelligence (AI) was coined, there have been various expectations of what it can achieve and how it can change society. Has AI met these expectations? Can it meet the challenges posed by the Fourth Industrial Revolution?

The First Industrial Revolution saw the emergence of the steam engine and iron and textile industries. Electricity, gas and oil, the telephone and telegraph, automobiles and planes were introduced as part of the Second Industrial Revolution. The Third Industrial Revolution was the era of electronics, the computer and nuclear energy.

In the Fourth Industrial Revolution, AI, which can be described as machine intelligence, has made an impact in industry, education and society. Some of the first contributions include diagnostic, planning and design systems, such as the scheduling of jobs on machines. As the field matured, AI has successfully been used in logistics for vehicle routing (determining the most cost-effective routes for delivery vehicles), airplane landing and financial forecasting. More recently, it has made an impact in smart cities and mining in areas such as autonomous vehicles and energy consumption. For example, this resulted in a 40% reduction in energy consumption at Google server centres. Similarly, an Australian mining company, Rio Tinto was able to improve productivity by 10% with the use of driverless vehicles at its mines.

The role of AI in the broadcasting and media industry is continually growing with current contributions in network optimisation, data analytics of customer viewership and content management. The Wimbledon 2017 highlights segment was created using AI techniques. IBM used AI software to compile the ultimate highlights package for viewers at home. Its software picked up the crowd cheering, players' facial expressions and point scoring to produce riveting two-minute highlights packages.

AI has also proven to be effective in various facets of computer security such as network intrusion detection and malware detection. Interestingly, it has also contributed to the software industry by automating the process of software engineering, which usually requires many hours of labour when done manually. The automated processes include software testing, software debugging, software optimisation and determining system requirements.

One of the contributions that AI has made to education is the provision of individualised tuition by means of intelligent tutoring systems. An automated teaching assistant at Georgia Tech University can answer student queries with a 97% accuracy. AI has also played a role in automated assessment and data analytics to identify learning difficulties among students. Based on students' responses to exercises in an online system, these techniques can be used to identify areas of difficulty they experience. It is anticipated that

we will see more widespread use of automated teaching assistants and intelligent tutors, as well as the use of data analytics, to understand learning difficulties, thereby improving throughput.

AI has had a positive impact on society. There have been major advancements in natural language processing that resulted in applications like Siri. Millions of people use GPS navigation every day. It has also challenged our masterminds in chess and Go. In 1997, Deep Blue, a chess player built on AI, beat chess champion Gary Kasparov. Twenty years later, in 2017, a machine-learning chess player, AlphaGo, beat the number one Go player in the world, Ke Jie, at the Future of Go Summit. Go is an abstract strategy board game for two players, in which the aim is to surround more territory than the opponent. The game was invented in China more than 2 500 years ago and is believed to be the oldest board game continuously played to the present day.

Meanwhile, evolutionary art has resulted in a generation of computer artists. These artists essentially use an artificial intelligence technique, called evolutionary algorithms, to create artwork digitally. This idea has also been extended to music composition. GenDash uses a genetic algorithm to produce orchestral music. Similarly, NEUROGEN employs neural networks to compose Western music compositions.

In South Africa, artificial intelligence has been used for crime prediction, including power cable theft and to prevent rhino horn poaching, in addition to applications in manufacturing, law and agriculture. In these instances, artificial intelligence techniques are used to predict when and where the crime will take place, based on previous statistics, and to prevent this from re-occurring.

There are over 20 artificial intelligence start-ups in South Africa. DataProphet, Aerobotics and MySmartFarm are among the pioneers, and incubators such as Standard Bank support them. Generally, all these start-ups employ artificial intelligence techniques to find solutions to problems with the aim of improving productivity and economic growth. Aerobotics finds solutions for the agriculture sector by employing drones to scan the farm and then applying artificial intelligence techniques to the collected data to find solutions to problems, such as the prediction of farming risks. MySmartFarm is similar and is a decision support system for farmers that analyses data such as soil moisture and weather patterns. These companies have chiefly contributed to the financial and agricultural sectors. It is anticipated that AI will contribute to an improvement in the annual economic growth rates in South Africa by 2035.

In the Fourth Industrial Revolution, AI has made an impact in industry, education and society. Its first contributions include diagnostic, planning and design systems.

Despite all its benefits, the incorporation of AI into industry and society is not without challenges. One of the main challenges is the resistance from society due to job loss fears. This can be alleviated by creating an awareness of AI and its benefit in providing support to the workforce, enabling it to be more productive rather than replacing it.

A further challenge is what happens when things go wrong and how can this be prevented. For example, a 16-month-old boy was injured by a robot at Silicon Valley Mall. On a more serious note, recently a pedestrian was killed by an autonomous Uber vehicle.

National governments need to set a code of ethics for the incorporation of artificial intelligence into industry and society.

While South Africa is not at the forefront and may not be making as big strides as better developed countries, it is making good progress, specifically within Africa. There needs to be collaboration between government, industry and universities to put business models in place. One such initiative is the Artificial Intelligence Expo Africa 2018, which was held in Cape Town in September 2018. Universities need to look at whether what is already in place is sufficient to prepare graduates with the necessary artificial intelligence skills to deal with the challenges facing industry. Such preparation can range from in-house online courses, short courses offered to industry, artificial intelligence modules included in curricula of degrees, to degrees with majors in artificial intelligence.

Prof Nelishia Pillay, Head of the Department of Computer Science in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria, delivered her inaugural lecture on 8 May 2018. She was recently appointed co-chair of the newly established MultiChoice Chair of Machine Learning along with Prof Pieter de Villiers from the Department of Electrical, Electronic and Computer Engineering. She holds a C1 NRF rating and is Chair of the IEEE Task Force on Hyper-heuristics within the Technical Committee of Intelligent Systems and Applications of the IEEE Computational Intelligence Society.

African businesses face the threat of becoming obsolete

"If African businesses do not adapt to the Fourth Industrial Revolution (4IR) they will become obsolete. At the very least, they will become isolated and unable to compete globally." These were the words of Dr Gustav Rohde, Chief Operating Officer of the global engineering company, Aurecon, at the 54th Hendrik van der Bijl Memorial Lecture. The Faculty of Engineering, Built Environment and Information Technology (EBIT), in collaboration with the South African Academy of Engineering (SAAE), hosts this annual lecture in honour of Hendrik van der Bijl, scientist, entrepreneur and industrialist, who founded Eskom, Iscor and the Industrial Development Corporation (IDC).

Dr Rohde said that he would prefer to see the 4IR as an opportunity for society, and specifically engineers, to play a much more constructive role in embracing the digital age. He emphasied that new technology enables us to offer deep scientific knowledge and solutions to complex problems.

Although there are pockets of excellence and areas of significant innovation in South Africa, the country is not adapting to rapidly evolving digital technology fast enough. A major concern is the lack of government-mandated Building Information Modelling (BIM) standards and practices. Without standard practices, the desire to create sustainable smart buildings and cities will not be possible. As a country, it will become increasingly difficult and expensive to catch up if this is not addressed urgently.

Dr Rohde cited a McKinsey report that estimates that, by 2030, at least one third of the activities of 60% of occupations will be automated. This means that, globally, up to 375 million people will need to change jobs or learn new skills. Mundane, machine-replicable jobs are threatened. However, if previous industrial revolutions are any indication, industry will see an increase in job types that did not exist in the past. New technology will spawn new industries, but the type of jobs will change.

For Dr Rohde, the challenge for formal industry will be to ensure that workers have the skills they need to transition to new jobs. Fortunately, the 4IR will allow broader and more affordable access to new technologies and applications. This should enable more start-ups and entrepreneurs to enter the labour market.

Engineers have to re-engineer themselves to think beyond their experience and knowledge of what

→ *Dr Gustav Rohde.*

works. In the 4IR, many of society's real problems will not be solved with a linear analytical approach. Engineers require a human-centric approach, which means they need to spend more time investigating whether or not they are solving the right problem. Engagement with end users and broader stakeholders allows engineers to create better and more sustainable solutions. According to a report by the World Economic Forum, some of the top skills required for the future include complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, service orientation and negotiation.

In this regard, Dr Rohde encouraged universities to focus on relevant and continued learning offerings. He noted that the knowledge and skills that helped people succeed in the past will not guarantee a successful career in the future. He emphasised the notion that lifelong learning is no longer an option, but rather an imperative to stay relevant. Nevertheless, he remains optimistic that the great entrepreneurial promise of Africa's people and their proven ability to leapfrog technological advances will allow them to leverage the opportunities of the 4IR.

CEFIM leads the way in microelectronics research

The Carl and Emily Fuchs Institute for Microelectronics (CEFIM) in the Department of Electrical, Electronic and Computer Engineering is leading the way in microelectronics research to meet the demands of the Fourth Industrial Revolution. In addition to fifth-generation (5G) technology that is already being commercialised by its inventors, several other research projects are breaking new ground.

One such research project, conducted by Piotr Osuch and Dr Tinus Stander, focuses on analogue signal processing (ASP) as a promising alternative to digital signal processing (DSP) techniques in future telecommunication and data processing solutions. This is because analogue devices outperform their digital counterparts in terms of cost, power consumption and the maximum attainable bandwidth. Second-order all-pass delay networks, the building blocks of ASPs, are currently primarily implemented in off-chip planar media, which is unsuited for volume production.

In this research, a novel on-chip complementary metal-oxide-semiconductor (CMOS) second-order all-pass network was developed that included a post-production tuning mechanism. It was shown that automated tuning with a genetic local optimiser could compensate for CMOS process variation and parasitics, which make physical realisation otherwise infeasible. Measurements indicated a post-tuning bandwidth of 280 MHz, peak-to-nominal delay variation of 10 ns and magnitude variation of 3.1 dB. This was the first time that measurement results had been reported for an active inductorless on-chip second-order all-pass network with a delay Q-value larger than 1.

To meet the demands of the Fourth Industrial Revolution, researchers at CEFIM are working towards solutions for the country's telecommunication and data processing challenges.

→ *Dr Tinus Stander.*

In another study by the same researchers, it was observed that data traffic of future 5G telecommunication systems was anticipated to increase 10 000-fold compared to current rates. This necessitates wideband millimetre-wave (mm-wave) front-haul links. This research focused on the development of an active on-chip mm-wave second-order all-pass network using a bipolar CMOS process with an effective bandwidth of 40 GHz, peak delay of 62 ps at 36 GHz and a magnitude ripple of 1.4 dB. This was the first reported mm-wave bandwidth second-order all-pass network and the first monolithic microwave integrated all-pass network with a Q-value larger than 1.

It is envisaged that further research by the research team of Dr Stander will deliver more patents and will provide the necessary solutions for the country's telecommunication and data processing challenges as we enter this new technological era.

Coping with the complexity of the Fourth Industrial Revolution by using enterprise architecture

Prof Aurona Gerber and Prof Alta van der Merwe

The Fourth Industrial Revolution (4IR) brings about the transformation of life, society and work through technology (Schwab, 2016). We are only beginning to experience the revolution that is inevitable when almost everybody and everything are connected via smart devices and sensors, giving access to unprecedented computing power and information access. This merging of digital and physical technologies often gives rise to mind-blowing prospects for industrial and manufacturing installations or any complex enterprise.

Analysing data from machines, plants and robots allows one to optimise their performance and monitor real-time health and functioning. When this information is consolidated and integrated into intelligent systems, entire facilities could be simulated and ultimately automated to run and repair themselves (Lu, 2017; Schwab, 2016; Viljoen, 2018). One can detect these trends in the effectiveness of digital twin implementations. Due to the effective integration of information from connected sensors and the Internet of Things (IoT) with intelligent systems, a virtual replica or "digital twin" of a system, plant or installation is created. Such a digital twin could be used to simulate the entire life cycle of an asset, or could be used to explore the impact of modified controls or processes (Lu, 2017; Uhlemann, Lehmann and Steinhilper, 2017).

The convergence of the physical world with technology and the resulting digitisation and virtualisation of industrial installations and enterprises creates unique management challenges. Virtualisation creates complex but intangible systems, and creating a common understanding of these relationships is difficult.

Enterprise architecture is a tool to assist with business strategy in the Fourth Industrial Revolution.

From a strategic perspective, management is challenged with questions such as the following: "How does one incorporate digitisation into business strategy?", "How does one align business with IT given digitisation and virtualisation?", "Which skills does one require and should one invest in to ensure competitiveness given virtualisation?" and "How does the integration of technologies such as IoT and Big Data influence one's business model?". Attempts to address such questions sparked renewed interest in enterprise architecture, which aims to model and manage all aspects of a business from different perspectives, allowing aligned decision-making at different levels within the business (Lapalme, Gerber, Van der Merwe, De Vries and Hinkelmann, 2016).

John Zachman is regarded as the father of enterprise architecture because of his original Zachman Framework for Enterprise Architecture (ZFEA), which he developed from a systems engineering approach (Zachman, 1987). The ZFEA specifies a universal set of descriptive representations from different views for enterprises as socio-technical systems. Since the advent of this original systems engineering perspective, enterprise architecture evolved through the employment of different goals and strategies such as business-IT alignment, enterprise-wide IT platforms and enterprise strategy (Lapalme, 2012).

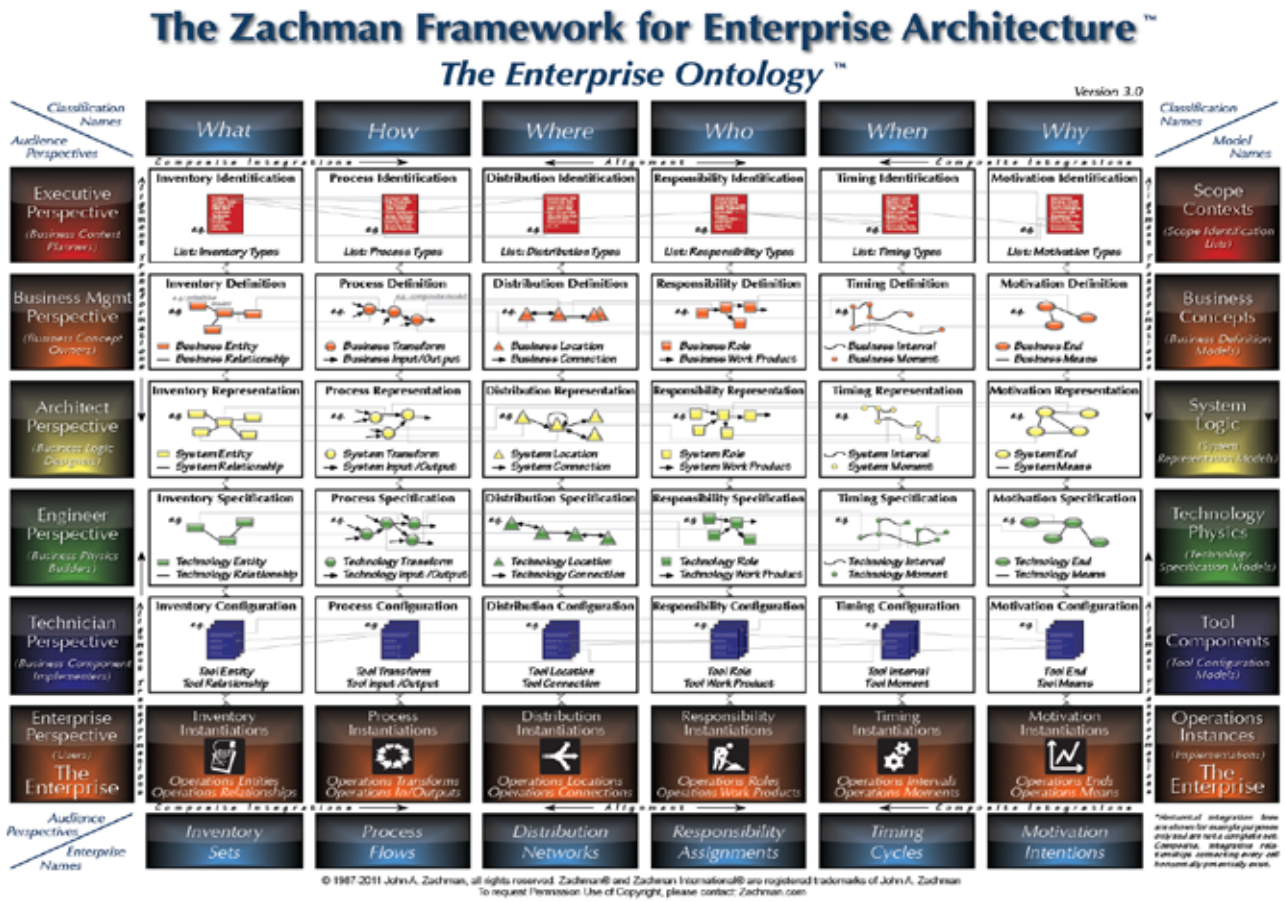


Figure 1: The Zachman Framework for Enterprise Architecture.

A recent perspective within the domain of enterprise architecture is enterprise architecture management (EAM), which is broadly defined as a management practice that establishes, maintains and uses a coherent set of models, guidelines, architecture principles and governance regimes to assist a business to achieve its vision and strategy (Ahlemann, Stettiner, Messerschmidt and Legner, 2012). EAM manages an enterprise through its enterprise architecture and proposes mechanisms and methodologies that businesses can adopt to develop and execute the business strategy of the emerging enterprises of the 4IR.

The ZFEA (see Figure 1) could be used within the context of an enterprise through its digital twin. One can recognise the systems engineering perspective in the ZFEA that demarcates the clear boundaries of a business, and depicts system components and interrelationships.

The columns in the ZFEA comprise the following design artifact abstractions: What it is made of (material), how it works (process), where the components are relative to one another (geometry), who is doing what work (operating instructions), when do things happen (timing diagrams), and why do things happen (engineering design objectives). The rows comprise design perspectives starting with the executive perspective at the top and culminating in the last row, which represents the physical instantiation or enterprise perspective.

When an enterprise architecture is fully modelled, it should be the design blueprint of the enterprise's digital twin. In addition, the different perspectives of the enterprise architecture provide unique perspectives as required by the different stakeholders of an enterprise. Unfortunately, a comprehensive enterprise architecture for a business is often unattainable due to the complexity and fast-changing nature of the business. Therefore, EAM proposes mechanisms and processes to manage risk using just-enough-modelling. When one makes the intangible business tangible for stakeholders using enterprise architecture, one has a tool to assist with business strategy in the 4IR.

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MultiChoice Chair of Machine Learning

The exciting new partnership between The Faculty of Engineering, Built Environment and Information Technology (EBIT) and MultiChoice South Africa intends to develop and sustain scarce artificial intelligence, as well as machine and deep learning skills in the country.

Prof Sunil Maharaj, Dean of the Faculty of Engineering, Built Environment and Information Technology, Mr Buti Manamela, Deputy Minister of Higher Education and Training, Prof Cheryl de la Rey, Vice-Chancellor and Principal of the University of Pretoria, and Mr Calvo Mawela, CEO of MultiChoice South Africa, at the launch of the MultiChoice Chair of Machine Learning

This partnership will see MultiChoice sponsoring a research chair in the Faculty. The Chair will guide the selection of projects and research topics for sponsorship, and will include the awarding of bursaries to students at all levels in engineering, data science and computer science. The projects will range from final-year and honours projects, to master's and PhD projects.

The field of artificial intelligence, and specifically machine and deep learning, is key to the Fourth Industrial Revolution and a truly digital future. There is a severe skills shortage worldwide, and even more so in Africa.

MultiChoice has identified opportunities to apply the very specialised fields of artificial intelligence and machine learning at various points throughout its value chain. This includes content creation, understanding what content to offer customers, customer service and improving interactions with its customers.

Partnering with an academic institution is a forward-looking way for the company to nurture these skills in South Africa. MultiChoice South Africa CEO, Mr Calvo Mawela, said that the Chair will help the company to grow its pool of talent in order for it to build a digital future. "Technology and innovation is part of our DNA as a company, so this is a natural extension to ensure that we remain at the forefront of developments," he says.

At the launch of the Chair, Mr Buti Manamela, Deputy Minister of Higher Education and Training, said that South Africa is fully on board the Fourth Industrial Revolution train, and that this initiative, which illustrates the partnership between the public and private sector, is indicative of the commitment to place the country at the centre of development. Vice-Chancellor and Principal of the University of Pretoria, Prof Cherly de la Rey, also expressed that it is vital for higher education institutions to invest in researching the next waves of technology.

Absa Chair in Data Science

With the ever-increasing amount of data available in all spheres of society, data analysis and understanding has become a complex problem. We are no longer faced with data sets of megabytes or gigabytes, but rather with data sets of terabytes and even petabytes. This increase in data, along with the demand for new, efficient data analysis techniques, has spawned the Data Science revolution. In answer to this, the University of Pretoria (UP) has filled the position of the Absa Chair in Data Science.

The Chair is hosted in the Faculty of Engineering, Built Environment and Information Technology (EBIT), in collaboration with the Faculty of Natural and Agricultural Sciences. It will focus on the promotion of multidisciplinary, collaborative research programmes in Big Data and Data Science across EBIT departments and other faculties. The goal is for UP to play an active role as an academic leader in the fields of Big Data and Data Science at national and international level. International collaboration is considered essential to further the scientific agenda and to forge valuable industrial partnerships.

Dr Vukosi Marivate has been appointed as chairholder of the Absa Chair in Data Science. He completed his BSc Electrical Engineering (Information Option) and his MSc Electrical Engineering degrees at the University of the Witwatersrand. He then moved to New Jersey in the United States to pursue his PhD in Computer Science at Rutgers

I am looking forward to leveraging Data Science to look at our local challenges, as well as using text data (which is very abundant) to extract insights.

– Dr Vukosi Marivate

Dr Vukosi Marivate.

University as a Fulbright Science and Technology Scholar. He was also a Pre-Doctoral Leadership Development Institute Fellow at this institution.

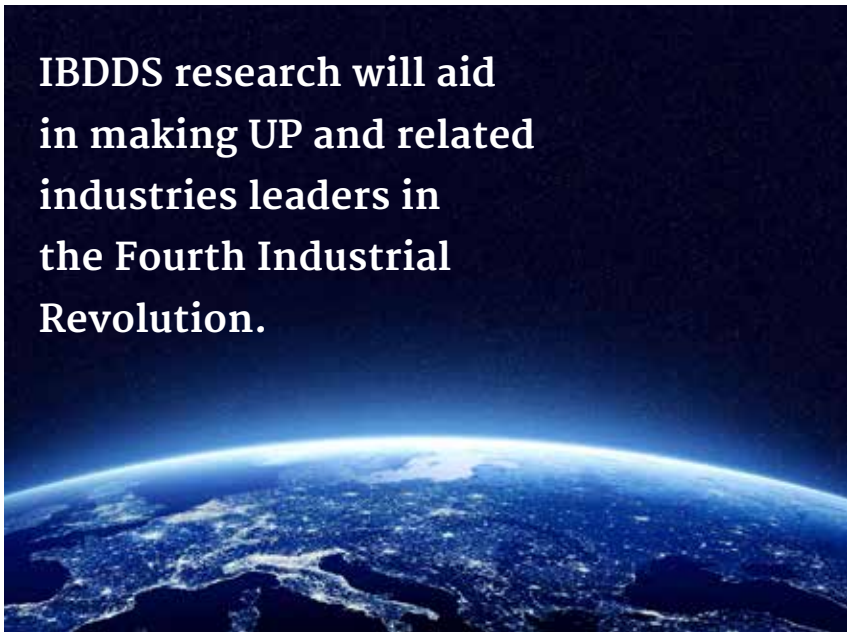
After obtaining his PhD, Dr Marivate led a Data Science team at the Council for Scientific and Industrial Research (CSIR). His team focused on Data Science for impact in South African society. Their work related to the development of machine learning and artificial intelligence methods to extract insights from data. At UP, Dr Marivate is interested in Data Science for social impact, using local challenges as a springboard for research problems. This has meant that, over the last few years, Dr Marivate has worked on collaboration projects for problems that include public safety incident detection on social media, models for better resource allocation, energy prediction and understanding government documents through text analysis, to name a few. He is also passionate about developing young people through research supervision and internships.

The Faculty is excited about its latest partnership with Absa, who is sponsoring the Chair. Absa is committed to furthering Data Science research in recognition of the importance of data in unlocking solutions in banking and other sectors in Africa.

Institute for Big Data and Data Science

Prof Andries Engelbrecht

The Faculty of Engineering, Built Environment and Information Technology's Institute for Big Data and Data Science (IBDDS) represents a multi-, inter- and transdisciplinary research cluster in the domains of Big Data (BD) and Data Science (DS). The IBDDS was created as a strategic initiative to leverage existing expertise in a number of research areas that form the foundations of BD and DS research.



The research agenda of the IBDDS mainly focuses on data analytics and the development of new, efficient machine learning and statistical learning approaches to extract hidden knowledge from small to very large data sets. Data analytics technology will be developed for stationary data and non-stationary data, specifically data streams. Many data analytics problems require the analysis of multiple data streams, often of different data sources and types. Another focus is on the development of algorithms to fuse and analyse such heterogeneous data streams.

BD and DS research, via the IBDDS, is targeted towards providing BD and DS solutions for the following main research focus areas:

- Astrophysics and the Square Kilometre Array (SKA)
- Digital forensics and cybersecurity
- Health and biological sciences, ranging from bioinformatics and genomic research to disease control and lifestyle research
- Financial and economic sciences, with a focus on the insurance, banking and finance industries
- Learning analytics, with the main purpose to understand and optimise learning
- Engineering sciences, with a strong focus on supply chain engineering and smart transportation

For all of the above focus areas, BD and DS technologies will aid in making UP and related industries leaders in the Fourth Industrial Revolution (4IR) in the specific context of the African continent.

These activities in the Faculty are strategically led by its leading, internationally recognised academics:

- Prof Andries Engelbrecht: IBDDS Director, DST/SARChI Chair in Artificial Intelligence
- Prof Jan Eloff: DRS Chair in Cybersecurity
- Prof Nelishia Pillay: MultiChoice Joint-Chair in Machine Learning
- Prof Pieter de Villiers: MultiChoice Joint-Chair in Machine Learning
- Dr Vukosi Marivate: Absa Chair in Data Science

DRS Chair in Cybersecurity

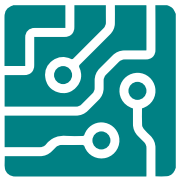
Prof Jan Eloff

Industry awareness and collaboration is essential for research to deliver relevant solutions. In the world of cybersecurity, this is no different. DRS, a South African cybersecurity firm that specialises in information security, has entered into a partnership with the Faculty of Engineering, Built Environment and Information Technology to form the DRS Chair in Cybersecurity.

Prof Jan Eloff has been appointed as the DRS Chair in Cybersecurity. He is an internationally recognised researcher in cybersecurity with over 5 000 citations based on his research outputs. Prof Eloff holds a B-rating from the National Research Foundation (NRF) and also serves as an editorial board member of multiple leading international journals in cybersecurity. He is a full professor in the Department of Computer Science, and has been serving as the Faculty's Deputy Dean for Research and Postgraduate Studies since 2016. He also leads the Cybersecurity Research Group. His research focuses on safeguarding platforms against societal cyber threats, and is currently concerned with the convergence of cybersecurity and Big Data Science.

The Chair aspires to be a world-class cybersecurity research facility, cognisant of the needs of the broader South African society and industry. It intends to focus on the following thrusts:

- ***Thrust 1: Cybersecurity and Big Data Science:***
  The focus here is to advance state-of-the-art research in the intelligent proactive detection of cyber crime. Identity deception (fake identities) on social media platforms is of particular interest, based on international collaboration with the Hasso Plattner Institute in Potsdam, Germany. Experimental work on the Data Science cluster, installed at the University of Pretoria and sponsored by the Department of Science and Technology, will continue.
- ***Thrust 2: Cybersecurity and Insider Threats:***
  Here, the focus is on the early detection of cyber-related threats on organisational level through the intelligent analysis of relevant company information such as email-communications. Anomaly detection is of particular interest in various application domains.



The Chair will focus specifically on cybersecurity as it relates to Big Data Science and insider threats.

The Chair also focuses on the following elements:

- Human capital development in cybersecurity for South Africa, where the aim is to create a pipeline of scare skills. This includes the identification of strategic areas related to cybersecurity, where specialised training is needed by the industry at large. As part of the human capital development programme, bursaries for undergraduate and postgraduate students will be awarded to develop the next generation of cybersecurity experts. Furthermore, DRS will offer cybersecurity student internships, giving students the necessary exposure to enhance their work-readiness.
- Collaboration between DRS and the University to identify potential research projects for postgraduate students on honours, master's and PhD levels.
- Developing collaboration opportunities and pooling resources for identified objectives through the business networks of both DRS and the University.

Intelligent and smart transportation systems

Prof Wynand Steyn

In the Faculty of Engineering, Built Environment and Information Technology, the Department of Civil Engineering's activities in the intelligent and smart transportation arena focus on the active and continuous collection of transportation users' activities and experiences, infrastructure conditions and user-infrastructure interaction. These studies support infrastructure owners' decisions regarding transportation services, infrastructure provision and levels of service, with the objective of an optimised and economically efficient transportation system.

The various subdisciplines within the transportation arena focus on the design, construction, maintenance and operation of transportation infrastructure. In the design phase, the emphasis is on the incorporation of novel materials into the pavement or rail structure to ensure sustainable structures with increased service lives. This typically ensures lower user and operational costs. The use of nano-modified stabilisers is evaluated for the modification of various marginal road construction materials. The design processes also entail the appropriate application of advanced computer models to evaluate the interaction between applied tyre loads and pavement structure response as the foundation of improvements in the combination of materials that make up the facility's structure.

In future, access to the data of an advanced national pavement materials reference laboratory will enable the incorporation of a database of actual material response inputs into these models, improving prediction and reducing the risks associated with pavement design.

During the maintenance and operation phase, it is important to predict and monitor the road or rail user's use of the facility or pavement, the interaction between the facility and the user, and ways of lowering the operational costs and improving the service life of the transportation system. This is done through an array of infrastructure sensors that are installed within pavement, rail and bridge structures to monitor their response to the environment. Traffic loading and user sensors are installed in vehicles and rolling stock to track use and monitor the interaction of the infrastructure between road and rail on the one hand, and user and vehicle on the other. This interaction includes the effect of the facility's condition on aspects such as agricultural cargo damage, which leads to alternative route selection and improved maintenance actions.

Data from structures such as bridges is used to improve engineering materials, as well as the structural response, design and operational models. Similar evaluations of infrastructure responses are conducted in the rail environment. The data is then modelled to develop and improve road or rail condition models that are implemented in an infrastructure maintenance system to allow for the prediction of future condition, and thus the budget requirements of the facility.

Various sensors that are developed in the Department are installed in rail and pavement structures to actively and wirelessly monitor responses to moving traffic. Most of this fieldwork is backed by the extensive laboratory evaluation of materials in the Department's structural, geotechnical and centrifuge laboratories, as well as in tests on the rail tracks on the University's Experimental Farm.

On campus, intelligent and smart transportation will become embodied over the next two years through the construction of a new Engineering 4.0 facility on the Hillcrest Campus.

This facility, which is funded through a South African National

Roads Agency SOC Ltd (SANRAL) grant, together with a UP grant, will initially entail an integrated road material reference laboratory, training laboratory and research laboratory.

This is combined with a live traffic research facility and an accelerated pavement testing (APT) facility on campus. The combination will allow for the development of an extensive database of road material properties in the country, and the evaluation of models in the APT and live traffic lanes by monitoring pavement response under both accelerated and live traffic.

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, 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. It will coordinate with international proficiency schemes to ensure that the South and southern African road materials testing processes are on par with international practice.

The integrated laboratory and live traffic facility will enable the Faculty's School of Engineering to combine its capacity in road engineering, sensor technologies and data science to further the goal of an intelligent transportation system where more economical solutions are provided for the provision, operation and maintenance of transportation infrastructure.

Intelligent and smart transportation will become embodied in the Engineering 4.0 facility. Its 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, high-quality research facilities and skilled staff.

Monitoring road and rail infrastructure

Prof Hannes Gräbe, Prof Wynand Steyn, Prof Stephan Heyns, Prof Schalk Els and Prof Johan W Joubert

Economies worldwide rely heavily on large rail and road infrastructure to move heavy loads and large quantities quickly and efficiently. A good example is the Sishen-Saldanha iron ore line, which is 861 km in length, and carries trains as long as 3 780 m (with eight locomotives and 342 wagons). These railway lines need to be monitored regularly for wear, cracks and other defects. The current monitoring processes are manual, labour intensive and costly. Monitoring requires an expert to visually inspect the infrastructure and carry out the required measurements. Defects are noted manually to prevent further deterioration and rolling stock damage.

A road/rail infrastructure monitoring system (RIMS) is proposed that can be used for the condition monitoring, characterisation and maintenance of road and rail infrastructure and the measurement of vehicle dynamics. The RIMS will have four main measurement components: a global positioning system (GPS), high-accuracy light detection and ranging (LiDAR) for creating digital elevation models, a 360° video camera and a sophisticated vehicle response measurement system (VRMS). The VRMS will comprise a range of sensors to measure the dynamic behaviour of the vehicle in response to the condition of the infrastructure.

The system will be installed on a road or rail vehicle that can reach measuring speeds of 100 km/h and 120 km/h on rail and road respectively. The proposed development will comprise the purchase of four standard but sophisticated measuring systems, followed by the integration and installation of the four systems on a vehicle that will be used on the road and rail networks in southern Africa.

A large proportion of the total project cost will be allocated to developing the integrated measurement system. The departments of Civil Engineering, Mechanical and Aeronautical Engineering, and Industrial and Systems Engineering at the University of Pretoria will use the interdisciplinary road/rail vehicle.

The vehicle and the proposed measurement system will be world class and unique, with high-impact research being carried out in the following fields:

- Transportation logistics and the use of high-accuracy GPS data to improve route planning in the country
- Road condition monitoring and the use of telematics data to address a range of road/vehicle interaction issues
- Vehicle dynamics measurements on road and rail to improve various aspects related to the design of road and rail vehicles
- Track condition monitoring by using vehicle dynamics, optical data and machine learning

In the final development stage of the integrated measurement system, an autonomous system will be developed that can be installed on standard road and track vehicles to carry out the proposed measurements and stream the data to a central server. Software will be developed to analyse the data and produce road, rail and vehicle condition and performance index values for improvement and maintenance actions. The equipment will be extremely versatile as it will be able to do condition monitoring on the South African road network as well as Transnet Freight Rail and Passenger Rail Agency of South Africa (PRASA) railway lines.

In addition, it will be running on the proposed 1.5 km Engineering 4.0

The road or rail vehicle and the proposed measurement system will enable high-impact research to be undertaken.

test track to be constructed on the University's Hillcrest Campus, which will allow students and research collaborators to develop, improve, test and calibrate the state-of-the-art measurement systems.

The equipment will be capable of a range of multidisciplinary measurement and monitoring functions, including the following:

- Creating high-resolution, digital 3D images of the road and rail infrastructure to millimetre accuracy covering a distance of at least 50 m on both sides of the transportation centre line
- Measuring the dynamic response of the vehicle as a result of the road or rail condition
- Tracking movement of the vehicle in 3D space to establish the relationship between energy use, freight load and the topography of the route
- Mapping the rail micro-structure in combination with previously funded equipment through the National Equipment Programme (NEP) to identify rail wear and fatigue as part of track maintenance planning
- The autonomous measurement of vehicle dynamics to quantify track roughness and enable the tracking of track deterioration with time
- The creation of 3D artificial intelligence (AI) imaging for the automation of track inspections

The versatility of the equipment in terms of capabilities is rooted in the fact that it is a normal vehicle that will drive on road and rail. The vehicle can firstly be instrumented so that the dynamics of its different components can be measured in response to the quality of the infrastructure it is driving on. Secondly, it can be used for the installation of a range of digital, optical and other condition monitoring systems that can then be brought in close contact with the road and rail. Lastly, the vehicle, with enough space at the back and a crane to lift and move its load, will be able to perform the function of a test vehicle on instrumented track and road infrastructure. It can therefore be used to perform test runs on instrumented pavements and pull other equipment on the road and track for research purposes.

Civil engineering research

Track inspectors who perform visual inspections cannot readily or easily detect certain track defects. The increased use of automated inspection systems provides the opportunity for inspectors to conduct more thorough visual inspections at problem areas identified by the automated inspection systems, which helps to prevent derailments.

The combination of high-density, geospatial and visual components will be achieved by attaching the developed measurement system to the road/rail inspection vehicle. Research will be conducted into the use of augmented and virtual reality systems with data source integration.

This research will establish a basis for a next generation of visual track inspection methods that could be carried out from an office with virtual reality or on-site through augmented reality. This research will improve the effectiveness of inspections, defect identification, root-cause determination and maintenance planning. South Africa is renowned for excelling in heavy haul rail technologies and this development will put the country in the lead when it comes to automated track inspection and visualisation technology.

The versatility of the equipment in terms of capabilities is rooted in the fact that it is a normal vehicle that will drive on road and rail.

RailPro Africa (Pty) Ltd

Track geometry is usually measured by a dedicated track infrastructure measurement vehicle, such the IM2000 measuring car. This vehicle can measure the profile, alignment, superelevation, twist and gauge of the track geometry. The global trend is to move away from track geometry measurements towards vehicle dynamics measurements, thereby interpreting the excitation of the vehicle through track irregularities and quantifying the condition of the track by the resulting vehicle dynamics and not the geometry of the track. The system that will be developed to measure the dynamic movement of the vehicle with accelerometers and linear variable differential transformers (LVDTs) will be used to research the relationship between track geometry and vehicle dynamics. This will enable the development of machine learning procedures that will be used to establish safety and maintenance limits for track infrastructure.

A different philosophy regarding track condition measurement has been implemented in Australia and to a lesser extent in North America. This involves the installation of autonomous measurement systems on normal freight wagons that are part of revenue-generating trains.

These systems are self-powered, switch on and off when vehicle movement is detected and stream the data to central servers via remote data transfer. A further research project will entail the development of such an autonomous measurement system for South African conditions. Aspects such as the risk of vandalism and theft will have to be considered when developing a rugged system for the South African rail network. Alternative power supply and data communication protocols will have to be considered. The system will initially be tested on the road/rail vehicle and will then be transferred to a normal freight wagon. The fact that in-train vehicle dynamics is measured will give a much more realistic assessment of track condition and derailment risk, as opposed to a special measurement vehicle.

Research on the evaluation of vehicle-pavement interaction and the response of road vehicles towards road unevenness and riding quality builds on the current evaluation of these aspects upon the condition of transported cargo, and the subsequent damage to such cargo on uneven roads. This leads to significant economic losses that can be averted through adequate road monitoring and maintenance programmes. The new dedicated road/rail measurement/inspection vehicle will enable researchers to do more research on aspects of uneven loads. An array of road condition measurement devices will be installed on the vehicle and measurements will be taken on a variety of road surfaces simultaneously. Significant advances are expected in this field. In addition, research output from this project will contribute towards the life cycle cost analysis (LCCA) or engineering-economic analysis of competing alternatives in the design and implementation of transport infrastructure projects. Minimising life cycle costs (present worth value) provides a prolonged service life with reduced user impact costs and, therefore, increases the sustainability (socio-economic and environmental benefits) of transport infrastructure systems.

Mechanical engineering research

The purpose of the project on AI with multiple cameras to identify road and rail surface micro-texture is to develop an automatic, rolling stock-based, condition-monitoring system for road and railway infrastructure monitoring. The system will acquire high-quality images of the road or track superstructure that will enable AI technologies to successfully identify predetermined infrastructure component defects and evidence of fatigue as part of the condition-monitoring inspections and maintenance planning on a rail or road network. This research will greatly enhance the subjectivity and repeatability of visual track inspections and will be applied to the rail, fasteners and sleepers of the track infrastructure.

The motion resistance, braking capability and comfort of vehicles are closely related to surface roughness and road hazards such as potholes and other defects. The aim of the tyre model development for the energy efficiency and road hazard detection project is to develop and parameterise tyre-road interface models that can be used to analyse ride comfort, braking and motion resistance with the aim of improving health, safety and energy efficiency.

Industrial engineering research

To date, researchers in the Department of Industrial and Systems Engineering have mainly relied on third-party data to study the vehicle telemetry and truck movements. Although valuable, the anonymised data sets are limited and miss crucial variables that inform an understanding of truck and driver behaviour. In the case of trucks, for example, the vehicle's load (and commodity), engine or powertrain, and environmental conditions such as road grade are necessary to more accurately interpret the movement (acceleration and speed) of a vehicle. Higher resolution positional data is also required to measure the turning radius and the associated effect it has on tyres (especially solid axles) on sharp corners. Research projects will be initiated to capture the mentioned dependent parameters as measured by the monitoring system on the road/rail vehicle and relating this to the independent variables related to the characteristics of the vehicle. The research will be used to optimise the cost of logistics in South Africa.

This research and development is aligned with innovation in the transportation sector (road and rail), as well as infrastructure development. The transportation planning and cost of logistics research will impact on the use of fossil fuels and global trends in the use of renewable energy. The proposed developments and research topics are highly innovative, as they will establish South Africa at the forefront of road and rail condition monitoring with autonomous measurement systems.

Multimodal transport modelling

Prof Johan W, Joubert

South Africa is characterised by high levels of inequality. This inequality is especially visible in the country's economic landscape and the lack of access to basic services and mobility. Many of these problems are still artefacts of the country's political past. To address these issues of inequality, government is charged with providing infrastructure in an equitable way. This infrastructure needs to answer the question: "Who gets the benefit of the infrastructure?" It also needs to answer the politically loaded counter-question: "Who pays for those benefits?"

To help government make transport infrastructure decisions, models are used as abstractions of reality to test what-if scenarios such as the possible improvements in traffic flow if another lane is added, the predicted ridership if the bus frequency is increased, or the number of people that will divert from the highway when the Gauteng highways are upgraded and tolled.

Models are useful because they allow for testing these scenarios in a safe, controlled environment, without a costly and disruptive trial-and-error approach in practice. To know whether they are succeeding at their endeavours, government must be able to measure the effect of their decisions at the individual and household level, and not the aggregate level, which is the state of practice. Unfortunately, state-of-practice modelling tools in large-scale scenarios like an entire city or province only allow for modelling at zonal level, so the detail impact on individuals, households and anyone who travels within the same zone is lost.

It is for this reason that the Centre for Transport Development in the Faculty of Engineering, Built Environment and Information Technology actively participated in the development of multi-agent transport simulation (MATSim) tools, and has taken the lead locally and in the rest of Africa. Essentially, each individual is modelled as a member of a household, through an entire day. Every activity in which the individual participates and the modal connection between activities is modelled explicitly. Figure 1 shows an example of the City of Cape Town just before 08:00. Every dot represents an individual and the colour of the dot represents the type of activity in which the individual is participating. Large quantities of green represent children at school, while red represents people at work. The key locations and corridors along which employment is found are quite visible. The high concentration of people at home is of concern, especially in low-income settlements in the Cape Flats, such as Mitchells Plain, Khayelitsha and Blue Downs.

The MATSim models include all modes of transport and look at the movement of both people and goods (road freight). Detailed synthetic populations, which are accurate at both household and individual levels, were generated using Bayesian networks applied to census data, and were published in the public domain (Joubert, 2018a). Early results of the multimodal models were published in Joubert, Fourie and Axhausen (2010).

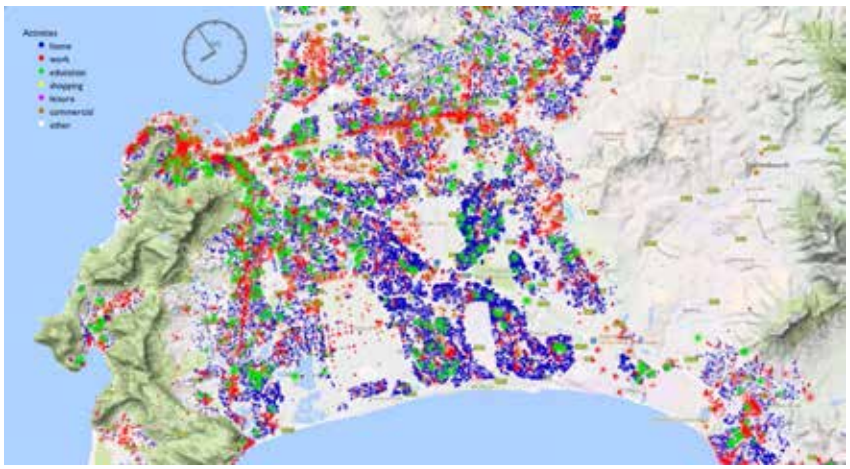


Figure 1: Cape Town residents' activities just before 08:00.

Modelling minibuses

Agent-based models can accurately capture the behaviour of the agents, the agents' interaction with one another and their interaction with the environment. In the context of transport, the agents are typically individuals and public transport vehicles. In South Africa, two additional agent types are frequently modelled. Firstly, there are the minibus taxi (paratransit) operators and associations. This was popularised by Neumann, Röder and Joubert (2015) and more formally in the doctorate of Neumann (2014).

In the absence of well-defined routes, the agent-based approach allows one to accurately capture and predict the dynamically evolving routes as the associations adapt to changing commuter demand patterns.

Freight

The second agent type that researchers in the Centre for Transport Development focus on is road freight and commercial vehicles. Commercial vehicles move between businesses and between businesses and end consumers to ensure that people have the goods and services they need.

It is the nerve system of the economy (see Figure 2). As urbanisation increases, more people move to the cities. Along with this trend, one sees an increase in the consumption of produce. These goods are delivered to the local supermarket by means of a commercial vehicle. This is where the conflicting objective arises. People want to buy their fresh goods from their local Woolworths store, but do not want to see trucks on the road.

The state of practice in transport modelling is to use tools, which were originally based on and developed for modelling the movement of people, and to apply it to commercial vehicles. However, Joubert and Axhausen (2011) showed that trucks move differently to people. They do not follow typical 24-hour days, and they perform many more activities than people do. They also typically travel over much longer distances.

Commercial vehicles do not just travel for the sake of travelling; they connect businesses with one another. These connections between businesses is what is studied using the field of complex network theory (Joubert and Axhausen, 2013; Joubert and Meintjes, 2015; Viljoen and Joubert, 2018). If one understands how businesses connect with one another, one can anticipate the impact on traffic if a company relocates a warehouse, for example, or if new vehicle restrictions are placed during certain times of the day (like truck bans). These evaluations are critical to the economic wellbeing of the country. It may be convenient not to have any trucks on the road during the morning peak commute to work, but the implication is that the company needs to increase its fleet size to account for all deliveries during fewer operating hours. This, in turn, has significant logistics cost implications that the consumer will ultimately feel through higher produce prices on the shelf. Again, it is the poor of our society – those living on the periphery of the cities – that are impacted on the most.

Better models for decision-making about transport and transport infrastructure means that researchers can anticipate (intended and unintended) consequences more accurately (Joubert, 2018b).

→ *Figure 2: Movement of approximately 20 000 trucks over a 24-hour period.*

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Better data for planning transportation systems

Prof Christo Venter

The Centre for Transport Development (CTD) in the Department of Civil Engineering is undertaking several research projects to evaluate and improve the use of new data sources in the planning and management of transport systems. It is forging partnerships with private sector technology providers, public sector units, and international research partners.

Some recent and emerging research questions include the following:

- ***How does Uber fit into the transport ecosystem?*** Examining the travel patterns of Uber passengers is crucial to understanding the emerging role that Uber is playing, both as a feeder to and from public transport, and as a mode in its own right. The CTD is collaborating with Uber South Africa to map big travel data from Uber, and is developing metrics to measure the potential for e-hailing alternatives to better support and connect with public transport services.
- ***How efficient are minibus taxi services, and how can they be integrated into multimodal transport networks?*** Through partnering with Big Data technology providers such as GoMetro that collects route and operational data from multiple minibus-taxi operators in South Africa, the CTD is developing a better understanding of the operating conditions that shape the informal taxi industry, and the impacts of specific operating decisions on passengers' travel time and costs. The goal of this research is to find and test ways of improving the services that are provided by informal operators, for instance by better integrating them with emerging bus rapid transit (BRT) systems.
- ***What can the Gautrain do to make it easier for passengers to get to its stations?*** The first and last mile trip to and from a rail or bus station is often a barrier to greater public transport use, whether it entails a long walk, a slow bus ride, or an expensive taxi trip. Researchers at the CTD are collaborating with the Gautrain Management Agency to collect data on the access trips of Gautrain users, which will allow them to estimate choice models to measure the quality and attractiveness of various first or last mile options. These models will be used to develop strategies for Gautrain and BRT planners to help attract more passengers to current and future lines.
- ***How does accessibility mapping help promote public participation in transport planning?*** In collaboration with the Massachusetts Institute of Technology (MIT), one of the CTD's partners in the BRT+ Centre of Excellence, researchers at the CTD are testing the use of mapping accessibility patterns to improve communities' engagement with authorities during the planning of new transport routes and services. A number of interactive workshops have been held in Tshwane, during which the mapping technology Collaborative Accessibility-based Stakeholder Engagement (CoAxs) has been tested to map the impacts of the contentious Line 2B of the BRT between Hatfield and Menlyn. The workshops demonstrated the potential usefulness of the technique to help non-technical audiences explore the impacts of transportation projects.

Transportation is a cross-sectoral enterprise that requires skills across a broad range of disciplines, including planning, engineering and social sciences.

Using Data Science to analyse waste collection activities

Dr Elias Willemse

Waste management is an important basic service provided by local municipalities and consists of the effective management of waste from its creation to its final disposal. Given their budgetary constraints, it is critical for municipalities in South Africa and other developing countries to get the most out of their limited waste collection resources.

To do so, a waste manager may need to solve the following decision-making problems:

- Determine the best type of vehicle to service a specific area
- Measure and compare the efficiency of the collection crews and utilisation of vehicles
- Predict how much a new subarea will cost to service
- Calculate a reasonable contracting fee to pay a private collector to service an area

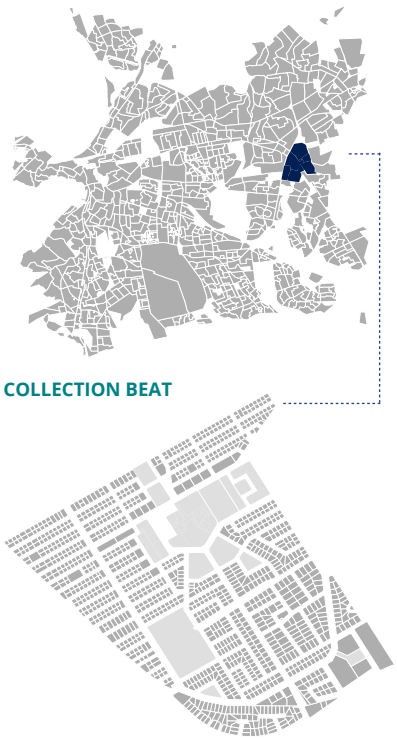
To solve the abovementioned problems, waste managers have to have access to accurate waste collection data. Using inaccurate, incorrect or outdated data can lead to the implementation of ineffective, costly waste collection technologies. Unfortunately, the budgetary constraints that necessitate municipalities to get the most out of their limited resources may hinder them from obtaining the required waste collection data to do so.

Ideally, municipalities should be able to continuously and cheaply measure the amount and location of the waste each household generated and to continuously monitor how well their existing resources are being used to manage waste. By using Data Science techniques, the Centre for Transport Development at the University of Pretoria is developing models that meet these requirements. The models can generate detailed collection statistics for each collection area, also referred to as a beat, over an entire service region (see Figure 1).

Data challenges in developing countries

Much research has been devoted to optimising waste collection and transportation operations, but a key assumption is that the data needed for better collection planning is readily available. This assumption rarely holds in developing countries. Some of the data needed by municipalities includes the following:

- The amount, location and composition of waste generated by residents and businesses
- Location and available capacity of waste disposal and recycling facilities



→ *Figure 1: Detailed collection statistics for each collection area.*

- Collection resources, including personnel and vehicles, and their operational activities

From the above categories, information on detailed waste generation is difficult to accurately obtain, since it cannot be measured for all citizens on a detailed and continuous basis.

An ideal solution would allow municipalities to continuously and cheaply measure the amount and location of waste generated per household. It would also allow municipalities to continuously monitor how well their existing resources are being used to manage waste and how much waste collection is costing the municipality.

Figure 2a shows GPS traces for 550 collection vehicles over the course of a single day, servicing a region of 32 km by 38 km in a South African city.

Figure 2a: GPS traces for 550 collection vehicles over the course of a single day.

The area has 883 pre-allocated collection beats (areas), as shown in Figure 2b, each serviced by a vehicle once per week. One such beat, outlined in black, will be used in the article to illustrate the Data Science models.

By combining the GPS records with readily available data sources, such as census data, detailed collection information can be inferred for each collection area.

Figure 2b: The 883 pre-allocated collection beats.

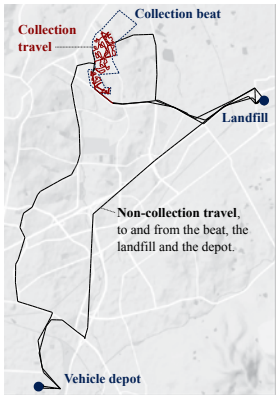
Calculating vehicle utilisation and collection costs

To calculate the collection cost of the beat, all the GPS records in the collection area were isolated and analysed. The collection vehicle assigned to and service day of the area could then be identified. After that, the GPS records for the assigned vehicle were analysed per collection day. Figure 3 shows the GPS travel path, and resulting model output, of the vehicle on one collection day.

For the analysis in Figure 3, it was assumed that the assigned vehicle was collecting waste when it travelled at a slow speed inside the collection area. The time spent collecting waste and travelling to and from the collection area could then be calculated. The analysis was repeated over 23 consecutive collection days and the vehicle utilisation and total cost of servicing an area were calculated.

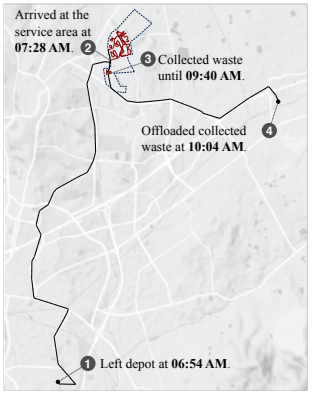
As shown in Figure 4, if the cost of the vehicle and crew are known, the annual cost to service the area can be calculated, and ultimately used to calculate per capita costs. The information can then be used to benchmark collection costs across different areas and to prioritise collection improvements. It can also be used to establish subcontracting fees.

FULL COLLECTION ROUTE



Complete route (06:54–12:51)

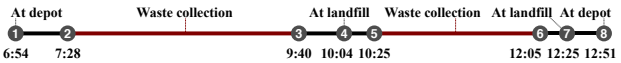
COLLECTION ROUTE SPLIT OVER ITS TWO SUB-ROUTES



Sub-route 1 (06:54–10:04)

Sub-route 2 (10:04–12:51)

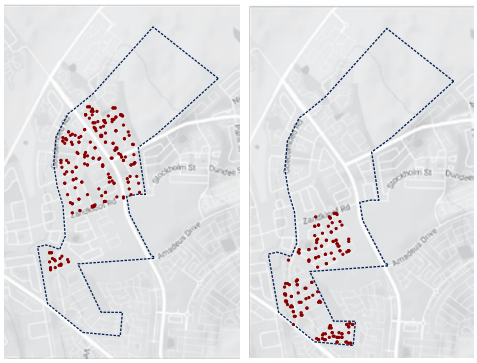
VEHICLE ACTIVITY TIME-LINE OVER THE COURSE OF A DAY



SUB-BEAT ANALYSIS

Through the GPS records it is possible to identify where and when the vehicle collected waste (2–3 and 5–6) and when the vehicle disposed of the waste (4 and 7). The two landfill visits result in two sub-routes. If weighbridge data is available, the weight of the waste as captured at the landfill visits can be allocated to sub-routes as shown on the right. The analysis can be automatically repeated for each collection day to create detailed waste collection information on a sub-area level.

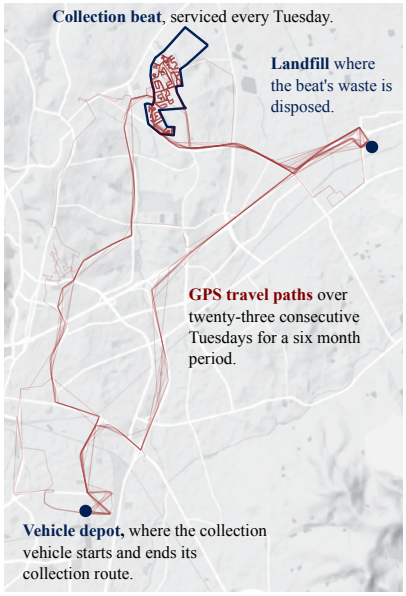
VEHICLE LOCATION WHILE COLLECTING WASTE



Collection of sub-area via sub-route 1 and sub-route 2

Figure 3: The GPS travel path, and resulting model output, of the vehicle on one collection day.

COLLECTION VEHICLE GPS RECORDS



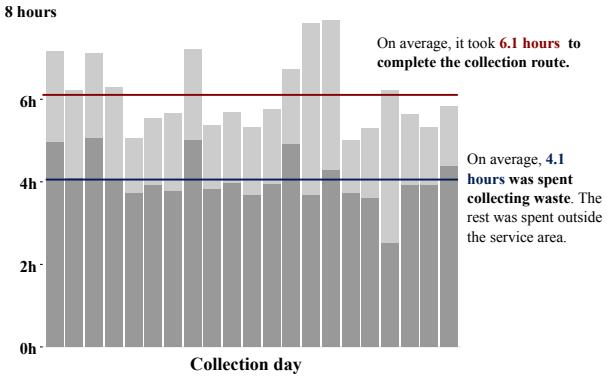
COST CALCULATIONS

At assumed cost of R16.50 per km for the waste collection vehicle and R180 per hour for the crew, it costs the municipality on avarage R2 402 to service the area on its collection day. Of the total cost, the capital and operational cost of the vehicle contributes 54% and the human resources 46%. Of the annual total cost, 58% can be attributed to indirect waste collection activities, while only 43% can be attributed to direct waste collection activities.

INFERRED COLLECTION INFORMATION

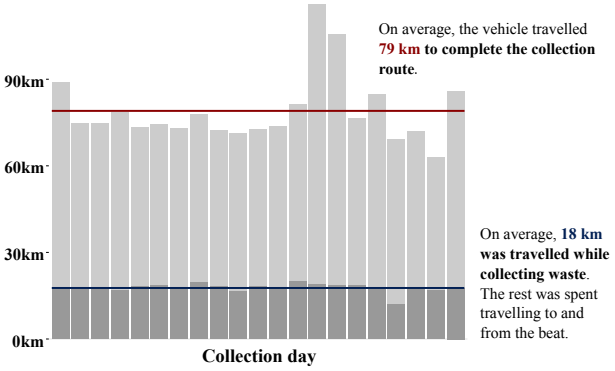
Time required to service the beat per collection day, including time spent collecting waste (bottom) and time spent outside the service area (top).

The vehicle spent 66% of its time collecting waste. The other 34% was spent travelling to and from the collection area and offloading waste.



Distance travelled to service the beat per collection day, including travel distance to collect waste (bottom) and travel distance to and from the beat (top).

A total of 22% of the distance travelled by the vehicle was for collecting waste. The other 78% was for travelling to and from the collection area.



→ *Figure 4: The collection vehicle GPS records, inferred collection information vehicle utilisation and cost calculations.*

Per capita collection statistics

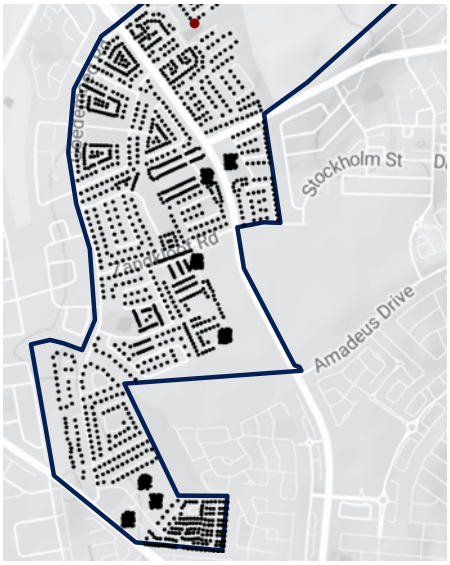
Lastly, by combining the collection information with a census-based synthetic population, it is possible to calculate detailed per capita (per person) waste collection costs for the area, as shown in Figure 5.

If weighbridge data is available, income-level based waste-generation rates and costs can also be calculated for each collection area.

Advantage of the models

The main advantage of the models is that the analysis is automated and can be repeated for each service area in the region. A further benefit is that the models make use of existing and cheaply obtainable data sources. The automation of the analysis makes the models cost-effective and allows for the continuous and accurate monitoring of waste collection activities and generation rates on a service-area level.

CENSUS-BASED SYNTHETIC POPULATION FOR THE COLLECTION AREA



AREA TOTALS

The collection area contains approximately 3 838 people, residing in 1 491 households. The density of the area is 2.57 people per household.

PER CAPITA COST

It costs the municipality R125 247 per year to service the area. The annual service cost per household is R84 per year, and the cost per person is R34 per year.

→ *Figure 5: Census-based synthetic population for the collection area.*

Notes

1. Python and R were used for the GPS analysis and primary visualisations. The figures were then imported into Inkscape and the shown infographics generated. All three are open-source.
2. The synthetic population, vehicle time and distance, and resulting utilisation statistics are based on actual GPS records and census data.
3. The R16.5 per km and R180 per hour costs are used for illustrative purposes only.

Numerical modelling of flexible pavement layers

Prof James Maina

A sound road network – which in South Africa is most often designed and evaluated using the South African pavement design method (SAPDM) – plays a key role in the socio-economic development of the country to support the movement of people and goods, as well as access to education and training, employment and health care. In the recent past, South Africa has experienced considerable growth in both passenger and freight traffic volumes because of increased economic activities. The high level of truck traffic is causing premature road failures, mostly on provincial and municipal road networks.

The South African National Roads Agency SOC Ltd (SANRAL) teamed up with the roads industry, the Council for Scientific and Industrial Research (CSIR) and academia in an effort to improve the SAPDM and the design of roads in South Africa. The universities of Pretoria and Stellenbosch played a prominent role in this regard. The partnership called for skills development and the building of capacity to optimise design, maintenance and repair strategies against premature road failures. To achieve this, a better understanding of the properties of materials used in road constructions and the modelling of the structural behaviour of pavements were deemed necessary.

The accurate numerical modelling of the behaviour of road pavement layers is an important requirement for the design and evaluation of road pavements. This modelling includes the prediction of pavement performance under the action of traffic loading, and environmental factors such as temperature.

Depending on the complexity of the models, the properties of pavement layers that may be considered are wide-ranging – from linear or nonlinear elastic to cross-anisotropic, through to linear visco-elasto-plastic. Some properties, such as cross-anisotropic, are not only related to the placement and compaction of the pavement layers, but are also inherent to the materials used. Other properties, such as linear visco-elasto-plastic, are specific to asphalt concrete, and depend on the speed and magnitude of traffic loading, as well as the environment in which the road or runway is located.

The SAPDM, which uses the multilayer linear elastic (MLLE) theory to determine pavement structural responses, was introduced in the late 1960s and early 1970s. Since its introduction, developments in material characterisations and numerical modelling have taken place. In addition, advanced computer software and hardware have been developed to determine the stress, strain and displacement distributions of pavements under surface loading in a matter of seconds.

Tyres form an essential interface between vehicles and road pavement surfaces as they are the only parts of a vehicle to be in contact with the road, and to transmit the vehicle loading to the road surface. In order to better understand the impact of increased loading on roads, studies on tyre-road interaction have gained prominence in recent years.

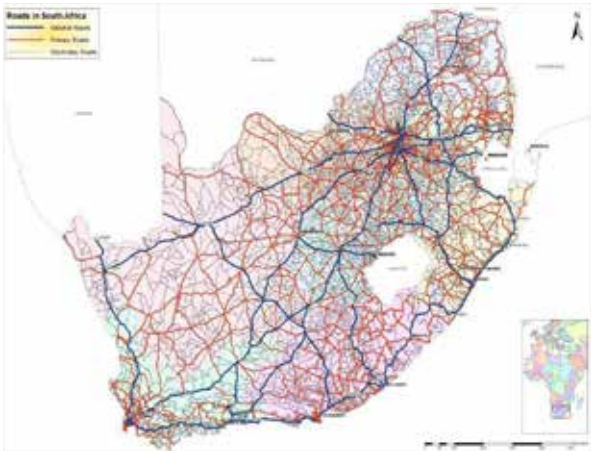
Although modern-era trucks transport heavier cargo, they are using relatively fewer tyres than their predecessors and are thus purported to be exerting much higher contact stress on the road surface.

Generally, trucks mainly use two different types of tyres: single (wide-base) tyres and conventional dual-tyres. A single wide-based tyre is a proportionately larger and more robust tyre that is used on trucks carrying heavier cargo. It is expected to replace the dual-tyre, on condition that it causes minimal damage to the existing road infrastructure.

To be able to carry the same load as dual-tyres, wide-base tyres may have a much greater tyre inflation pressure, and a larger individual "footprint". Research on tyre-pavement stresses has shown tyre-pavement contact stresses to be mostly rectangular and occasionally circular in shape, depending on the loading magnitude and the inflation pressure.

Research championed by Prof James Maina of the University of Pretoria in collaboration with Prof Futoshi Kawana of the Tokyo University of Agriculture and Prof Kunihito Matsui of the Tokyo Denki University involved the development of the two-pronged numerical modelling of flexible pavement layers.
The first development enabled consideration of both circular and rectangular surface loadings. The second development introduced the capability to consider cross-anisotropic material properties (with isotropic properties as a special case). These models are not available in the existing SAPDM software.

A trend that has been identified is that, although modern-era trucks transport heavier cargo, they are using relatively fewer tyres than their predecessors. As a result, they are purported to be exerting much higher contact stress on the road surface. This motivated the researchers to not only conduct numerical modelling on the effect of circular loading, but also to investigate the effect of rectangular loading on the surface of a multi-layered pavement system. They realised that a good understanding of tyre-road contact stress, together with the ability to model the macroscopic behaviour of materials when subjected to varying traffic loading and environmental conditions, is important for better road pavement



→ *The South African national road network.*

design and improved pavement performance.

For the purpose of this study, a pavement structure comprising five main layers, constituted of isotropic and cross-anisotropic (transversely isotropic) material properties, was analysed, first for a circular surface loading, and then for a rectangular surface loading. In order to vary some of the layer properties with depth, the main layers were sub-layered, resulting in a 17-layer pavement system.

In both phases of the research (modelling for a circular surface loading and modelling for a rectangular surface loading), solutions were used to compute responses at different positions within a pavement structure. In the first phase, a tyre vertical load of 21.5 kN on a square patch with a diameter of 238 mm, resulting in a 483 kPa contact stress, was used in the analysis. In the second phase, based on historical tyre loading on South African roads, a tyre vertical load of 21.5 kN on a rectangular patch of 231 mm by 238 mm, resulting in a 390 kPa contact stress, was used in the analysis.
In both phases of the research, all layers except the asphalt layer were modelled with isotropic, linear-elastic properties. The asphalt layer was modelled with cross-anisotropic, linear elastic properties.

In the modelling for a circular surface loading, the vertical stiffness in the asphalt sub-layers showed a marginal increase close to the surface. This was a function of the effect of temperature variations with depth for a specific time of the day. In the modelling for a rectangular surface loading, the vertical stiffness in the asphalt sub-layers also showed a marginal increase close to the surface that may be attributed to binder ageing, but more probably to a slight reduction in the temperature conditions. In both phases of the research, the top and bottom asphalt sub-layers showed significant reduction in the effective horizontal stiffness resulting from cracking, which initiated from both the top and the bottom of the main asphalt layer.

This research resulted in the development of a numerical tool for the analysis of an elastic multilayer system under the action of both circular and rectangular loading, considering both cross-anisotropic and isotropic material properties. This numerical tool is capable of performing analyses for an unlimited number of points in an elastic multi-layered pavement system with an unlimited number of layers, and on the surface where an unlimited number of uniformly distributed circular and rectangular loads act. It can therefore be used to improve the design, evaluation and analysis of road and runway pavement systems.

After rigorous validation and verification, this software has become the analysis engine of the new SAPDM and will be used to evaluate the effect of surface loading on road pavements. When the updated and more comprehensive road design analysis and evaluation system is launched, it will be under the name South African Roads Design System (SARDS).

Vehicle dynamics and mobility research gains momentum

Prof Schalk Els

Vehicle dynamics and mobility is of general importance to South Africa as vehicles of different kinds remain the main mode of transport for the majority of people and local industries. The Vehicle Dynamics Group (VDG) in the Department of Mechanical and Aeronautical Engineering has taken research in this field to new heights over the past decade.

In order to be internationally competitive, but still be relevant to South Africa, the VDG has strong collaborative links with industry and academia at local, national and international level. Its focus is multifaceted and includes the following:

- It exposes scholars and students to vehicle dynamics and mobility.
- It promotes the study and understanding of vehicle dynamics and mobility through student designs and projects in the final-year Mechanical Engineering curriculum.
- It promotes the study, understanding and application of vehicle dynamics and mobility nationally and internationally through the South African version of the Baja SAE® competition in collaboration with local industry.
- It encourages research activities through postgraduate studies at master's, doctoral and postdoctoral degree levels.
- It facilitates national and international collaboration with other institutions.

The objective of the VDG's research is to improve vehicle safety, occupant safety, comfort, reliability and efficiency. This is achieved by applying the fundamental principles of science and engineering. Extensive use is made of experimental, analytical and computational tools and techniques to achieve a deep fundamental understanding of vehicle dynamics. Much emphasis is placed on the realisation and demonstration of new technologies.

The expertise that is currently available in the VDG has been established by funding obtained from local and international research institutions and industry partners. Its global recognition as a centre of excellence is rapidly increasing. Papers presented at local and international conferences, as well as published peer-reviewed journal articles, ensure continued exposure to the international research community. This helps to establish a wide international network of scientific and engineering knowledge.

The VDG has a strong experimental focus and capability, both for laboratory and field testing. Testing capabilities range from laboratory tests on individual components to full vehicle systems that are tested on the proving ground and under realistic operating conditions. Experimental data is used extensively to develop and validate models of vehicles and components.

Research focus areas

The VDG has a number of research interest areas, which include the modelling and characterisation of tyres, the measurement and modelling of terrain properties, and controllable suspension research.

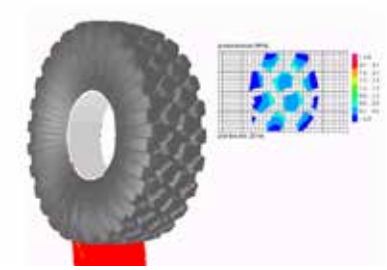
Tyre characterisation and modelling

Research is focused on the large off-road tyres that are used in the commercial, agricultural, mining, construction and forestry sectors. Aspects of interest include force generation, rut depth, slip and slip angle dependencies. Important issues are fuel efficiency, wear, and off-road and on-road performance. Unique testing equipment has been developed to test and model these tyres in laboratory and field conditions, using both test rigs and *in situ* testing on vehicles.

This includes wheel force transducers to measure the force and moment

components between rim and tyre, and a tyre test trailer and static tyre test rig to test tyres for the purpose of parameterising tyre models.

Measurements are also conducted inside tyres to determine the deflection of the inside of the tyre carcass as the vehicle is driven over any terrain. This has extensive application possibilities in terramechanics research, as well as in the validation of tyre models.



Tyre modelling using FTire.

Wheel force transducer fitted to an off-road vehicle tested on snow.

Tyre test trailer.

Static tyre test rig.

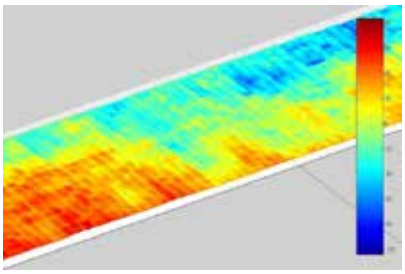
Terrain property measurement and modelling

With the exception of aerodynamic forces, all other forces acting on a vehicle are transmitted through the tyre-terrain contact patch. Accurate vehicle dynamics analyses are therefore not possible without proper knowledge of the terrain properties. Highly detailed terrain profiles are required for use in simulation and model validation. Measured terrain profiles must be developed into road models for use in simulation. The measurement and modelling of terrain profiles are applicable to hard terrains and soft soil. These profiles are necessary to validate and calibrate existing rough road profilometers and improve their accuracy.

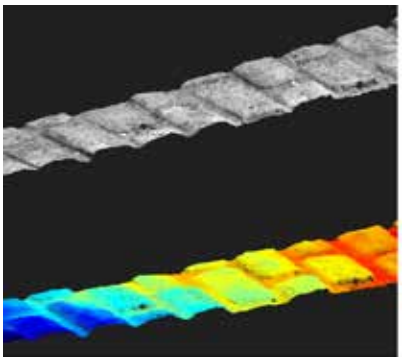
Profilometers are used to obtain profiles of representative terrains. Measured terrain profiles must be implemented in simulation in the form of two- and three-dimensional road models that can be used in conjunction with tyre models to determine the accuracy of the modelling approach. Terrain roughness is important for operator comfort and vibration research. Macro profiles, such as side slopes and inclines, are important for performance analysis such as traction, fuel consumption, braking and optimal gear selection. The characteristics of soft soil directly influence vehicle performance and operational efficiency.

Digital image correlation techniques are used to accurately measure three-dimensional terrains for use in simulations, to measure vehicle parameters such as slip and slip angle, and terrain parameters such as terrain profile, roughness and rut depth, and to determine specifications for vehicle design requirements such as ride. Not only do these techniques improve the VDG's measurement capability, but they can be implemented in real-time to provide driver feedback and control feedback. Stereo vision and other camera techniques are used to enable the measurement of vehicle dynamics that it was not previously possible to measure. This gives many additional possibilities and accuracy, as well as resolution benefits. By means of vehicle dynamics test and measurement systems, the VDG uses novel techniques, developed in-house, to measure vehicle dynamics parameters such as slip angle and tyre slip over off-road terrains such as sand, gravel, mud, snow and ice. Commercial sensors often fail to give accurate measurements under these conditions.

Servo-hydraulic testing facility used for damper characterisation and life tests.



Can-Can terrain profilometer results for Belgian Paving.



Digital image correlation profile showing texture.

Controllable suspension research

Many agricultural vehicles, such as tractors, have limited suspension systems, or do not have any suspension systems at all. Higher mobility, better ride comfort, handling and improved safety requires modern technology. Controllable suspension systems can more easily adapt to changes in vehicle mass due to payload changes while maintaining ride, handling and safety. Ride height control on the suspension can be used to lift up the vehicle, which will increase ground clearance for better off-road mobility. At higher speeds, ride height can be reduced, which will improve high-speed handling and roll-over stability.

Additional technologies, such as semi-active springs and dampers, active anti-roll bars and all-wheel-steering, can adapt the vehicle to different operating conditions and can even be applied to improve structural life.

The ride comfort vs. handling compromise

The suspension characteristics that are required to achieve good vehicle handling differ substantially from the characteristics required for good ride comfort. This problem becomes more severe when the change in payload is significant. Characteristics for on-road driving also vary significantly from those required for good off-road mobility. The situation becomes even more complex when roll-over and structural life requirements are added to the list of specifications. A significant contribution can be made by developing algorithms for making the ride comfort vs handling decision and controlling the suspension and other vehicle systems accordingly. Techniques for classifying the driving scenario are new approaches that can add significant value to the decision-making process.

Advanced driver assist systems and control of autonomous vehicles

The complexity of modern vehicles and operational requirements often put additional strain on drivers. The control of autonomous vehicles on off-road terrain remains a considerable challenge. Steering control, speed control, transmission control and braking control need to be integrated into a workable solution. Many technologies that are developed for autonomy can be applied as driver aids and can therefore be implemented on normal vehicles where control can improve comfort and safety by aiding the driver.

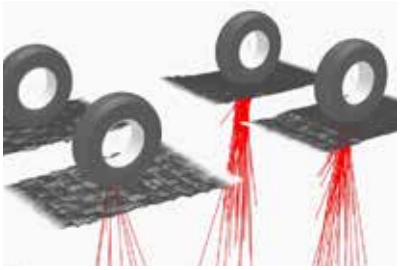
By means of the VDG's autonomous control and advanced driver assist research platform, it is able to develop and evaluate state-of-the-art autonomous control for off-road vehicles, and to test its advanced driver assist and collision management systems.

→ *Fishhook roll-over test using steering robot.*

Vehicle dynamics modelling

Although acceptable results have been achieved in developing validated vehicle models, there is still significant room for improvement. The vast majority of the validated models were only developed for four-wheeled vehicles. Vehicles with multiple axles, as well as multiple tyres per axle, pose additional challenges. Many heavy vehicles fall into this category and the modelling of ride comfort, handling, roll-over, stability and forces applied to vehicle structure must be verified and validated against test results. The main aspects of importance are operator comfort, handling and roll-over.

Commercial vehicles are constantly being upgraded to carry higher payloads while reducing vehicle weight. Furthermore, the difference in weight between empty and fully laden vehicles is substantial and has a negative effect on vehicle mobility



→ *Testing 3D tyre-road interaction in vehicle dynamics.*

and dynamics. The reduction in mobility is a direct result of the added mass that lowers the power-to-weight ratio, increases the pressure of the tyres in contact with the terrain and detrimentally changes the vehicle dynamics due to the increased centre of mass height and mass moments of inertia. It is therefore of utmost importance to address vehicle roll-over stability. The scope for saving lives is enormous.

By means of vehicle dynamics modelling, testing and model validation, the tyre, terrain and component testing and modelling capacity of the VDG's equipment can be used to develop full, non-linear vehicle dynamics models to predict ride comfort, handling and the stability of vehicles.

Other activities

The VDG has a rapid prototyping facility to keep concept-to-implementation time to a minimum. The typical application of this capability is to provide a quick turnaround time for applications such as the custom manufacture of adapters for a wheel force transducer fitment to any rim, the design and machining of custom wheel force transducers for any given vehicle, and the design and manufacture of custom data acquisition systems for the measurement of any vehicle-related scenario.

Furthermore, the VDG is able to provide a facility for the complex testing and characterisation of components such as springs, dampers and elastomeric components. Potential future focus areas are that of asset integrity management and technology for Africa.

Developing research-based solutions for the mining industry

It is generally acknowledged that the mining industry in South Africa is one of the country's main sources of economic growth and social transformation. A challenge for the Department of Mining Engineering is therefore to develop innovative, quality, research-based solutions to ensure the sustainability of the industry.

Cognisant of the important role it has to play to enhance the research capability of the mining industry, the Department of Mining Engineering is committed to conducting cutting-edge research. This is driven in particular by its concern about the ongoing economic downturn in certain commodities and the uncertainty that exists in the industry's ability to continue to serve as a major provider of employment in the country.

Its intellectual strengths are located in two industry-sponsored research chairs, the Harmony Chair in Rock Engineering and Numerical Modelling, and the African Explosives Limited (AEL) Intelligent Blasting Chair for Innovative Rock-breaking Technology. It also hosts a leading research centre that conducts multidisciplinary contract research for industry, the Mining Resilience Research Centre.

Many collaborative and cross-cutting research initiatives have been created within the Department. This contributes to enhancing its profile as a leading, research-intensive department that pursues excellence in teaching and learning and is recognised for the quality of the graduates it delivers.

The Department's national and international standing is strengthened by research in several key focus areas, including rock mechanics and underground mine design, rock-breaking and surface mining, mine ventilation engineering, risk management and mineral economics.

Its research activities are further enhanced by the immersive technology located in the Kumba Virtual Reality Centre for Mine Design. This is particularly relevant when researching operational risks across industries by making use of the Centre's innovative approach to information optimisation and visualisation.

In addition to its industry-sponsored research chairs, the Department benefits substantially from external funding from industry.

This contributes to reinforcing its reputation as a leading, research-intensive mining engineering department in Africa, which is recognised internationally for its quality, relevance and impact, and for developing people, creating knowledge and making a difference locally and globally.

Rock engineering expertise delivers cutting-edge research

The Department of Mining Engineering plays a leading role in enhancing the capabilities of the mining industry through cutting-edge research. Rock mechanics and underground mine design is one of its key focus areas. The significance of this research for industry is reinforced when one considers the recent occurrence of a number of rock-burst accidents in the South African gold mining industry. This resulted in a renewed focus on methods that can be used to mitigate this risk.

A typical deep gold mine stope showing the installed support.

South Africa's gold mines are the deepest in the world, and a large number of seismic events are recorded on a routine basis. The research programmes that were conducted in the 1960s and 1970s, mostly led by the former Chamber of Mines Research Organisation (COMRO) and – in later years – the Council for Scientific and Industrial Research (CSIR) Miningtek, have resulted in a number of innovative developments to assist with the establishment of a safe mining environment.

These include numerical techniques based on elastic theory to simulate the stress concentrations in irregular tabular mining layouts, yieldable support systems with energy-absorbing capabilities, and mining strategies such as preconditioning and centralised blasting to control seismicity.

However, according to Prof Francois Malan, Director of the Department's Mining Resilience Research Centre, not all of these techniques are perfect. "The commonly used assumption of an elastic rock mass at great depth and the design criteria associated with this, such as energy release rate, are only first-order assumptions," he explains. "Extensive fracturing of the rock mass is encountered underground on some reef horizons and this affects the behaviour of the rock mass."

The research that is conducted to investigate the development of improved design criteria for deep tabular layouts can be used to assess and mitigate the risk of rock-bursts. Such criteria will be of interest for mines that target remnant areas, as this may prolong the life of a number of older shafts.

A key feature of this research is the use of limit equilibrium models in boundary element codes to simulate the fracturing of the rock mass on the reef plane. This approach has allowed the effect of parameters, such as mining rate, to be investigated for the first time. These models also compute energy dissipation in the fracture zone near the edges of excavations, which allows the released energy to be used as a measure of expected seismic activity. They also address a number of the weaknesses in the traditional use of the energy release criterion for the design of deep gold mine layouts.

Research outputs

The high quality of the Department's research is indicated by the publication of articles in leading

international journals in 2018. Examples include "A limit equilibrium fracture zone model to investigate seismicity in coal mines", published in *International Journal of Mining Science and Technology*, and "Simulation of tabular mine face advance rates using a simplified fracture zone model", published in *International Journal of Rock Mechanics and Mining Sciences*.

Further research published by Prof Malan, who is also the acting chairholder of the Harmony Chair in Rock Engineering and Numerical Modelling, and Prof John Napier, an extraordinary professor in the Department, examines the reassessment of continuous stope closure data using a limit equilibrium displacement discontinuity model.

This research made use of time-dependent closure data in deep hard-rock mines, which appears to be a useful diagnostic measure of rock behaviour. The researchers realised that understanding this behaviour may lead to enhanced design criteria and modelling tools. The time-dependent limit equilibrium model was therefore used to simulate historical closure profiles collected in the South African mining industry. Earlier work indicated that a visco-elastic model was not suitable for replicating the spatial behaviour of the closure recorded underground. The time-dependent limit equilibrium model available in the TEXAN code appeared to be a useful alternative as it could explicitly simulate the on-reef, time-dependent failure of the reef. A key finding of this research was that the model gave a much better qualitative agreement with the underground measurements. The research also determined that explicit simulation of the fracture zone in the face appeared to be a better approach to simulating the time-dependent behaviour in deep hard-rock stopes.

Another article, published by Prof Malan and PhD candidate Dr Michael du Plessis, focused on mining with crush pillars. Once in a crushed state, the residual strength of the pillar provides a local support function and must support the hanging wall to the height of the highest known parting. The design of crush pillars is mainly limited to specifying a width-to-height ratio of approximately 2:1. A pillar is required to crush close to the face while it is being formed. On many mines, the crush pillar system is problematic, owing to the difficulty in controlling pillar sizes. This is mainly caused by poor drilling and blasting practices. As a result, pillar crushing is not always achieved.

The research that is conducted to investigate the development of improved design criteria for deep tabular layouts can be used to assess and mitigate the risk of rock-bursts. Such criteria will be of interest for mines that target remnant areas, as this may prolong the life of a number of older shafts. A key feature of this research is the use of limit equilibrium models in boundary element codes to simulate the fracturing of the rock mass on the reef plane. This approach has allowed the effect of parameters to be investigated for the first time.

In this research, the influence of mining losses (potholes) and the use of sidings were investigated as possible contributors that impact on crush pillar behaviour. A limit equilibrium model was implemented in a displacement discontinuity boundary element program that was used to demonstrate crush pillar behaviour. The results were compared to the pillar behaviour at an underground investigation site, which supported the preliminary findings of the research.

Industry support

Research into rock engineering and numerical modelling in the Department is supported by Harmony Gold, which has sponsored the Harmony Chair in Rock Engineering and Numerical Modelling since June 2013.

This research chair was established as a vehicle that could assist the South African mining industry to conduct research in rock engineering, particularly the use of numerical modelling techniques in the field. It is envisaged that this research will ultimately be able to serve the whole mining industry and elevate substantially more rock engineering issues than originally intended. Research projects focus specifically on rock engineering issues in order to provide a safer working environment in deep-level hard-rock mines. The current focus of its work is to examine the effect of mining rate on excavation stability. Harmony is particularly excited about research to calibrate the software that has been developed by researchers in the Department with actual underground mine closure rates and seismic behaviour at selected Harmony

Gold operations, according to Peter Steenkamp, Chief Executive Officer of Harmony Gold.

Harmony Gold had originally committed its financial support to this research chair until the end of 2016, but has extended its support for a second three-year period until the end of 2019. This is due to its recognition of the importance of the research conducted to the current and future hard-rock mining environment of South Africa.

A second research chair was established in the Department at the beginning of 2018 with the support of African Explosives Limited (AEL) Mining Services, which will continue until the end of 2020.

Research in the AEL Intelligent Blasting Chair in Innovative Rock-breaking Technology focuses on determining safe clearance radii for blasting and ensuring that South African blasting practices have kept pace with new developments internationally. Research will focus specifically on three-dimensional blast simulation and the visualisation of new research, as well as incorporating research into blasting engineering practices. This research will pave the way for future investigations into innovative rock-breaking technology. The research chair is set to establish the University as a centre of excellence for emerging rock-breaking technologies and related mining methods.

Cross-cutting research initiatives

Following the recognition in academic circles that mining in South Africa was not meeting the full expectations of investors, government, employees, organised labour, communities and other stakeholders for a number of complex reasons, the University of Pretoria established the Mining Resilience Research Centre (MRRC) in the Department of Mining Engineering.

Researchers in the MRRC coordinate research on many of the cross-cutting initiatives that affect the sustainability of the mining industry.

→ *Prof John Napier.*

Its vision is to establish itself as a leading international contributor to solutions for complex problems in the mining industry. Through rigorous, integrated scientific research, it intends to increase the resilience of the mining industry by contributing towards practically implementable solutions.

It has received external research funding from the Mine Health and Safety Council (MHSC) specifically to conduct contract research for the Council related to mine health and safety.

An important element of the work of the MRRC is the platform it creates for academia, the industry and government to work collaboratively to research critical issues within the mining industry. In this regard, it has spearheaded the University's engagements and coordination in the South African Mining, Extraction, Research, Development and Innovation (SAMERDI) initiative. This is a collaborative initiative among the CSIR, the University of Pretoria, the University of the Witwatersrand and the University of Johannesburg, which is coordinated by the Mining Precinct, a division of the CSIR. Several research projects have been undertaken under the auspices of this initiative, including the mechanisation of gold and platinum group metals (PGM) mines using drilling and blasting, the non-explosive rock-breaking of gold and PGM mines, and the development of real-time information management systems for underground mining.

→ *Prof Francois Malan.*

International recognition

Members of the MRRC and the Harmony Chair in Rock Engineering and Numerical Modelling have received several accolades for the quality of their research.

In 2017, Prof Malan was invited to present the Franklin Lecture of the International Society of Rock Mechanics (ISRM). This lecture recognises members of the ISRM who have made a significant contribution to rock mechanics.

Dr Du Plessis was awarded the prestigious ISRM Rocha Medal for 2018. This international award is presented for the best PhD in Rock Mechanics for that particular year. Of particular interest is the fact that Prof Malan, who had supervised Dr Du Plessis' research, was awarded the Rocha Medal in 2001 for his own PhD research.

In 2018, Prof Napier was elected as a foreign member of the National Academy of Engineering in the USA. The mission of this academy is to promote a vibrant engineering profession by marshalling the expertise and insights of eminent engineers to provide independent advice to the federal government on matters involving engineering and technology. Only 262 foreign members are elected.

Immersive technology enhances research in mining engineering

Since its launch in August 2015, the Kumba Virtual Reality Centre for Mine Design in the Department of Mining Engineering has contributed to teaching and research to benefit the mining industry.

The 3D 360° cylinder in the Kumba Virtual Reality Centre for Mine Design.

This centre strives to be a world-class, innovative resource for bringing real-world scenarios to individuals to enhance their exposure to their chosen industry, as well as to allow technical and other practitioners the opportunity to simulate plans and designs in a risk-free environment with minimal time and resource allocation.

It comprises a three-dimensional (3D) 360° cylinder that can accommodate 25 people. It is supported by a state-of-the-art 76-seat lecture hall and a 3D cinematic theatre that can seat 47 people. By making use of virtual reality, it presents an environment for "immersive" experiences that are destined to change the face of education, research and design in mining and other industries that incorporate operational risk. It also facilitates an improved understanding of difficult mining layouts and other technical aspects pertaining to mining.

There are numerous operational benefits to be gained from interpreting and portraying actual data in the high-quality and realistic visual format offered by the virtual reality centre. These include the following:

- Operational productivity and overall effectiveness can be achieved by playing out different scenarios before committing resources to a particular course of action.
- Engineers, planners and other stakeholders are better positioned to make choices that take into account the long-term and socio-economic consequences of their financial and technical decisions by first considering these in a virtual environment.
- Incidents that may pose an operational risk can be minimised by simulating activities without actually exposing people or equipment to harm.
- Virtual reality allows multiple data sets to be converted into strategic business information. Once decision-makers are exposed to an immersive experience that portrays their data visually, it becomes easier to make decisions and improvements on project design and other activities that operationalise strategies.

These benefits are underpinned by the centre's innovative approach that enables the optimisation and visualisation of information by incorporating immersive-related technology such as augmented virtual reality and other relevant and related technology. It is anticipated to revolutionise the way industries create solutions to complex challenges.

As South Africa prepares for the Fourth Industrial Revolution, EBIT focuses its research efforts on bringing competitive knowledge to industry, education and society.

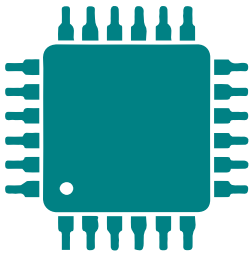
– Prof Sunil Maharaj, Dean

Research team investigates the efficiency and functionality of thermoSMART devices

Prof Josua Meyer

Modern microprocessors in smart phones, high-performance computing clusters or advanced electronic equipment in space have a common need: increased parallel functionality at top processing speed and durability. Maintaining top processor speeds generally means high power consumption, which causes power dissipation and heating.

In order to sustain high speeds and reliable operation, this heat must be dissipated, ideally at the same rate as it is generated. The current state-of-the-art conventional air-cooling is ineffective with 40% of air not playing a role in dissipating heat (Nakayama, 2018). To help solve this problem, a research team from the University's School of Engineering will participate in a two-year Horizon 2020 project with 17 other universities from across the world.



ThermaSMART will address the multi-scale nature of phase-change right from evaporation at the solid substrate to the ensuing vapour-phase dynamics that results in condensation, leading to the cross-fertilization of ideas relating to processes with shared characteristics.

Horizon 2020 is the biggest European Union (EU) research and innovation programme ever with nearly €80 billion in funding available over seven years (2014 to 2020) – in addition to the private investment that this money will attract. The project looks at the smart thermal management of high-power microprocessors using phase-change. The project will be known by its acronym, ThermaSMART. The team of researchers will include the cream of the research talent in the Department of Mechanical and Aeronautical Engineering, together with their associates. These include Prof Josua Meyer, Prof Jaco Dirker, Dr Mohsen Sharifpur, Prof Johan Slabber, Dr Christiaan Le Roux, Prof Ken Craig and Dr Alex Lexmond.

ThermaSMART aims to ensure the design success of phase-change-based cooling technologies specifically for microelectronics used both terrestrially and in space. While the efficiency of phase-change-based cooling devices is very high, recent developments in phase-change-based cooling devices have largely been empirical as there is limited understanding of the complexities of flow phenomena occurring in them. This empirical approach has been a major bottleneck in terms of technology uptake and further innovation, and has hampered full exploitation of the potential of phase-change cooling.

Since 2006, only a few low-power devices (such as those for cooling laptops) have been employed, but this limited understanding has meant that the potential for the miniaturisation of devices has yet to be exploited. These complexities are the basis of the ThermaSMART team's activities, which

Prof Josua Meyer, Chair of the School of Engineering, leads the ThermoSMART research team.

include the dynamics of populations of evaporating or condensing droplets and bubbles, the influence of patterned substrates on droplet or bubble populations, the phase-change of binary or multicomponent mixtures, and vapour clouds in chambers. Through the planned secondments, the project team aims to understand these complexities in phase-change phenomena, develop mitigation strategies and exploit their role in the design of micro-channel-based cooling devices. They envisage that the results of the investigation will be design principles, together with an appraisal-cum-assessment of applications where these complexities will play a decisive role that will impact on device efficiency and functionality.

ThermaSMART will address the multi-scale nature of phase-change right from evaporation at the solid substrate to the ensuing vapour-phase dynamics that results in condensation, which is a particular strength, leading to the cross-fertilization of ideas relating to processes with shared characteristics.

This collaboration will enable knowledge transfer and access to unique facilities at the National Aeronautics and Space Administration (NASA), Intel, Brazilian Furnas, Hitachi, IBM, the Indian Tata Institute of Fundamental Research (TIFR), Toronto SIE Lab, Tianjin Key Lab and Pretoria Thermofluid Lab, as well as the training of 43 early-stage researchers in the latest experimental and modelling techniques.

The expertise will be transferred through the planned secondments and exposure of all secondees to different research environments. Besides regular meetings and technical workshops, the collaborators will hold training schools at Edinburgh, Kyushu, Maryland, Toronto and Warsaw. This will consolidate the position of the EU at the forefront of cutting-edge research in this area and will promote long-lasting collaboration between academia and industry.

The University of Pretoria will offer its heat transfer and nanofluid laboratories and phase-change computational fluid dynamics (CFD) tools. A novel experimental set-up will be used in which the local heat fluxes can be measured. The ThermaSMART team will build on its previous project on the thermal management of high-power microsystems using multiphase flows, which led to major advancements in a fundamental understanding of phase-change phenomena.

The EU-funded project brought together 12 partners with complementary expertise in microfabrication, experimental techniques, and analytical and numerical modelling. The project looked at developing an integrated cooling system in electronic micro devices interfaced with an external circuit to take advantage of strengths in high-energy efficiencies of phase change.

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The spontaneous microencapsulation of geraniol by zein

Ignatius Ferreira, Walter Focke and Elizabeth du Toit

The overuse of pesticides on agricultural crops remains a matter of concern. Their high toxicity and non-biodegradable properties result in harmful residues, not only in crops, but also in soil and water resources. Research conducted in the Institute of Applied Materials in the Department of Chemical Engineering is looking at improving the sustained release of pesticides that are based on essential oils. Alternative pest management strategies with a lower impact on human health and the environment are subsequently encouraged.

A growing body of research has shown that essential oils can be used as an alternative to synthetic pest control products. The active components that tend to combine with or dissolve in lipids or fats in these oils can act as toxins. They can also act as deterrents to feeding and egg-laying to a wide variety of insect pests.

The major challenge concerning the use of essential oils for pest management is the sustained release of the active ingredients over an extended period. Unfortunately, many components of essential oils also show a lack of stability when exposed to environmental conditions. Furthermore, their high volatility necessitates relatively high application rates and/or frequent re-application when applied in emulsion form. This renders their use for large-scale agricultural applications both impractical and uneconomical. The encapsulation of volatiles in a polymer shell is a well-known technique to manage the controlled release and protection of active ingredients. In addition, encapsulated oils may be easier to handle and, depending on the solubility of the encapsulating polymer, they can be dispersed as water-based formulations.

In this research, geraniol was chosen as an essential oil component for encapsulation in the biopolymer zein. Geraniol is an acyclic monoterpene alcohol and a major component in various essential oils. It exhibits insecticidal and repellent properties and can be used as a natural pest control agent with low toxicity.

Zein is a protein found in the endosperm of the corn kernel. Although the Food and Drug Administration approved it for oral use, it has poor nutritional value. The high percentage of non-polar amino acid is responsible for its unique solubility behaviour. It is insoluble in water, but readily dissolves in aqueous mixtures of ethanol and methanol. It can easily be converted into colloidal particles by changing the solubilising capacity of the primary solvent through dilution with water. Several investigators exploited this behaviour to encapsulate essential oil components using zein. However, all the capsules that were produced using this technique were in the nano-sized particle range. Larger particles in the micrometre size range would be more suitable for industrial applications.

In addition, relatively large amounts of oil can be contained in such structures. The aim of this research was to specifically produce micron-sized zein-based core-shell particles that act both as reservoirs and as controlled-release devices for the chosen essential oil component. A one-step phase separation method with aqueous ethanol as solvent was used to produce the capsules. The geraniol-to-zein ratio was varied to show that micron-sized capsules can be produced if the relative solubility of the components in the solvent phase is considered. The morphology of successfully produced capsules was characterised and the temperature-dependent release kinetics of geraniol was measured and modelled.

The limited solubility window of zein in water-ethanol mixtures was exploited to micro-encapsulate geraniol in a one-step process conducted at ambient conditions. High encapsulation efficiencies and good particle yields were obtained at geraniol-to-zein mass ratios above unity, but poor yields were obtained at lower ratios. This was explained in terms of the variation in the relative positions of the phase separation boundaries, for geraniol and zein respectively, as their mass ratio in the starting solution was changed.

Producing biofuel from microalgae as an alternative to fossil fuel

Derick Lubbe and Deon Brink

Fossil fuels, renewable energy, greenhouse gases and untreated wastewater are topics of concern in today's world with its growing population and dwindling natural resources. According to the US Environmental Protection Agency (EPA), fossil fuels account for nearly 80% of greenhouse gas emissions in the USA. In South Africa, the energy sector alone accounts for 84% of national greenhouse gas emissions, mostly from the incineration of coal.

It is well known that anthropogenic greenhouse gas emissions from fossil fuels contribute to climate change. There is a growing worldwide demand for the generation of wastewater. South Africa is also facing a growing potable water crisis. Policy makers and researchers therefore need to dedicate time to seek lasting solutions.

Fossil fuels not only provide energy, but also support a wide range of downstream industries, such as the chemical and cosmetics industries. Base chemicals for these industries come from refined oil, natural gas and – in South Africa – coal. Replacing fossil fuels will therefore not only require the reinvention of the energy sector, but also the downstream sectors, such as the chemical industry.

Alternative energy crops such as canola and sugar cane have had some commercial success as feedstock in the biofuels energy chain. However, plants such as canola and sugar cane are water- and nutrient-intensive, and require fertilizer, large quantities of suitable water and land on which to grow. With these requirements, they also compete with food crops and impact on food security. In South Africa, where arable land is scarce and needs to be prioritised for food production, sustainable alternatives that do not compete with food crops for agricultural land must be found to supply feedstock to the biofuels industry.

A surprising solution to all three of these problems may come in the form of small but potent organisms: microalgae.

Microalgae are a biologically diverse group of single-celled, photosynthetic organisms that inhabit a range of aquatic habitats. Conversely, macro-algae are multi-cellular organisms

→ *Experimental batch reactors used in measuring growth parameters (the algae in the foreground is* Chlorella vulgaris*).*

like kelp and seaweed. Microalgae are capable of both heterotrophic and autotrophic carbon fixation, which means that they can use both organic and inorganic carbon sources for the growth of cells and generation of biomass. Microalgal biomass has a wide range of uses and can be used as a precursor for various other applications such as fertilizer, energy fuels (such as biodiesel, biohydrogen, biogas and bioethanol), pigments, cosmetics, pharmaceuticals and animal feed.

Microalgae can be successfully cultivated in wastewater from various origins. Algae cultivation has shown promise in both municipal and agricultural wastewater. In the process, the microalgae purify the wastewater as the algae absorb organics, as well as nitrogen- and phosphorous-containing compounds for cellular growth. In comparison with energy crops such as canola, algae can be grown on land that is not suitable for agriculture, thus the

microalgal-derived biofuels of the future will have a minimal impact on food security.

In order to supplement growth, microalgal cultures can be provided with an inorganic carbon source. This means that carbon dioxide, a by-product of many industries in South Africa, can be reused instead of being disposed of into the atmosphere. Switching to bioenergy derived from algae fed with industrial carbon dioxide has the potential to eventually eliminate fossil fuels from the carbon cycle, providing a sustainable, renewable resource from which the entire South African population can benefit.

Current research in the Department of Chemical Engineering is exploring the possibility of integrating both inorganic and organic carbon fixation in microalgae into a single process that can yield valuable chemicals and upscale that process to an industrial scale, which can be expanded and integrated at regional wastewater treatment plants. This could potentially expand the scope of wastewater treatment as an activity with a net economic benefit. Part of the goal is to study the carbon-capturing abilities of the organism in combination with domestic and/or industrial effluent to grow microalgae that can be harvested and converted into biodiesel. This technology could potentially be integrated into both rural and urban communities and can provide a stimulus for economic growth in both the water treatment and biotechnology sectors. By conducting this research, researchers envision a future where communities can be sustainably self-sufficient in terms of both wastewater treatment and energy generation.

Currently, Derick Lubbe, a master's degree student in the Department, intends to continue with doctoral studies on this topic, and the Department is planning on bringing more young and promising researchers on board.

Lubbe's research aims to characterise the growth and kinetics of microalgae in wastewater supplemented with

This research could expand the scope of wastewater treatment as an activity with a net economic benefit.

inorganic carbon, with a focus on carbon dioxide. He is performing the characterisation based on various parameters such as wastewater quality, light intensity and duration, concentration of organic and inorganic carbon and type of inorganic carbon. With this research, he is attempting to generate enough data to successfully design a continuous process that is suitable for South African conditions.

Experiments will initially focus on *Chlorella*, a common species of algae with a well-established fatty acid methyl ester (a form of biodiesel) yield. After the performance of this species has been established as a baseline, the experiments will expand to prospecting for suitable species from local bodies of water that may yield better growth rates and higher yields of biodiesel.

Currently, research at the University focuses on batch processes to delve into the fundamentals of algal growth and oil production patterns. Once these are better understood, research will start to focus on developing a continuous flow process that will be tailored to the South African landscape. Other areas that may be explored in the future include improving algal harvesting techniques and developing sustainable methods of biodiesel extraction that can be implemented in rural communities.

The research will not be limited to growing algae solely for producing biodiesel. Other alternative uses for algal biomass will also be explored in future research, such as the production of base chemicals for the biorefining industry and utilising algae as a carbon source for other water purification processes involved in heavy metal removal.

Research on utilising algae as a carbon source for heavy metal removal has already been underway at the University for some time and has been published in international journals.

Concurrently with the research in biodiesel, Lubbe has also developed a novel way of monitoring the growth of laboratory cultures with cheap, off-the-shelf equipment, which can be used to replace expensive machines for routine measurements. With this development, Lubbe hopes to empower research in biotechnology in developing countries and at schools, where money and technical expertise to purchase and maintain expensive laboratory equipment is often scarce.

The University of Pretoria does not stand alone in its research, but seeks to collaborate with other role players in the water treatment and biotechnology sector. It has already approached the Water Research Commission (WRC) for funding and partnership in the research. Microalgal-derived biofuels are categorised as third-generation biofuels and the University's research is in line with the sustainable goals set in the Bioeconomy Strategy issued by the South African Department of Science and Technology.

Microalgae, those simple single-celled organisms that are often a nuisance in many South African swimming pools in the summer months, thus have the potential to revolutionise the way we see biofuels and the water treatment industry. The South African economy can only benefit if these microscopic photosynthetic organisms are exploited to their full potential – a booming biotechnology industry that integrates sustainability with energy self-sufficiency.

Conserving water by implementing user authentication at communal taps

Water conservation in South African municipalities is an ongoing challenge. The problem of water leakages and the abuse of water by users are affecting the municipalities financially. South Africa's Free Basic Water Access Policy, which is managed by metropolitan or local municipalities, determines how much free water is allocated to qualifying households in rural, informal or formal settlements.

Prof Reza Malekian, Head of the Advanced Sensor Networks Research Group, who is responsible for the identity authentication system.

However, municipalities cannot accurately monitor the use of water from communal taps and issue penalties in cases of water abuse, as they rely only on the water meter readings of those communal taps. In an effort to counteract inaccurate water meter readings, systems such as the smart water meter system (SWMS) or the smart water interface unit (SWIU) have been developed. Municipalities can install this system on their selected communal water meter taps. It allows the municipality to view the real-time water consumption, as well as the historical data for instantaneous and accumulative daily and monthly water consumption. Furthermore, the system can compare the water consumption between any two selected days. It also identifies any water leakage or unattended open tap in the actual water flow system.

Despite these technological advances, it is still a challenge to identify the users of those taps. Collaboration between the Advanced Sensor Networks Research Group in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria, headed by Prof Reza Malekian, and Council for Scientific and Industrial Research (CSIR) Modelling and Digital Science aims to address the challenge of identifying individuals who use a lot of water from the communal tap.

The research group also aims to restrict the use of those taps to authorised residents and provide them with their allocated quota.

The project develops a low-cost, low-power identity authentication hardware token system that will allow the enrolled indigent user to access a pre-determined amount of water from communal water taps that are managed by the municipalities. The research team is working on a prototype and has established proof of concept for the project. If there is enough financial support, they can continue the project by implementing it in a test environment.

Water conservation can be simplified by the Internet of Things (IoT). Advanced sensor technologies that will not cost municipalities millions of rands is a way to effectively manage the water that communal taps in indigent communities provide. An IoT protocol layer can be used for the development of such a user identification system. Radio-frequency identification is the most common technology used in the IoT and sensor environment.

Prof Malekian, together with his group members, postgraduate students and researchers in the Advanced Sensor Networks Research Group, is developing industrial systems and technologies using IoT and sensors.

Understanding systems engineering

Dr Michael Ayomoh

Due to its versatility, systems engineering means different things to different people based on their background and experience. However, over the last couple of decades, systems engineering has been bridging the gap between the humanities and technical disciplines. It has also been bridging the gap among specialist engineering disciplines, especially at the formative level of conceptual design in a complex playing field.

While the hard systems approach focuses more on technical and computational problems, the soft systems approach deals with the social and societal problems that require some form of judgmental inference. Senge (1990) states that "systems thinking is a discipline for seeing the whole, a framework for seeing interrelationships and patterns of change rather than things and static 'snapshots' ". Systems engineering is both multidisciplinary and multi-skilling in nature The multidisciplinary act of systems engineering relates to the coordination and management of a complex team of domain specialists in problem solving. Multi-skilling refers to the capability of demonstrating a wide range of technical interests and competencies to facilitate an effective management process.

The origin of systems engineering

No particular date can be ascribed to the origin of systems engineering, especially in the context of managing complexity within the framework of multiplicity and diversity. Systems engineering principles and practices date as far back as the ancient records of Noah's Ark, the Tower of Babel, the Egyptian Pyramids and a host of other historic monuments that depict complexity.

According to Hall (1962), the use of the term "systems engineering" can be traced back to the renowned Bell Telephone Laboratory that Alexander Graham Bell founded sometime around 1887. This laboratory is known to have produced eight Nobel laureates. The recognition of systems engineering as a distinct activity is often associated with World War II and especially the 1950s, 1960s and 1970s during the Cold War era.

During this period, a few textbooks that first identified systems engineering as a distinct career path in the engineering profession were published. In 1990, a professional society for systems engineering, the National Council on Systems Engineering (NCOSE), was formed in the USA. The name was modified to the International Council on Systems Engineering (INCOSE) in 1995.

Eliminative versus curative strategy

From within a pool of ongoing research, an overview on the concept of interaction dynamics, also known as the relationship of things (RoT), is presented. The interactions that take place among the internal elements of a system (intra-interactions) and the interactions between a system and its external environment (inter-interactions) are both classes of a dynamic phenomenon that can be either physical or virtual. Hence, the ability to holistically identify all interacting entities in a given system's network, to categorise them into major and minor interactors, and negative and positive elements, and to compute the magnitude of their effect can be a major step towards prolonging the life span of a system, which minimises its decay or failure rate.

A simple illustration can be taken from the failing health of a human being. A sick individual, who is considered to be the system in this case, is seen to interact with a diversified class of external entities at different levels of magnitude. If a holistic network of these interacting entities is established, the negative interactors can be identified and addressed by minimising or eliminating their interactive effect. Often, in the human society, rather than give initial priority to the eliminative strategy of identifying and addressing the effect of negative interactors, the curative strategy is adopted to suppress the negative interactors. The puzzle at hand becomes that of eliminative versus curative strategies.

If the quantification of the rate of occurrence or computation of the magnitude of negative interactors is not adequately addressed, the applicability of the eliminative strategy may not be in sight. This concept of thinking can be adapted to all facets of the human endeavour, which opens the door to interaction dynamics, which interplays failure and system performance. Issues relating to the failure of systems being inferred from their performance can be an interesting subject in the field of systems engineering and other related disciplines. However, dealing with this class of problem from the systems thinking perspective provides ample opportunities for modelling procedures to be carried out on a holistic consideration of all external entities that act on the system under investigation.

Furthermore, this class of problem can be extended to social interactions in the human society. These are interactions such as governance, administration, information flow in an organisation, the relationship among people and a whole lot more in the social engineering research space, which can be contact based (physical interaction), contactless (functional interaction) or both. From an earlier perspective, Newton's law of universal gravitation states that a particle attracts every other particle in the universe with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. The primary focus in the universal gravitational model is the force of interaction between any two entities.

However, interaction in the context of interaction dynamics focuses on identifying all types of relationship variables that act on a system of interest, and evaluating the magnitude at which these interactions take place. Hence, the identification of all external entities that act on any one body physically and/or functionally is the first building block. These interactions can be premised on force application, vibrations, touch, stimulation, signal

Systems engineering has bridged the gap between hard and soft sciences. It is both multidisciplinary and multi-skilling in nature.

emissions, outputs such as heating or cooling effects, information flow and odour or fragrance. The interest is to investigate how these factors influence a system under investigation and, finally, the ability to use either the system's performance (inter-relationship) or the component's performance (intra-relationship) to judge or predict its failure.

Some associated research questions within this problem space of interaction dynamics include the following:

- When a system interacts with its environment or a component interacts with other components within a system, by how much can these diversified interactions be accurately modelled and quantified in real terms following the likely non-linearity within this multi-echelon problem space?

  Some external entities have a stronger influence on a given system than others. Hence, the need for the fuzzification of these interactions becomes paramount. If computational techniques are developed to optimally estimate these interactions, the life of a system or its components can possibly be extended. This can be achieved by first identifying all the ill relationships and their respective causative factors prior to applying corrective remedies to interactions that are seen to be mostly negative in the network.

- How does one define optimal interaction among the interacting elements of a system or between a system and its external environment? By relating interaction with performance and vice versa, the implication is that the optimal performance of a system or a component can only be premised on an optimum relationship between a system and its external environment or a component and a neighbouring component in the case of an intra-relationship.

  A system starts to fail when the interaction of its members or internal organs begins to decline below a minimum threshold that can be a variant for different systems. This may not necessarily be a visible event. Hence, systems do not only fail because they were poorly designed; rather because the interaction level of their members is weakening. This is why it is necessary to compute dynamic interaction functions orchestrated on several known unknowns or unknown unknowns. If the rate at which this phenomenon takes place is known and the corresponding effect is well captured, an estimated failure time for a system can be realistically predicted.

Summarily, the ability to holistically identify all interacting entities in a given system's network, and categorise them into major and minor interactors, negative and positive elements, and to compute the magnitude of their interactive effect can be a major step towards prolonging a system's life span.

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The development of a crane index for the South African building industry

Prof Hoffie Cruywagen

According to Steyn et al. (2007), price changes have an effect on the lives of every family. Such changes, also called inflation, cause the constant rise in the cost of living, which, in turn, lead to higher salaries and an increase in production cost. Flemming and Tysoe (1991) define an index as "a convenient means of expressing changes over time in the cost or prices of a group of related products in a single summary measure". An example of a typical index that is used worldwide is the Consumer Price Index (CPI) that measures changes in the prices of goods and services consumed by households.

Types of indices

The International Labour Organisation (ILO) (2004) states that many different kinds of mathematical formulae have been compiled and proposed over the past 200 years. The ILO (2004) further mentions that, while there is no single formula that would be preferred in all circumstances, economists and compilers of consumer price indices worldwide seem to agree that the preferred formulae belong to a small group of indices called superlative indices.

However, before one can look at the group of superlative indices, it will be good to go back to the basic compilation of indices. Steyn et al. (2007) are of the opinion that one must distinguish between simple and composite indices on the one hand, and unweighted and weighted indices on the other. According to Steyn et al. (2007), a simple index is used to represent the price change of a single commodity. In a composite price index, the price changes of all commodities are regarded as equally important, while in a weighted composite price index, different weights are allocated to different commodities according to the relative importance of each.

Crane index methodology

There is not a great deal of literature available on the crane index methodology. A crane index is a tool utilised across the world to monitor activity in the construction sector. Two global companies that are involved with the construction and property industries, Rider, Levett, Bucknall (RLB) and Deloitte (Real Estate), were found to conduct and publish information on crane indices. RLB is an independent, global cost management, quantity surveying,

A South African crane index will be based on the RLB Australia crane index, which is published every six months.

project management and advisory consultancy with a worldwide network of offices on all continents. It publishes a crane index on a regional basis such as in the Middle East, Australia/New Zealand and North America. Each region is subsequently broken down into the major cities of that region. For example, the cities in Australia that are used are Adelaide, Brisbane, Canberra, Darwin, Melbourne, Perth and Sydney, while North America consists of Boston, Calgary, Chicago, Denver, Honolulu, Los Angeles, New York, Phoenix, Portland, San Francisco, Seattle, Toronto and Washington DC.

Deloitte refers to Deloitte Touche Tohmatsu Limited, a United Kingdom (UK)-based private company with a network of firms in various countries. Deloitte's crane survey concentrates on the UK and separate reports are published for Birmingham, Leeds, London, Manchester and others. Deloitte's crane survey for London is further subdivided into a general and an office crane survey.

The basic methodology of the RLB crane indices, where the first

Australian crane index was published in 2012, is that the number of cranes in a city are tracked on a biannual basis. Previously, the number of cranes in the city's central business district was calculated, followed by a calculation of the number of cranes that are visible within a 5 km radius from the city centre. Currently, an attempt is made to count all the cranes within the city's boundaries. A brief report is also given with each publication on the location of the major sites in each city where these cranes are situated. The movement of the numbers is also reported, which refers to whether there was either an increase or a decrease in the number of cranes. A summary of all the cities is also given in each biannual publication with a legend indicating a significant increase, a significant decrease or a steady number of cranes. With this summary, a comparison can also be made of the general movement of building activity between various cities in the country.

The Deloitte survey, which is published on a quarterly basis for Belfast, Birmingham, Leeds, London and Manchester, does not count cranes anymore and has evolved to a survey that indicates new developments that may or may not include cranes. Such a report also contains an indication of the area of new buildings that have started construction since the previous survey and is subdivided into residential, office, hotel and educational spaces. This information is summarised in a table that indicates developments by name, developer, total size (in floor area), completion date and comments.

KPMG in Georgia has recently started the publication of the biannual study of a crane index for Tbilisi in order to contribute to the Georgian construction market. This crane index is similar to the Australian and New Zealand RLB publications. By periodically counting the number of cranes in a city, it helps the reader to understand the construction trend over time.

If a crane index is therefore published from information based on the movement of a number of cranes only, it will be classified as a simple index because, as indicated previously, it represents the changes in a single commodity.

A crane index for South Africa

A local quantity surveying firm, RLB Pentad Quantity Surveyors, became part of the RLB Group in 2013. As RLB aims to ensure the "global ownership" of crane counts and indices, RLB Pentad was asked to start a crane index in South Africa that is similar to that already published in Australia, New Zealand, the USA and other countries.

To assist RLB Pentad in this endeavour, Prof Hoffie Cruywagen was approached to be part of RLB's global research committee. Prof Cruywagen's research focuses on construction cost indices and escalation. He also did a pilot study on crane indices for the City of Tshwane Metropolitan Municipality in 2016.

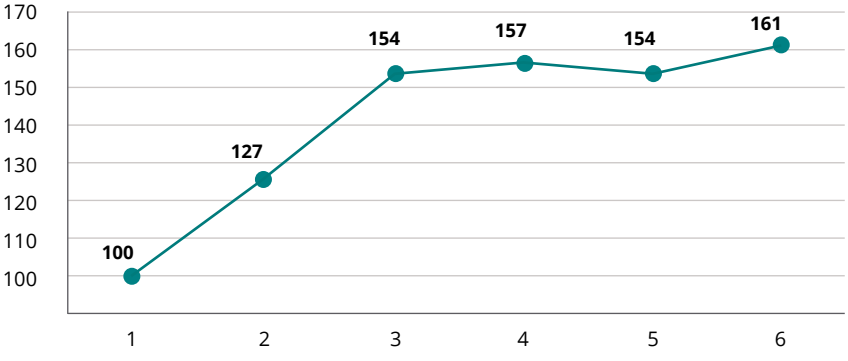
It is envisaged that a South African crane index will be based on the RLB Australia crane index. The Australian publication was originally a two-page document that was mostly published for marketing purposes. This publication has evolved into the current 16-page document highlighting heat maps, a graphical representation of the historical index and sector movement summaries.

Over the past five years, RLB Australia has published 12 editions of the RLB crane index. The index is published every six months (April and October) and all editions have received excellent national press coverage. The purpose of the publication is to engage with the property industry and media with a "quick and easy" indicator of the construction industry cycle.

→ *Table 1: An extract of the data collected for the Australian crane index over the past five years (RLB Australia, 2017)*

	Quarter 2 2015	Quarter 4 2015	Quarter 2 2016	Quarter 4 2016	Quarter 2 2017	Quarter 4 2017
Adelaide	100	117	150	250	250	283
Brisbane	100	142	142	130	111	116
Canberra	100	120	340	480	380	360
Darwin	100	50	50	17	–	–
Gold Coast	100	107	200	227	200	207
Hobart				100	25	75
Melbourne	100	117	127	116	126	130
Newcastle		100	113	113	50	63
Perth	100	109	109	112	56	58
Sydney	100	131	178	188	206	216
Total	**100**	**127**	**154**	**157**	**154**	**161**

The index, which is represented graphically in Figure 1, is a linear representation of the number of fixed cranes in Australia over time.



→ *Figure 1: An RLB crane index movement Australia*

The publication of a crane index will add great value to the South African building industry, as it will provide a trendline of building activity in each city where cranes are being counted, as well as for South Africa as a whole.

Developing a crane index for South Africa will follow the same methodology as described for Australia. Each RLB Pentad office, currently situated in Cape Town, Durban, Johannesburg, Pretoria and Stellenbosch, will physically count all cranes in the respective cities twice yearly (previously no mobile cranes were included in the Australian reports, but recently "long-term" mobile cranes were also included). It is envisaged that, cities such as Bloemfontein and Port Elizabeth may also be included in the survey at a later stage with the help of local universities. This information will then be applied to a base date (Quarter 4, 2018), which will enable the RLB Pentad South Africa crane index to be calculated. It will highlight the relative movement of crane data over time for each city, and for South Africa as a whole. Each publication will include the following information:

- Crane counts
- Trends over time
- Sector spread
- Visual mapping of crane distribution
- Commentary on key movements and crane numbers

The physical methods of collecting crane data utilises the following three data collection techniques:

- Physical crane count by one or more dedicated persons
- RLB staff survey: using staff to observe crane locations when going about their normal lives to assist in the sourcing of cranes that are not easily identified
- Contacting crane suppliers by telephone: these companies normally lease or rent about 80% of the cranes available in a particular location.

The publication of a crane index will add great value to the South African building industry, as it will provide a trendline of building activity in each city where cranes are being counted, as well as for South Africa as a whole. It will provide a quick indicator of the state of the building economy, with the link between number of cranes and economic strength. What such an index therefore portrays is more of an indication of activity to the public rather than trying to count every crane that has been erected.

The University of Pretoria's Department of Construction Economics is proud to be involved in a global initiative where South African data can be published for comparison with most of the major cities in the world.

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Large-scale industry surveys benefit the local publishing industry

The publishing studies research team in the Department of Information Science at the University of Pretoria (UP) actively engages with the local publishing industry through its survey research efforts. Members of the team have been responsible for the annual publishing industry survey on behalf of the Publishers' Association of South Africa (PASA) since 2002, and the Department has been involved with survey research for the South African Booksellers Association since 2016.

These surveys are the primary sources of research and decision-making data for the local publishing industry. They illustrate the value of the industry in terms of both its financial and employment contributions, and report trends based on an accurate representation of industry players. In practice, the surveys are used by commercial publishers for effective decision-making, as well as by stakeholders for lobbying purposes to government entities such as the Department of Basic Education and the Department of Trade and Industry.

The PASA survey is a flagship research project in Africa. It is one of the few datasets that have come about as a result of a direct survey, which is the most accurate research method for this type of project, and includes the most significant sample of any local publishing industry on the continent. As such, this data is frequently cited by policy makers on an international level to address industry gaps in Africa. This includes entities such as the World Intellectual Property Organisation (WIPO).

Through these projects, the research team has the opportunity to develop a close relationship with many prominent members of the publishing industry. This interaction then feeds back into the Department's teaching efforts for the publishing degree programmes based on the feedback received from industry participants. The courses presented to publishing students in the Department also benefit PASA and the industry. Such evidence-based teaching has resulted in the continuous delivery of industry-ready graduates. This is in accordance with UP's approach to academic planning, which advocates graduate attributes that are aligned with the human capital needs of the economy and society.

The publishing sector requires graduates to master a range of specialised skills in order to meaningfully contribute to the industry. The undergraduate publishing degree programme is the only one of its kind in South Africa, which means that the industry has representation of a large portion of UP graduates. It is therefore essential for the Department to be responsive to the latest industry developments in order to arm a new generation of publishing professionals with relevant knowledge and skills.

Evidence-based teaching has resulted in the continuous delivery of industry-ready graduates.

Vertically Integrated Projects programme breaks ground in Africa

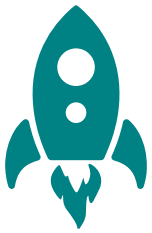
The Department of Industrial and Systems Engineering in the Faculty of Engineering, Built Environment and Information Technology is changing the face of engineering education with the Vertically Integrated Projects (VIP) programme. This is the first implementation of its kind in Africa. The VIP programme is a joint initiative with the top-ranking Georgia Institute of Technology that creates a multidisciplinary, vertically integrated and long-term project-based learning environment. These projects aim to solve real problems where innovative solutions are needed.

Background

The VIP programme extends project-based learning beyond a single semester, with students participating for up to three years. Team members may change during the course of the project, but the project remains the same. This sets the VIP programme apart from similar programmes. It provides students with the time and context to learn and practice professional skills, make substantial contributions, and experience different roles in large multidisciplinary project teams in the University's School of Engineering. It also contributes to the requisite practical hours that students have to accumulate as part of their engineering study programmes.

In many ways, feedback and grading in a VIP programme are similar to an evaluation in the workplace. Work is evaluated, guidance is given, and students have the opportunity to improve. Students will then receive a certificate to prove their participation, which may improve their employment prospects. Long-term student involvement is imperative to team success, which is why the VIP programme follows a multi-tier format where students at different academic levels participate. When students join a team, they spend much of the first semester getting up to speed. They make their largest contributions in subsequent semesters, both in technical contributions and in team leadership.

The VIP team model allows for larger-scale and longer-term projects than



VIP teams function much like small start-up companies.

a single semester or year would permit. This allows the Faculty to take on projects that are more ambitious. It also gives new students experience in getting up to speed on an existing project and providing students with leadership experience, as they orientate new members. The VIP programme's long-term nature creates a mentorship environment where faculty members supervise teams, experienced students mentor new members, and students move into leadership roles as others graduate. VIP teams function much like small start-up companies. While students develop and apply skills from their disciplines, they also develop and apply professional skills that are important to team functioning and values in the workplace.

VIP teams differ from traditional classes. Each student is required to commit at least five hours a week and each team meets with their supervisor once a week. The rest of the time is spent on the planning and implementation of their projects.

The VIP programme teams tackle real problems for real clients.

The VIP programme, which is coordinated by Dr Nadia M Viljoen, a lecturer in the Department, serves the Faculty by welcoming students from all disciplines to participate in project-based learning. In collaboration with the Georgia Institute of Technology, the University aims to grow the programme to a point where many teams from various faculties provide thousands of students with the opportunity to learn by doing. The two pilot teams, Campus Mobility and Wispeco Aluminium, were expected to set the standard in 2018.

Full faculty engagement underlies the success of the VIP programme. To sustain full engagement over many years, projects must be aligned to the supervisors' research interests. Supervisors get the opportunity to publish research, as they have a team of young minds to accelerate it. Students need to set up the project in such a way that they can pass on parts of it when they move on. They need to learn that projects exist apart from them and that continuity is a critical part of each project. They participate on a semester basis, but participation should ideally stretch over more than one semester to get the project and leadership established. Students will also benefit from seeing the project in different phases, which will allow them to hone their leadership skills.

Project team progress

During an end-of-semester ceremony on 28 May 2018, the two project teams presented their progress and received certificates recognising participation in the projects' first semester.

The Campus Mobility team was asked to determine the most efficient way to move students around campus. This is a multi-faceted dilemma and the team first had to identify a specific project and define its goals. The University's Department of Facilities Management approached the team to determine how many bicycles enter the Hatfield Campus each day.

This first project proved to be a valuable learning curve for the students, as they learnt how to deal with challenges. During the course of the project, they realised that the number of bicycles on campus is far fewer than the number of students who use the buses every day. This presented an opportunity to optimise this mode of campus transport, as students need to move between different campuses. One such example is the route from the LC de Villiers Sports Grounds, where many students have to park due to the lack of parking at the Hatfield Campus. Students can take buses to the Hatfield Campus to get to class. The team decided that the first step would be to map the various bus routes and schedules for various campuses. Thereafter, it would be possible to make this information available on a live platform similar to the way that Google helps commuters to find different public transport routes to their destination. This will help students to plan their travels more accurately, which will allow them to be on time for classes at other campuses. Looking ahead, the team aims to accelerate new members' induction so that they spend less time catching up and more time as productive team members. Their supervisor is Prof Johan W Joubert, an associate professor in the Department. This project drew students from the industrial, electronic and electrical, as well as civil engineering disciplines.

The Wispeco Aluminium team was tasked with optimising the sorting of scrap at the remelting plant. Each day, approximately 40 tonnes of scrap material arrives from suppliers. This material includes aluminium, steel and even plastic that needs to be sorted by hand. The Wispeco team set out to find a way to make this process more efficient. They also needed to categorise the scrap from different suppliers. The team determined that the best way of

dealing with this challenge was to automate the process. During a site visit, they learnt more about the aluminium remelting process and analysed the plant's process and equipment to see where there is room for improvement. The team also found a way to optimise their productivity by forming subgroups that had to each come up with a solution to the problem at hand. Ultimately, the best solution was chosen. This healthy competition in the Wispeco team ensured that each member gave his or her best to the project. Looking ahead, this team hopes to complete the cost benefit analysis and convince the organisation's leadership of their plans. Mr Roland Röhrs, Wispeco Aluminium's Chairman of the Board, is an external lecturer at the Department and has volunteered to mentor the Wispeco Aluminium team. This project draws students from the metallurgical, mechanical and industrial engineering disciplines. The team is led by Madeleen Esterhuyse, an Industrial Engineering graduate in 2017, who now works at Wispeco.

VIP programme collaboration

With the establishment of its VIP programme, the University has also joined the VIP Consortium. With the support of the Leona M and Harry B Helmsley Charitable Trust, the VIP Consortium was established in 2015. It includes a wide variety of institutions, and UP is currently the only partner institution in Africa.

Through the consortium, partner institutions seek to establish VIP programmes in a variety of institutions, share effective practices and disseminate experiences and findings, among other things. Dr Viljoen also hopes that UP's project teams will increasingly use this platform to collaborate on similar projects.

Dr Viljoen has had the opportunity to collaborate with Prof Ed Coyle, the director of the VIP programme at Georgia Institute of Technology. He has been instrumental in establishing the University's VIP programme and his mentorship has been invaluable.

Looking ahead

Currently, the students who participate in the VIP programme are drawn from the School of Engineering, but ideally, the teams should extend beyond engineering into the rest of the Faculty, as well as other faculties. However, it remains a challenge to attract enough project supervisors. Dr Viljoen hopes that the projects will expand to include postgraduate students.

Plans for the second semester of 2018 include the addition of four new project teams. Dr Tinus Stander and Prof Warren du Plessis from the Department of Electrical, Electronic and Computer Engineering will supervise the circuit reliability team and the electronic warfare team respectively, while Paul Sonnendecker from the Department of Chemical Engineering will co-supervise the renewable energy team, and Dr Viljoen the multi-agent transport simulation team.

Poster exhibitions and collaboration with international VIP programme teams are also goals for 2019.

The Campus Mobility team.

The Wispeco Aluminium team.

Dr Nadia M Viljoen recently returned to the University of Pretoria after nine years working on transport system modelling research in industry. She completed her undergraduate and honours degrees in Industrial Engineering at the University of Pretoria. Later, she completed her master's degree in Industrial Engineering at the Georgia Institute of Technology. As a graduate researcher at Georgia Tech, she was asked to assist one of the first (and still existing) VIP programme teams, Intelligent Transport Systems. Although she was thoroughly impressed by the programme, her career in South Africa took her further into industry for the next few years. She started the University of Pretoria's VIP programme six months after rejoining academia. Apart from coordinating the VIP programme, Dr Viljoen is a senior lecturer in Industrial Engineering and focuses her research on freight transport systems.

Mining students benefit from innovative support initiatives

Students in the Department of Mining Engineering are benefitting from several innovative support initiatives that have been launched in the Department. Two of these – the Mining Engineering Leadership Academy and the English Literacy Training Programme – are unique to the University of Pretoria and give its Mining Engineering programme the competitive edge in terms of student support.

Mining Engineering Leadership Academy

The Department recognises the fact that it makes an important contribution to the mining industry by providing it with the future leaders of industry. Although its students are well educated in mining engineering skills, they need to be prepared for the challenges they will encounter in the workplace. It therefore developed a focused leadership training programme that focuses on self-awareness, interpersonal communication skills and the ability to work in multidisciplinary settings and within a diverse group that spans many generations.

Final-year students are enrolled in a six-month leadership programme at the beginning of the year. This builds up to the second half of the year, when they are divided into teams for their Mine Design course. The programme entails the following:

- Students are introduced to the leadership role they will play in future. They also undergo psychometric assessments in conjunction with academic performance, commodity and biographic profiles.
- Students work in teams of four members from diverse backgrounds and embark on an experiential outward-bound weekend where they are exposed to vocational preparation and the practical application of their skills.
- Students attend practical management workshops on topics such as planning, leading, organisation and control, and interpersonal skills such as conflict management and developing emotional intelligence.

The programme is managed by Dr Johann Uys, a senior lecturer in the Department, and a psychologist with decades of leadership experience in mining and related industries.

English Literacy Training Programme

The Department furthermore recognises that excellent communication skills are essential for students' success in their academic skills and in the workplace. As it attracts students from across the entire spectrum of the South African population, one of the significant challenges it faces is the English language diversity of the students who enrol. Only 13% of all the students in the Department have English as their first language.

In an effort to help students whose home language is not English cope academically, the Department has appointed an English literacy coordinator, Ms Isabella Venter.

In addition to assisting undergraduate students with writing, communication and presentation skills, Ms Venter's activities include the marking of assignments, with specific reference to improving students' English writing and communication skills. In the past, lecturers spent too much time correcting students' English rather than concentrating on the technical subject matter.

Students are prepared to enter the industry as work-ready graduates.

The new frontier in multimedia research, teaching and learning

The Department of Information Science has launched a state-of-the-art research, teaching and learning facility through its new Virtual Reality and Interaction (VRI) laboratory. The VRI Lab is set to open new pathways for students and researchers in the field of multimedia studies to engage in immersive research in several virtual reality (VR)-related fields, including user experience design and interaction design in VR.

> VR is a game-changing tool to interact with people in an immersive way that leaves a lasting impact.

With VR quickly becoming part of the mainstream technologies available for both business and entertainment, industry players have become increasingly interested in leveraging this cutting-edge technology. Absa, as the primary funder of the VRI Lab, has, for example, found VR to be a game-changing tool to interact with people in an immersive way that leaves a lasting impact. The company's partnership with the Faculty of Engineering, Built Environment and Information Technology has made it possible for postgraduate students involved in multimedia studies to help move this technology from novelty to application and come up with workable VR approaches through immersive learning. South Africa is in the process of catching up to global developments in VR infrastructure, which makes this an exciting time for the incorporation of this technology into research, teaching and learning.

The VRI Lab gives postgraduate students in the Department access to world-class commercial VR equipment. It incorporates fully equipped, self-contained VR pods for use by individuals or research groups. These pods facilitate an optimal working environment without interference. They contain cameras and controllers that detect motion. This allows students and researchers to get an immersive feel for the projects they are working on in order to deliver informed results. The VRI Lab also hosts a 3D scanner and a 3D printer for developing models during the course of VR research.

From a research perspective, the VRI Lab facilitates the practical implementation of theory, which allows students and researchers the freedom to push the boundaries of the current knowledge and uses of VR. In this way, they can develop exciting ways of utilising this technology to surpass current solutions to real-world problems. It also provides a platform for collaboration. Potential fields of interest include VR applications in mining and architecture.

Business incubator fosters brilliant innovation

Anéa Burke le Roux

The University of Pretoria's technology business incubator and accelerator, TuksNovation, has been launched. The incubator primarily supports students and alumni, as well as academic staff from the University of Pretoria. Established in partnership with the Small Enterprise Development Agency (Seda), the Department of Small Business Development, the Department of Trade and Industry and the University of Pretoria, TuksNovation is aimed at providing innovative business incubation services to develop and commercialise the University's laboratory-developed technology into new, sustainable enterprises with social and economic impact in South Africa.

The Fourth Industrial Revolution is reshaping the way we live, work and communicate. It is transforming almost every aspect of society, from education and healthcare to commerce and government. Digital transformation presents both challenges and opportunities to South Africa's economy. Although it may displace jobs, it presents an opportunity for local innovators to come up with solutions to meet society's needs and aspirations, and increase South Africa's international competitiveness in doing so.

Despite the promises of innovation that the Fourth Industrial Revolution brings, the recent release of South Africa's latest unemployment figures reminds us of the task that lies ahead. Some 6.1 million of South Africa's working population is unemployed with youth unemployment standing at 38.8%. Youth unemployment among graduates is also of concern, with young graduates having an unemployment rate of 11.9%. As many as 39% of PhD graduates are not employed within the first year after graduation and 21% of PhD graduates are not working in their field of specialisation.

In light of this, regulators and academic institutions are looking towards youth entrepreneurship as a viable solution. However, according to the Global Entrepreneurship Monitor, South Africa has a low entrepreneurial intention rate, raking 39 out of 54 countries. This means that only about 12% of the population between the ages of 18 and 64 intends to start a business in the next three years.

The mammoth task of addressing South Africa's unemployment crisis calls for government, industry and academia to come together to create new economic opportunities through the power of entrepreneurship.

Tertiary education institutions are well positioned to address graduate unemployment by promoting and creating opportunities for entrepreneurship. The University is also ideally positioned to contribute to the local entrepreneurial ecosystem as its vast multi-disciplinary expertise enables it to facilitate the creation of diverse technology innovations and spinouts. The opportunity is timely because many students are still unclear about their career decisions, and entrepreneurial intentions tend to decrease with age.

Historically, universities have relied primarily on intellectual property licensing as a means of commercialising technology. However, in an effort to empower graduates and create more jobs, the focus is shifting to spinning out new companies to develop and commercialise nascent technologies. Despite this change in focus, the cost and risk of developing and commercialising new technologies remains high, making it extremely hard for aspiring young technology entrepreneurs to start businesses.

According to the Vice-Chancellor and Principal of the University of Pretoria, Prof Cheryl de la Rey, the University has increased its efforts to implement innovative strategies to leverage and commercialise home-grown technologies in order to create sustainable new enterprises and job opportunities. By developing and commercialising research and development projects within academic institutions and by creating new spin-off companies, universities can contribute to job creation and economic development.

The TuksNovation Business Centre.

The University of Pretoria is positioning itself as an entrepreneurial university through collaboration with government, industry, alumni and other stakeholders. TuksNovation came about from this vision.

As a high-tech business incubator, TuksNovation fosters innovation by providing specialised product and business development support to technological start-ups. By identifying and supporting promising early-stage innovations, TuksNovation lowers the risk in the technology development and commercialisation stages for both inventors and investors.

Its approach is rooted in the triple helix model by building strong networks between academia, government and industry in order to create new spinout companies that will benefit society. Open innovation allows its corporate partners to get first access to a pipeline of new innovations, which may in turn lead to new products for customers.

TuksNovation initially supported the creation of spinouts in the Faculty of Engineering, Built Environment and Information Technology. It was a logical starting point, as the Faculty comprises four schools with various departments. The School of Engineering is ranked number one in Africa. TuksNovation is now expanding its services to technology innovators from other faculties within the University.

TuksNovation fosters innovation by providing specialised product and business development support to technological startups. This lowers the technology development and commercialisation risk for both the inventors and investors.

TuksNovation's three core programmes offer tailored support to each incubated start-up. These programmes are supported by the University 's business school, the Gordon Institute of Business Science (GIBS), its Department of Business Management, its Graduate School of Technology Management (GSTM), its Technology Transfer Office (TTO), as well as industry mentors and panellists.

During the 12-month Virtual Incubation Programme, TuksNovation initially provides technology and business model development support to ensure that the technology is fully developed and addresses a relevant market need. This support is delivered by business mentors in partnership with industry and faculty members of the University. Clients also have access to selected University laboratories, hot-desking space and prototyping facilities in the TuksNovation Business Centre.

TuksNovation has the potential to foster some of the brightest innovators in the country, and to add to the entrepreneurial skills pool.

The four-month Business Launch Bootcamp helps prepare start-ups for the launch of their businesses. At the end of the bootcamp, students pitch their business cases to investors and industry leaders. They are required to secure funding or market access opportunities in order to enter the Acceleration Programme.

The Acceleration Programme provides practical support to early-stage start-ups to help them grow their businesses. During this programme, industry leaders provide business mentorship and critical industry linkages for market access. Start-ups in this programme may make use of offices in the TuksNovation Business Centre.

TuksNovation runs competitions to identify potential projects from across the University's faculties. Earlier in 2018, TuksNovation hosted the Tech Launch Pad Competition in collaboration with the Department of Informatics. The challenge was open to all UP students for idea generation. The winning teams received seed funding and expert business development support through TuksNovation's incubation programmes. A team of technically skilled second-year, third-year and honours informatics students' ideas were employed to further develop the ideas into minimum viable products.

Winners also had access to a well-equipped Mobile Applications Development Lab (MadLab) and state-of-the-art 3D printing facilities. One of the winners of this competition was a medical professional smart phone application that connects these professionals with relevant locums who are available in the sector. Another application that fared well in the competition was an insect tracker that uses the Internet of Things (IoT) to track a certain type of moth that destroys citrus crops. The last winner was a geo-location-based dating application.

TuksNovation Activate is an annual competition that searches for cutting-edge and innovative technologies and start-ups that can be grown into successful businesses. The 2018 competition was open to all registered postgraduate and final-year students who will enrol for postgraduate studies in the Faculty in 2019, as well as those enrolling in the Faculty of Natural and Agricultural Sciences. Winners receive a year of business incubation and technology development support in the TuksNovation Virtual Incubation Programme and win R10 000 cash.

The TuksNovation Business Centre is located in the Humanities Building on Hatfield Campus. It boasts a state-of-the-art prototyping and development facility with 3D printers and a computer numerical control machine, the Inventor's Lab. Its Sky Lab comprises hot-desking space. It also includes a meeting area, boardroom and office space for start-ups that are trading.

→ *The launch of TuksNovation was attended by Prof Sunil Maharaj (Dean), Prof Cheryl de la Rey (Vice-Chancellor and Principal), Ms Lindiwe Zulu (Minister of Small Business Development) and Ms Mandisa Tshikwatamba (CEO of Seda).*

Community-based project module never fails to impress

The students enrolled in the Community-based Project (JCP) module for 2018 have continued with the success established by their predecessors. In 2018, 1 499 students were engaged in community engagement projects in the Faculty. The JCP module is a compulsory module for all undergraduate students of the Faculty of Engineering, Built Environment and Information Technology. Students have the option to complete the 40 hours of work from February to October. They also have to do various reflection assignments, deliver a presentation on the outcomes of their project, as well as write a report and produce a YouTube video.

Renovations at the Whispers Speech and Hearing Centre

The group consisting of Constantinos Andrianatos (BSc Computer Science), Matthew Charles, Dietmar Marggraff and Gary Summerfield (all BEng Computer Engineering) completed a renovation project at the Whispers Speech and Hearing Centre. The principal of the Centre, Ms Brenda Schmid, indicated that these are passionate young men who are willing to go the extra mile in their community work.

Teaching Mathematics: One of the most popular JCP projects

Teaching Mathematics is a popular project in the JCP module. Louis Chabangu (BEng Electrical Engineering) assisted Grade 12 learners with their Mathematics and Science homework at Bunny Khosa High School, Mpumalanga. He indicated that the project made him realise the importance of helping others. Kgoale Delton Rathoakga (BEng Metallurgical Engineering) conducted a tutoring project for Grade 12 learners at Mohumi High School, Limpopo. He says one must be accountable and confident when one teaches. He enjoyed helping learners overcome the struggles they have with their school work.

Keep That Gold Shining illuminates hope

Keep That Gold Shining is a non-profit organisation that was started by students who were enrolled in the JCP module. Each year, the organisation hosts a Mathematics, Accounting and Physics (MAP) competition. This year's JCP students tutored Grade 10 and Grade 11 learners for the regional MAP competition. This competition comprises a pre-test, tutoring and a post-test. The competition took place at eMakhosini Combined Secondary School, Botse-Botse Secondary School and Soshanguve Secondary School in Soshanguve and Makgetsi Secondary School in Hammanskraal. Four Keep That Gold Shining tutors facilitated the MAP competition at Makgetsi Secondary School and 48 JCP students facilitated the competition in Soshanguve. Nearly 500 learners were involved in the five-day MAP competition. The competition continued in August when the top 200 learners of six different provinces wrote a test. The final award ceremony will take place at the University of Pretoria.

ECHO Youth Development Farm Project

A team of four engineering students, Waldo Gerber, Bart-Jan Hulsman, Hannah Johnson and JJ Krause, ventured all the way to Frankfort in the Free State to contribute to the ECHO Youth Development's farm project. ECHO Youth Development is a registered non-profit organisation that was founded in 2001. It provides a support system for vulnerable youth in South-Africa. High school learners and young adults from different cultures live together in 13 houses, called ECHO communities. At the ECHO farm, they engaged with the community and contributed to the development of a small-scale liquid fertilizer farm. The project aims to improve the farm's self-sustainability and to provide the community with an additional source of income. The project entailed the transport of 14 oil drums to the farm from Pretoria and the construction of a supporting stand or base structure on which to place the drums to avoid rust and other damage. Having only limited resources, the students decided to make use of the eucalyptus trees that grow locally. This is an invasive species in South Africa, but it provided durable and reliable building materials to build the supporting base structure. They cut down two eucalyptus trees, divided them into 28 stumps of 60 cm each and levelled them to provide a sturdy base. The project, although simple in principle, came with intense mental and physical challenges. The farm will be able to use the excrement from the various species of livestock to create their signature fertilizer, which will be developed into a concentrate of nutrients when mixed with water and left to ferment. ECHO can use its vegetable gardens or sell vegetables as an additional source of income. The students indicated that they had learnt valuable skills, grown as a team, made new friends and taken to heart the importance of supporting those in need.

Lory Park Animal and Owl Sanctuary

Lory Park Animal and Owl Sanctuary in Midrand is a very accommodative campus-community partner. It is always willing to accommodate JCP students. One of the groups dedicated this year to revamping the cockatoo enclosure. The students, Sybrand Botes (BSc Information and Knowledge Systems), Raymond Frauendorf, Courtney Hart and Jonathan van der Breggen (all BIT Information Technology), indicated that it was a great experience to take part in the community-based project, as it made them realise that they have an additional responsibility to society. They noted that "people should be positive to participate in community-based projects because even though we might think that there are better things to do with our time, someone else is being uplifted through our involvement. One should also see the struggle of other people. When one is alone in the world one day, one will realise that we all need to look after one another as we all live together in this world after all".

Architecture: 75 years and counting

Dr Nico Botes

The Department of Architecture at the University of Pretoria celebrates its 75th anniversary in 2018. To commemorate this historic event, we invite you to join us on a journey through the development of this unique Department.

1908

On 11 February, the first students register for classes at the Pretoria Centre of the Transvaal University College (TUC), initially as subjugate to the University of the Cape of Good Hope.

1927

The promulgation of the Architects and Quantity Surveyors Act, Act No. 18 of 1927, sets in motion the regulation of the education of architects and quantity surveyors in the Union of South Africa.

1929

The Secretary of Education, Dr SFN Gie, defines the role of universities in the education of architects and quantity surveyors. This serves as impetus to initiate studies in architecture at TUC. H. Bell-John (1874–1942) is appointed as part-time professor.

1930

The programme in architecture for a part-time diploma is listed in the TUC's yearbook for the first time. An act of Parliament facilitates the TUC to become the University of Pretoria at a time when it already had more than 900 students, making it one of the largest tertiary institutions in the country.

1931

Part-time classes in architecture commence at UP.

1932

The Minister of Education appoints UP as an examining authority in architecture and quantity surveying. Nonetheless, a formal agreement is signed between UP and the University of the Witwatersrand (Wits) according to which Wits prescribes the syllabi and conducts the examinations in architecture and UP does the same for quantity surveying. It is thought to be unsustainable for two schools to offer both courses in such close proximity to one another.

1942

On 28 May, the UP Council, with architect Gerard Moerdyk as chairman, decides to end the agreement with Wits and to present courses in architecture itself.

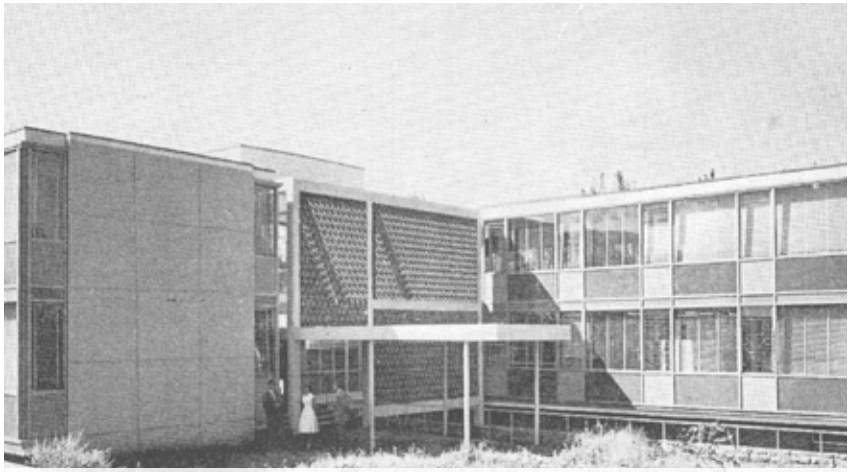
1943

The Department of Architecture and Quantity Surveying is formally founded in the Faculty of Science as the third school of architecture in South Africa, the other two being the University of Cape Town and Wits. Prof At Meiring (1904–1979), a practicing architect, is appointed as the first full-time professor and

Head of Department from 1 March. The Department is situated in Vermeulen (now Madiba) Street in the Pretoria inner city. Students can either enrol for a five-year full-time degree or a part-time diploma. Part-time students must be employed in the office of an architect.

1957

The Department moves from the city to the Hatfield Campus and sojourns in a variety of locales while a new building is completed.



The original Boukunde building in 1960. It was a Modernist curtain-walled structure designed by Prof Meiring and his staff next to the old Weather Bureau Building (now Communication Pathology) on Lynnwood Road.

1960

The Department moves into the completed Boukunde Building, a Modernist curtain-walled structure designed by Prof Meiring and his staff next to the old Weather Bureau Building (now Communication Pathology) on Lynnwood Road.

1961

The part-time diploma course in architecture is discontinued and replaced by an eight-year, part-time degree course, while the five-year, full-time degree is extended to a minimum of six years.

1967

Prof Alewyn Burger is appointed as Head of Department from 1 June. The part-time programme is finally discontinued.

1971

The Department's name is shortened to the Department of Architecture, as quantity surveying becomes a separate managerial entity. Prof Roelf Botha is appointed to the new chair in Landscape Architecture on 1 January 1971 and eight students enrol for the new four-year Bachelor of Landscape Architecture (BL) degree.

1972

Substantial reconstruction that envelopes the existing structure of the Boukunde Building is undertaken and the building is extended with an off-shutter concrete shell designed by architect Daniël S de Beer (1927–2008). During the winter, the construction causes considerable disruptions. The third- and fourth-year studios are temporarily relocated to a farm shed near Ifafi (east of the Hartbeespoort Dam) and students and lecturers are transported there daily by bus. The reconstruction is completed in 1973.

1974

The Bachelor of Architecture (BArch) course is shortened from six to five years, as the year of work experience falls away according to the provisions of the Architects' Act, Act No. 35 of 1970. Students will in future be required to work in practices during the university recesses.

1983

UP introduces a semester course system that has a significant impact on curricula.

1985

Prof Dieter Holm is appointed as Head of the Department and successor to Prof Burger on 1 October.

1986

Prof Chrisna du Plessis is appointed as Chair of the National Architecture Students Union (NASU) until 1988.

1987

The Department of Landscape Architecture becomes an independent entity under the headship of Prof Michael Murphy.

1988

Prof Willem van Riet is appointed as Head of the Department of Landscape Architecture. In the same year, he receives the first doctoral degree in landscape architecture to be awarded by UP. The Department hosts the National Architecture Students' Congress, with speakers Reuben

Mutiso (then President of the Union of International Associations) and Mbali Swana. This is the first architectural event in South Africa at which black professionals are invited to speak. Heidi Zöllner was elected to succeed Prof Du Plessis as NASU's Chair. This means that, for three consecutive years, NASU not only had a female leadership, but benefitted from the expertise of leaders from UP.

1992

The Division for Environmental Design and Management (later to evolve into the School for the Built Environment) is established.

1993

The Department of Architecture celebrates its golden jubilee with a student congress, exhibition and special publications. In the same year, the first students enrol for a degree in interior design at the Department of Home Economics (now Consumer and Food Sciences).

1994

The first democratic elections are held in South Africa and the country is re-admitted to the Commonwealth. Subsequently, the Commonwealth Association of Architects visits and accredits the Department's professional degree in architecture. Accreditation by the Royal Institute of British Architects follows a year later.

1997

The name is changed to the Department of Architecture and Landscape Architecture as the two programmes are re-amalgamated under the Headship of Prof Schalk W le Roux. Prof Roger C Fisher is appointed as Curriculum Co-ordinator to resolve the restructuring of the programmes in architecture and landscape architecture in anticipation of the proposed new tiered categories of professional registration for the two professions.

1999

Prof Fisher's new equifinal curriculum structure, which does away with the typical division between the programmes into professional silos, is implemented and the first enrolments in the new three-year undergraduate degrees in architecture and landscape architecture commence. The integrated core curriculum would become a strength and a feature that distinguishes it from other schools of architecture.

The Programme in Interior Design is transferred to the Department of Architecture and the Federation of Interior Architects and Designers and Design South Africa accredit the four-year Bachelor of Interior Design (BInt) degree.

2000

UP implements a new faculty structure and the Division for Environmental Design and Management is renamed the School for the Built Environment in the new Faculty of Engineering, the Built Environment and Information Technology.

The Architectural Profession Act, Act No. 44 of 2000, and the Landscape Architectural Professions Act, Act No. 45 of 2000, are promulgated and new tiered categories of professional registration are introduced.

2001

The first cohort that enrolled for the new BSc(Arch) and BSc(LArch) degrees complete their undergraduate studies.

2002

The first students enrol for the MArch(Prof), ML(Prof) and MInt(Prof) programmes. At this stage, they are two-year postgraduate degrees with the option of a stand-alone honours year. The first students complete their studies towards the new BSc(Int) degree.

2003

The programme in Landscape Architecture celebrates its 30th anniversary with exhibitions, publications and an open lecture series. The programme in Interior Architecture celebrates its 10th anniversary with the Young Designer Installation at Rooms on View.

2004

Prof Fisher is appointed as Acting Head of Department from 1 January 2004 until Prof 'Ora Joubert's tenure as Head of Department commences on 1 September 2004. The two-year professional postgraduate degrees are divided into a one-year honours degree, followed by a one-year professional master's degree.

2008

Prof Fisher is again appointed as Acting Head of Department from 1 October after Prof Joubert's tenure ends.

2009

Prof Karel A Bakker (1956–2014) is appointed as Head of Department from 1 January.

2014

Prof Fisher is appointed as Acting Head on 1 October due to Prof Bakker's illness. Prof Bakker passes away on 19 November.

2015

Prof Fisher acts as Head of Department until Prof Chrisna du Plessis is appointed on 1 October.

2016

Alumna Karlien Thomashoff of Thomashoff + Partner Architects is appointed to oversee renovations of the Boukunde Building. Services, especially the wet core, have become untenable and accessibility had to be improved. A link to the new Javett Art Centre to the west will provide opportunities to resolve the programming of the Boukunde basement, much of which survives from the 1960 structure. The annual vertical studio is themed around social learning spaces, including those in and around Boukunde.

2017

The Department moves to the Technika Building on the Groenkloof Campus in July as construction starts on the remodelling of the Boukunde Building in the third quarter.

2018

The Department celebrates its 75th anniversary with a series of lectures by alumni as a critical reflection and sharing of visionary ideas on ways of practice. Members of staff and students curate, contribute to and present numerous exhibitions and events at the annual national ArchitectureZA Conference, themed Memory and Resilience, which the Department co-hosts with the South African Institute of Architects (SAIA). A celebratory publication is planned for the end of the year.

A studio in the 1960 Boukunde Building with the large glazed surface facing Lynnwood Road. The impact of traffic noise from the street was addressed in the 1972 renovation.

The Department has continued to grow from strength to strength. It has the highest qualified contingent of staff of any department of architecture in the country, with consistently good results in teaching and quality outputs in research. It has delivered a consistently excellent body of graduates that have made a large impact in practice and academia.

A more detailed timeline of the Department's history is available at http://www.artefacts.co.za/main/Buildings/articles.php?artid=388

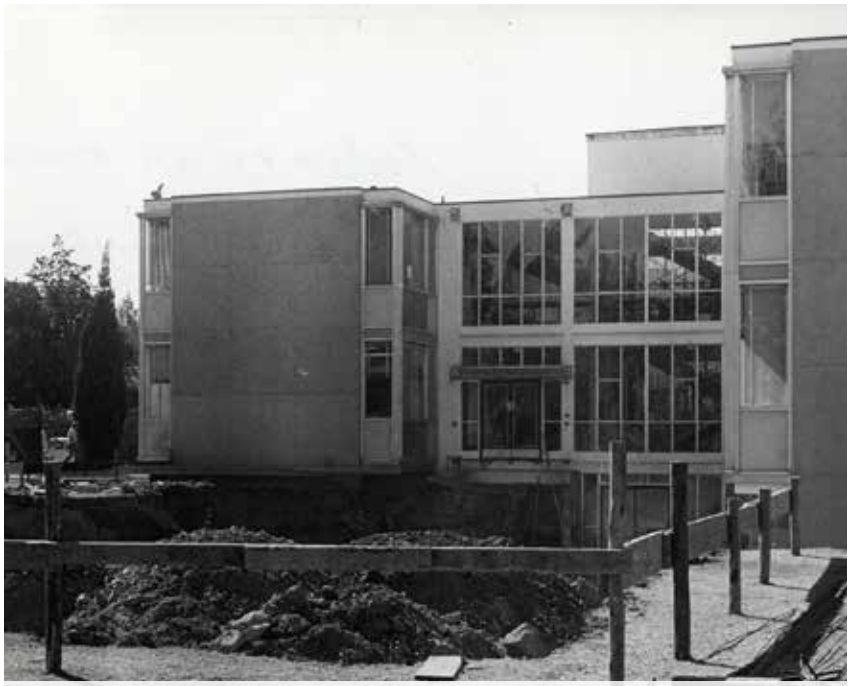
Celebrations

To launch 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.

As part of the 2018 75-year celebrations, the Department hosted a four-part lecture series over the course of several months. Topics included architecture as urbanity, from tradition to vision, atypical interiority and landscape outlooks. In the first semester, the students and staff were treated to an informal celebration of their Department's notable milestone. The celebrations also included an exhibition of work from the Department's archive, students and alumni to coincide with its awards evening and the ArchitectureZA Conference in May 2018. The Department also took part in an exhibition and collaboration on visual design with UP Arts during the 2018 Principal's Concert.

A new jacket for Boukunde

Ever since its construction in 1960, the Boukunde building has been more than a building. It has become synonymous with a unique, close-knit community of students and lecturers.



The western façade of the original building.

The original building

According to Ms Karlien Thomashoff, the architect for the project, it is important to know the history of the building, because it has to be future-proof. The new building has to be used for the next 50 years.

The Boukunde Building was completed in 1960 at a cost of £61 500 and could cater for 182 students. The Department's permanent staff designed the original building, which was a collection of glass and steel boxes.

In the 1950s and1960s, architects worked on drawing boards and depended on natural light. Southern light is crucial for natural light and the original Boukunde Building's southern wall was uniquely suited to this. However, the noise from Lynnwood Road soon became problematic. The glass and steel that had been used in the building's construction also posed a challenge, as the building could become uncomfortably hot in the summer.

The first renovation

In 1973, additions were made to the building and a concrete shell was added to solve the heat problem, as well as to eliminate the noise from Lynnwood Road. Although the heat and noise issues had been addressed, the concrete diminished the amount of natural light that reached the studios. It was also necessary to introduce mechanical ventilation, which made it an energy-intensive building. Lecture halls were added as well.

During the first renovation, the construction work caused considerable disruptions. The studios of the third- and fourth-year students were temporarily relocated to a shed on a farm near the current Ifafi (east of Hartbeespoort Dam). Students and lecturers were transported to the venue daily by bus. One of the projects undertaken there included the redesign of the farm as a suburb.

For the next 45 years, the Boukunde Building continued to house the

→ *Additions being made to the original building in 1973.*

Department's activities and many students graduated. However, it became apparent that the building once again needed refurbishment.

The second renovation

According to Prof Chrisna du Plessis, Head of the Department of Architecture, the renovation team had a long list of items to address. The central theme for the second renovation centred on using spaces for multiple functions. For example, discussion rooms are not only used for discussions, but also for research, lectures and exhibitions. These multiple uses contribute to the building's future-proof quality.

The renovation team's first priority was to improve wheelchair access to the building. A lift was installed and the appropriate toilets were added to each floor. Ramps were also built for better access to the building.

The original building did not meet the appropriate fire safety standards. The renovation team therefore had to make many adjustments so that the building was compliant with modern standards. The most significant of these was the new fire escape.

In addition to these changes, the studios needed natural light and the building needed improved air-conditioning and ventilation. In the 58 years since the original building was built, the world has changed drastically, as have the teaching methods. Nowadays, only the first- and second-year students work on drawing boards, after which they start working on computers. As a result, the students who sat in the middle of the studio did not have access to power outlets for their computers. During the past few decades, attempts had been made to alleviate this problem, but it was not always according to safety regulations, which posed dangers to the students and lecturers. During the renovations, outlets were added to the middle section of each studio to help facilitate a conducive learning environment.

Each floor features gender-neutral toilets that can be converted back to gender-specific toilets if the Department deems it necessary.

Another significant addition is a proper space for the Department's architectural archive. This archive is the most extensive and noteworthy of its kind in South Africa. It includes nearly 80 collections, including the records of much-respected South African architects like Norman Eaton, Gerard Moerdijk, Gordon McIntosh, Gawie Fagan and Alan Lipman.

Local and international researchers use this archive regularly. There is a dedicated storage space for this unique archive. Ms Thomashoff is very excited about this part of the project. Some of the items in the archive are invaluable teaching tools and will be used in a modern digital space alongside modern tools. A resource centre (reading room) was added with proper lighting and surface areas for handling sensitive materials. The resource centre provides work spaces for individual and small group work, as well access to the material samples collection, journal collection and other special resources, including some of the archive materials.

Another big part of the project is Boukunde's connection to the new Javett Art Centre at the University of Pretoria (Javett-UP). Currently under construction on the South Campus, the development is set to become an iconic feature on the capital city's landscape, attracting art lovers, residents and tourists alike, and providing a unique resource for academics, researchers, students and learners. Boukunde will be connected to Javett-UP due to its proximity to the bridge that crosses Lynnwood Road. The bridge will also form part of Javett-UP. As a result of this connection, architecture students will also have access to an outdoor courtyard and Makerspace. It will include critique rooms, which can be used as an exhibition space.

Memories

Over the years, Boukunde has became the home of a tight-knit community of students and staff members who have spent many late nights in the studios. Although the building's second renovation will usher in a new era, hundreds of former staff and students will fondly remember the good memories they made during the time they spent at Boukunde. The renovated building does not entirely erase the past, as some memories of the old building have been left in place. This includes a place where students marked their heights on a door frame and a few other graffiti gems. Even mysterious neon orange numbers on the ceiling

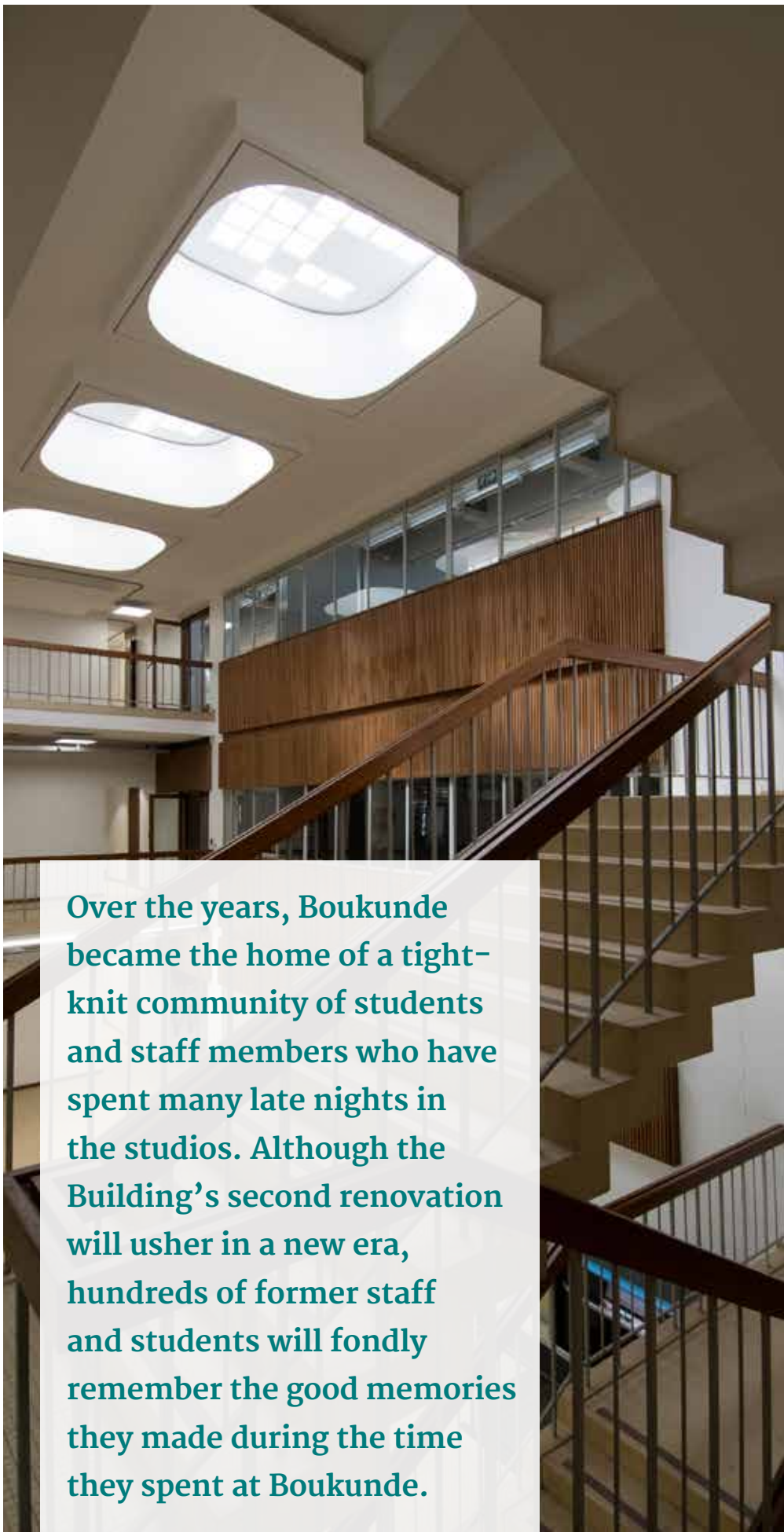
of one of the studios dating from the 1960s were left undisturbed. During the renovations, a little note was found under one of the tiles. The note read: "Put the tile back, please. It is UP property. Taking it is stealing." Ms Thomashoff posted the note on Facebook and asked if anyone knows who had put it there and when. Anette Clavier, an alumna who now lives in Stuttgart, Germany, claimed to be the author of the note. She explained how she and her friends painstakingly removed the tile one night to place the note there. Ms Clavier graduated in 1994. The note is now housed in the Department's archive.

Mysterious orange numbers on the ceiling of one of the studios dating from the 1960s.

The renovated building is indeed an amalgamation of old and new, as parts where the buildings of 1960, 1973 and 2018 meet were left exposed after the renovations so that students can see them and learn from them.

Conclusion

Over the past 58 years, the Boukunde Building has become one of the University's most iconic buildings because of the sense of community its occupants have felt since its construction. The newly renovated building, which was completed in September 2018, will be the catalyst for innovative teaching and learning practices and will be at the centre of architectural excellence in South Africa for many years to come.



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A living laboratory for architecture

Over the past few decades, the digital era has accelerated at a rapid pace and the Department of Architecture has certainly not escaped it. A pitfall of this rapid acceleration is an increasing reliance on technology in the learning space. Architecture is a sensory discipline that requires students to know how different building materials and textures feel. A computer screen cannot replace the sensory learning experience of being in touch with one's surroundings.

With the renovation of the Boukunde Building in 2018, special attention was paid to ensuring that the new building reflects the teaching and learning methods of the 21st century.

To keep abreast of the changing teaching and learning environment, the newly renovated building was therefore established as a living laboratory.

According to the European Network of Living Labs (ENoLL) (2018), a living laboratory is a user-centred, open innovation ecosystem based on a systematic user co-creation approach that integrates research and innovation processes in real-life communities and settings.

The Boukunde living laboratory will encompass a number of aspects. Students sometimes struggle to visualise the building components they learn about, which is why the renovated building is dedicated to showing students some of these components. The first step was remove coverings and fittings that are designed to hide the building services.

Students can see where electricity, ventilation ducts and various other building services are placed in the building. An example of this is the open air conditioning ducts in the first-year studio (illustrated in the photograph above), which reveals all components of the air circulation system. Students can also see where data and network cables run through the building. Photographs of the electrical distribution boxes in various stages of installation were printed on the covers of the boxes. Sponsor PG Bison has also collaborated in creating a materials demonstration hub in the new resource centre.

The new fire escape is another example of the building as a teaching tool. Ms Thomashoff instructed the contractor to make mistakes while casting the concrete to show students what can go wrong in concrete structures. The flaws do not compromise the structural integrity of the building and serve as a valuable practical teaching tool. Because the building's ceilings have been stripped, students will also be able to see where the original building and new building

A computer screen cannot replace the sensory learning experience.

come together. This is symbolic of Boukunde's rich history and the new era.

Students could make suggestions for improvements to the building during two vertical studios before the project began. These suggestions were taken into consideration during the renovation.

The University already has strong links with two other living laboratory hosts, namely the Delft University of Technology and Chalmers University of Technology. Industry-linked research projects on acoustics and green walls using the building as test bed are also being developed. The Department looks forward to the research and collaboration opportunities that a living laboratory will bring.

References

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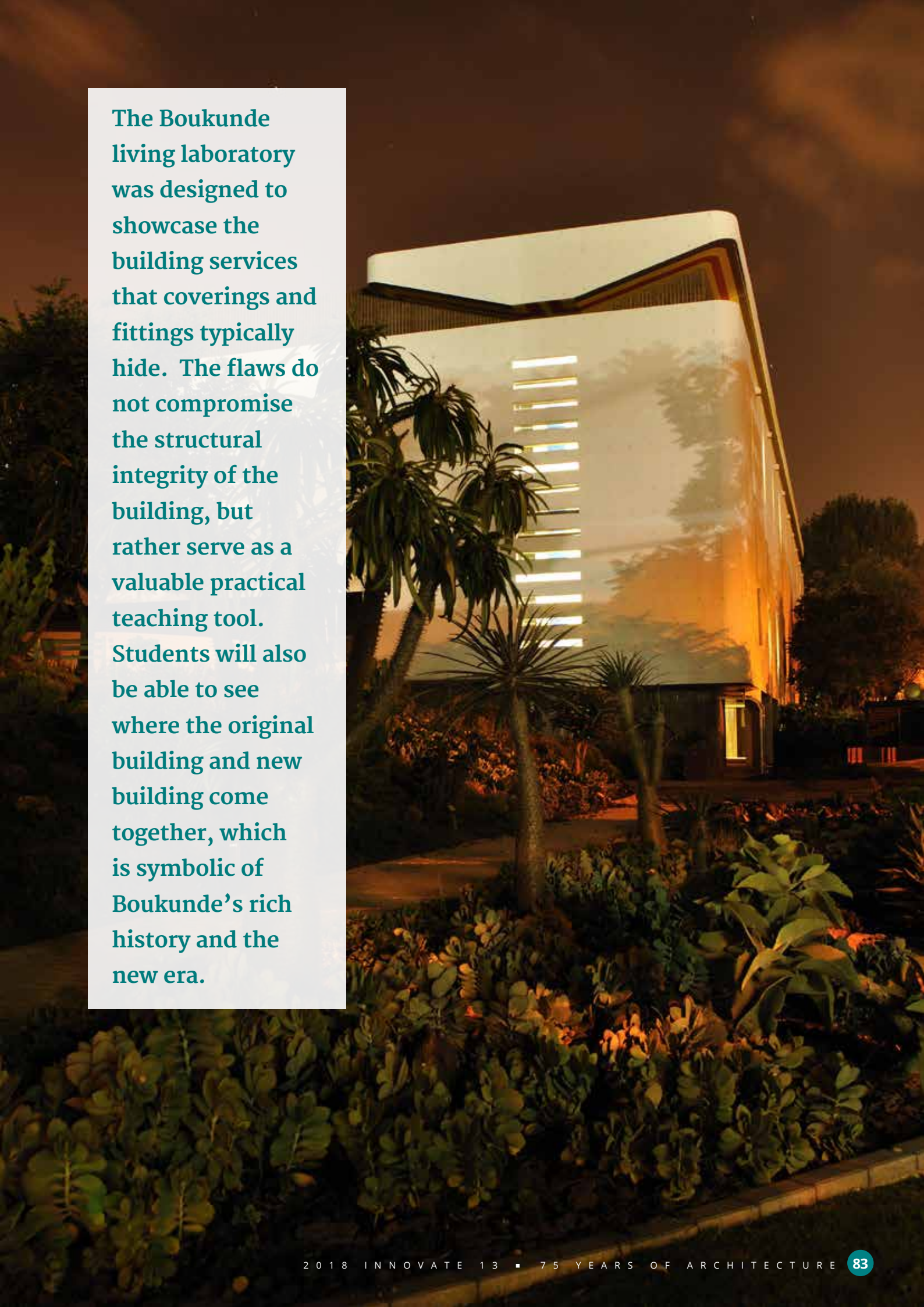
A new generation of architecture students admire the new Boukunde Building.

The contractor was instructed to deliberately introduce mistakes in the new fire escape so that it could be used as a teaching tool.

An exposed cable tray will help students learn about building services.

A joint has been left exposed to show students what it looks like.

Students will be learning from their environment in a practical way.



The Boukunde living laboratory was designed to showcase the building services that coverings and fittings typically hide. The flaws do not compromise the structural integrity of the building, but rather serve as a valuable practical teaching tool. Students will also be able to see where the original building and new building come together, which is symbolic of Boukunde's rich history and the new era.

Celebrating 30 years of excellence in engineering and technology management

The Graduate School of Technology Management (GSTM) commemorated 30 years of excellence in technology management on 24 November 2017.

The event was hosted by Prof Elma van der Lingen, Head of the Department of Engineering and Technology Management. Guests were provided the opportunity to celebrate the Department's success and accomplishments by taking a journey through the milestones that characterised the development of the GSTM from the perspective of its successive heads of department: Prof Gideon de Wet (1987–1991), Prof Antonie de Klerk (1991–2000), Prof Tinus Pretorius (2000–2016) and Prof Elma van der Lingen (2016 to date).

Engineering management as a discipline was introduced at the University of Pretoria with the establishment of an industry-sponsored Chair for Engineering Management in 1987. Prof De Wet was the first chairholder and developed a Master's in Engineering Management (MEM) programme. A first group of 45 students was admitted in 1989, and since then, between 40 and 60 practising engineers from across the industry spectrum have registered for the programme each year.

Building on the successes achieved during these early years, a separate department was established in the former Faculty of Engineering in 1994. The Department of Engineering and Technology Management was the first and only one of its kind in South Africa. Prof De Klerk became its first Head of Department.

Towards the end of 1999, the University embarked on a restructuring of its faculties. This brought about the establishment of the Faculty of Engineering, Built Environment and Information Technology (a consolidation of the former Faculty of Engineering and certain departments in the Faculty of Natural Sciences related to the built environment, as well as those related to information technology). This also brought about the establishment of the GSTM as a fourth school in the new faculty. In 2000, Prof Pretorius was

The GSTM has been leaving its mark on the engineering and technology management industry for three decades. As it enters its new phase of existence, the focus is on maintaining its reputation of excellence in the globally evolving discipline of engineering and technology management.

The four heads of department in the GSTM's history: Prof Gideon de Wet, Prof Antonie de Klerk, Prof Tinus Pretorius and Prof Elma van der Lingen.

appointed as Chairperson of the GSTM, as well as Head of the Department of Engineering and Technology Management. Under his leadership, the Department's postgraduate student numbers soon exceeded 1 000. Its Honours in Technology Management (MOT) programme was launched in 1995. The Master's in Project Management (MPM) programme, established in 1999, grew from an initial 45 students to between 70 and 80 students registering for the programme each year.

In 2004, a Master's in Technology Management (MTM) programme was introduced, which was aimed at graduates with an honours degree in Management of Technology. The MTM degree prepares these candidates for leadership roles in business through professional postgraduate education.

In 2018, the Honours in Technology Management and the Master's in Technology Management programmes were changed to the Honours in Engineering and Technology Management (ETM) and the Master's in Technology and Innovation Management (MTIM), respectively.

The GSTM is registered by the Project Management Institute (PMI) in the USA as a global education provider and claims to be the capital for project management research and training in Africa. In 2008, the MPM programme received international accreditation from the PMI's Global Accreditation Center for Project Management Education Programs.

Today, the School offers a variety of programmes related to engineering management, project management and technology and innovation management. Several individuals from industry are involved on a part-time basis. The GSTM offers internationally recognised programmes at honours, master's and doctoral level. Its programmes address different needs in the field of technology management, project management, engineering management, life cycle management and asset management.

A strong focus on research ensures competitive education. Research also ensures relevance to the market in terms of increased competitiveness, optimising product life cycles, technology transfer and the positioning of technological abilities within the international context. The GSTM's academic and research offering and consultation services to industry contribute to relevance, competitiveness and excellence.Collaboration with both local and international institutions is of great importance to the GSTM. It has several long-standing collaborations, including with Tilburg University in The Netherlands. Academics from both institutions engage in exchange programmes for research and teaching activities.

Following the end of Prof Pretorius's contract as Head of Department at the end of September 2016 after 16 years of heading the GSTM, he was succeeded by Prof Van der Lingen, who is focused on ensuring that the Department maintains its reputation of excellence in the globally evolving discipline of engineering and technology management. Building on the success achieved over the past three decades, she is confident that the GSTM will equip postgraduate students and industrial leaders with the ability and management skills that are needed to enhance the potential of technology to the benefit of the national and international community.

Chair of GSTM delivers inaugural address

Prof Elma van der Lingen, Chairperson of the Graduate School of Technology Management (GSTM) and Head of the Department of Engineering and Technology Management, delivered her inaugural address on 24 July 2018. The topic of her address was "Managing innovation in a technology dominated world".

According to Prof van der Lingen, a wide range of interrelated digital technology systems, such as Big Data, the Internet of Things, advanced robotics, artificial intelligence and online platforms, have emerged over the past few years. Their interrelated nature enables the systems to build on each other. Incremental innovations in any of these and/or other technology-related systems can cause acceleration. The Fourth Industrial Revolution has become important in product and process innovations to generate significant productivity gains and sustain a competitive advantage.

The recent technological advances have prompted various innovations. Innovation is enabled and influenced by a large number of diverse factors, including technology and manufacturing as hard issues, and leadership and new skills as soft issues.

The disruption caused by digital technologies has been fundamental to business model innovations, which became essential for creating new value propositions. Business model innovations are often considered more important than technological innovation or product innovation.

The influence of digitisation on industrial decision-making has become eminent, but also the important role that universities and government need to fulfil. The Triple Helix theory suggests that interaction among university-industry-government is the key to improving conditions for innovation. She concluded her address by focusing on the importance of managing innovation in the digitisation era.

→ *Prof Elma van der Lingen.*

The interrelated nature of a wide range of digital technology systems enables the systems to build on each other. Incremental innovations in any of these and/or other technology-related systems can cause the acceleration needed to sustain productivity and competitiveness in the Fourth Industrial Revolution.

Relaunching the International Centre for Information Ethics

Rachel Fischer and Jared Bielby

After 20 successful years, the International Centre for Information Ethics (ICIE) has been relaunched under a new administration towards a revision of the goals and mission of the ICIE community.

Beginning with the launch of a new website, the ICIE has been rebuilt to reflect a community-led philosophy that includes an open membership model, as well as a members' community forum for discussion and for the edification of the field of information ethics.

Since the establishment of the ICIE by Rafael Capurro of the Stuttgart Media University, Germany, in 1999, the ICIE pioneered the advancement of the field of information ethics, offering a platform for the intercultural exchange of ideas and information regarding worldwide teaching and research in the field. The new era of the ICIE will be led by Jared Bielby as Chair and Rachel Fischer of the African Centre of Excellence for Information Ethics (ACEIE) in the University of Pretoria's Department of Information Science as Co-Chair. This partnership is pivotal because it closely aligns collaboration between the ICIE and the ACEIE.

Building from its original purpose and goals, the relaunch of the ICIE has extended its mission to provide a greater opportunity for community interaction and collaboration between colleagues in the field. The ICIE's aims are the following:

- It seeks leadership and excellence in all aspects of the information ethics discipline, including research, teaching, advocacy and practice. Supporting eight global chapters, the ICIE provides resources for and encourages the growth of information literacies and digital cultures throughout the world.
- Pursuant to its mission, the ICIE actively seeks partnerships with relevant individuals, institutions, societies and communities in the information fields. It advocates for and supports the growth of healthy and informed information cultures in the digital age, providing a centralised forum for sharing and communication in the field.

The ICIE has been a leader and pioneer in the field of information ethics since 1999. The success of the ICIE community has always depended on the efforts and participation of those involved. It is through the sharing of related interests and knowledge with others that the ICIE has thrived over the years. As such, the launch of the new community forum for the ICIE will allow direct member-to-member interaction and collaboration. The ICIE has four main focal areas for 2018.

Acknowledging its historically defined origins and looking to its current iterations, the ICIE community will consider the evolution of the field to identify core focal points as currently applicable.

Since its establishment, the ICIE has pioneered the advancement of the field of information ethics, offering a platform for an intercultural exchange of ideas and information regarding worldwide teaching and research in the field.

Affirm the current parameters of the field of information ethics

Using a community-led philosophy, the ICIE Advisory Board will preside over a community forum discussion towards the reaffirmation of the parameters and prerogatives of the field of information ethics as the field stands in 2018. Acknowledging its historically defined origins and looking to its current iterations, the ICIE community will consider the evolution of the field, seeking to recognise its broader aspects, but identifying core focal points as currently applicable. Thus, establishing a set of parameters for the field, the ICIE will revisit the definition of the field annually, updating aspects of the field once a year as necessary. These definitions will be disclosed on the ICIE website and will be connected to the annual output. All themes and focal areas will be discussed and confirmed by the members of the ICIE Advisory Board.

Establish foundational partnerships with regional information ethics communities in the nations of Brazil, Russia, India, China and South Africa (BRICS)

The ICIE will reaffirm or establish foundational partnerships with existing information ethics communities from the BRICS countries, forming partnerships where none exist or strengthening currently existing partnerships within BRICS's information ethics communities. The ICIE will affirm representatives from each BRICS country and establish said representatives under the corresponding ICIE regional chapter head. Chapter heads, along with their ICIE BRICS representatives, will work together to establish ongoing regional goals and objectives for the BRICS countries of the ICIE.

In addition to these focus areas, the ICIE also focuses on establishing the North Africa chapter, which includes 22 countries from the Arab region, and finalising the Latin America chapter. This formalising of the Latin America chapter will enable the organisation of the second conference on International Policy Dialogue on Information for All Programme (IFAP) priority areas in the BRICS countries in Brazil in 2019, following on the success of the first conference held in Cape Town, South Africa, in July 2018.

Publish a special edition of the International Review of Information Ethics (IRIE) outlining the current parameters of the field of information ethics

Leading from community forum discussions outlining the parameters of the field of information ethics, as established above, the ICIE will publish a special edition of the IRIE. The special edition will seek to address the evolution of the field of information ethics and its current state and look at possibilities for a taxonomy for the field. It will formalise the ICIE Forum's community discussions into scholarly articles.

Fostering active international dialogues between the Global North and the Global South

In consideration of debates on cognitive justice, the ICIE and ACEIE emphasise the importance of multiway dialogues, namely North-North, South-South and North-South. It is argued that the active endeavour towards representing minority points of view, together with strengthening the theoretical framework underlying these, will contribute to equal representation. While the ICIE acknowledges its international scope and focus, the ACEIE acknowledges its African scope and focus.

The ACEIE and ANIE networks are proud to be partners of the ICIE and look forward to both strengthen their own research and to present it on an international platform.

For more information, please visit https://www.i-c-i-e.org/.

ACEIE engages in international policy dialogue

Naailah Parbhoo-Ebrahim and Rachel Fischer

The African Centre of Excellence for Information Ethics (ACEIE) and United Nations Educational, Scientific and Cultural Organization (UNESCO) co-organised the International Policy Dialogue on Information for All Programme (IFAP) priority areas in the Brazil, Russia, India, China, South Africa (BRICS) countries, which was held in Cape Town, South Africa, from 4 to 6 July 2018.

Participants from the International Policy Dialogue on IFAP Priority Areas in the BRICS countries.

The conference aimed to provide a platform for the International Policy Dialogue on IFAP priority areas and support the development of a sustainable dialogue group in BRICS, African countries and the Pacific Region. It also strengthened collaboration between the BRICS countries and revitalised the IFAP structures and networks.

The six IFAP objectives include information for development, information literacy, information preservation, information ethics, information accessibility and multilingualism. The conference themes included cultural diversity, radicalism in the digital environment, digital learning among BRICS countries, cyber journalism and ethics, multilingualism, migration and adaptation, equitable and sustainable development, gender and inclusivity, and the impact of the Fourth Industrial Revolution on cultural diversities and development. The countries that participated in the conference included Brazil, Burkina Faso, Canada, China, Egypt, Eritrea, France, Germany, India, Kenya, Libya, Malawi, Mozambique, Russia, South Africa, Sudan, Zambia and Zimbabwe.

Addresses were delivered by Prof Archie Dick, Head of Department of Information Science at UP, Boyan Radoykov, UNESCO Chief Knowledge Societies Division, Carlton Mukwevho, Secretary-General of the South Africa National Commission for UNESCO and Prof Rafael Capurro of the Capurro-Fiek Foundation in Germany and founder of the International Centre for Information Ethics (ICIE).

A gala dinner was held on 5 July 2018. The guest of honour was former President of South Africa, FW de Klerk, who talked about "the accommodation of cultural, religious and ethnic diversity: a core challenge for the 21st century for South Africa, for Europe and for the world". The participants were treated to cultural events such as a visit to Table Mountain and Robben Island. At the gala dinner, they were introduced to cultural music and instruments such as the marimba.

The outcomes of the conference were for the BRICS representatives and African scholars, along with the academics from the international community, to develop, finalise and distribute the Cape Town Declaration, ensuring the way forward for future collaboration with UNESCO IFAP and the BRICS countries for other activities and the second conference in Brazil in 2019.

For more information, please visit www.up.ac.za/aceie.

Huawei launches Authorised Information and Network Academy

Huawei and the University of Pretoria (UP) have launched the Huawei Authorised Information and Network Academy (HAINA). The HAINA initiative is a global ICT technology education programme that authorises universities and tertiary education organisations to deliver Huawei certification courses to their students. This is the fourth accreditation in South Africa, following established programmes at the Tshwane University of Technology, the University of Johannesburg and the University of the Witswatersrand. The ICT Academy at UP will be the first to offer Storage Technology training (HCNA/P-Storage). UP is also considering the possibility of offering training in LTE (HCNA/P-LTE) and Access Technologies (HCNA/P-Access).

Maison Mei (Director: SAEBSD), Michael Meng (Vice-President: SAEBSD), Kelvin Yao (Director: South Africa Human Resource Department), Prof Sunil Maharaj (Dean: EBIT), Dr Jacques van Wyk (Department of Electrical, Electronic and Computer Engineering) and Prof Johan Joubert (Head of Department).

The programme adopts the increasingly popular university-enterprise cooperation model and includes training and industry certification in popular information and communication technologies (ICTs), such as WLAN, security, storage and cloud computing. The Faculty of Engineering, Built Environment and Information Technology is proud to partner with this global leader to bring competitive ICT skills to its students.

HAINA students will acquire knowledge of cutting-edge ICTs and gain elaborate hands-on practical training experiences. Students going through HAINA labs will be able to obtain the following certification paths: HCNA/P-R&S, HCNA/P-WLAN, HCNA/P-Security, HCNA/P-Storage and HCNA/P-Cloud Computing, thus boosting their ICT skills to increase their chances of gaining employment. Additionally, HAINA-trained graduates will be given first priority for internships and employment opportunities at Huawei and its partner companies.

Huawei provides a certification service by leveraging its years of experience in developing ICT talent. The certification is created to match the career development life cycle of talent for the ICT industry, meeting the needs of various roles, from students to workplace beginners, associates, professionals and experts.

Michael Meng, Vice-President of Hauwei's Southern Africa Enterprise Business Service Department (SAEBSD), said that the company is committed to continuous knowledge-sharing efforts and the development of a technical workforce for the sustainable growth of the ICT ecosystem. As an international ICT innovator, Huawei actively works with partners on joint projects that are dedicated to upskilling educational environments and providing the youth with more opportunities to meet the ICT ecosystem's long-term need for talent.

The Faculty looks forward to facilitating closer interaction between academia and the industry to help strengthen and provide human resources that are in high demand for the IT and telecommunications fields in the region.

EBIT researchers publish in top-ranked engineering and technology journal

IEEE Communications Surveys and Tutorials **is an online journal published by the Communications Society (ComSoc) of the Institute of Electrical and Electronics Engineers (IEEE). It is considered to have the highest impact factor among 87 journals in the field of telecommunications and 148 journals in the fields of computer science and information systems.**

The journal's impact factor, as released by ISI Clarivate Analytics, increased from 17.188 in 2016 to 20.230 in 2017. It also has the highest impact factor of all the IEEE journals. Articles selected for inclusion in this journal go through a rigorous review process before their publication.

An article was recently published in *IEEE Communications Surveys and Tutorials* by a group of researchers in the Faculty of Engineering, Built Environment and Information Technology (EBIT) (Dr Uche Chude-Okonkwo, a Senior Postdoctoral Research Fellow, Prof Reza Malekian, Head of the Advanced Sensor Networks Research Group, and Prof Sunil Maharaj, Dean of EBIT), in collaboration with Prof Athanasios Vasilakos from Lulea University of Technology in Sweden. The article comprises a review on nanonetworks and molecular communications,

Prof Reza Malekian, Dr Uche Chude-Okonkwo and Prof Sunil Maharaj.

including the Internet of Bio-Nanothings, an application area of the Internet of Things in healthcare. This is a developing area that brings telecommunications and health sciences together in a novel way. Research in this field is being undertaken in the Faculty's Sentech Chair in Broadband Wireless Multimedia Communications under the chairholder, Prof Maharaj. Both he and Prof Malekian are senior members of IEEE.

Prof Josua Meyer receives NRF A-rating

Prof Josua Meyer, Head of the Department of Mechanical and Aeronautical Engineering, is currently the only researcher in mechanical and aeronautical engineering in South Africa to receive an A-rating from the National Research Foundation (NRF). This is the highest rating conferred on individuals who are unequivocally recognised by their peers as leading international scholars in their field.

Prof Meyer currently leads the Clean Energy Research Group (CERG) that he established in the Department. This research group focuses on thermal-solar, wind and nuclear energy. Over the years, he has grown this group to approximately 50 full-time graduate students and 10 staff members. With his group members, he has designed and constructed more than 12 unique experimental setups.

International awards he has received for research include the Thomas Price Award, Rand Coal Award, South African Institute of Mechanical Engineers Medal, LT Campbell-Pitt Award, Literati Award, Chairman's Award of the South African Institute of Air-conditioning and Refrigeration, and the Will Stoecker Award. He is a member or fellow of various professional

Prof Josua Meyer.

institutes and societies such as the American Society of Mechanical Engineers (ASME), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), American Institute of Aeronautics and Astronautics (AIAA) and the Royal Aeronautical Society.

Recognising outstanding academic performance

Each year, the University of Pretoria pays tribute to its exceptional academic achievers. The Faculty of Engineering, Built Environment and Information Technology is proud of the outstanding performance and commitment of its academic staff. These researchers make important contributions to the Faculty's academic mission.

Exceptional young researcher

This 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. Anyone who has been evaluated by the National Research Foundation (NRF) as a P-rated researcher automatically enjoys Exceptional Young Researcher status.

Dr Mardé Helbig is a senior lecturer in the Department of Computer Science. Her research focuses on solving dynamic multi-objective optimisation (DMOO) problems using computational intelligence techniques. Dr Helbig is very active in the computational intelligence community and serves as Vice-Chair of the Institute of Electrical and Electronics Engineers (IEEE) Computational Intelligence Society (CIS) task force on evolutionary multi-objective optimisation. She is also a member of the IEEE CIS Emerging Technologies Technical Committee, and the IEEE CIS Women in Computational Intelligence and IEEE CIS Young Professionals subcommittees. She has organised numerous special sessions and delivered tutorials on DMOO at top conferences in the field. She has also delivered four keynote addresses at international conferences in the last two years. She received a Y1 rating from the NRF in 2016, and was selected as a member of the South African Young Academy of Science (SAYAS) in 2017.

NRF-rated researchers

A-ratings

A-rated researchers are unequivocally recognised by their peers as leading international scholars in their respective fields for the high quality and impact of recent research outputs. Acquiring an NRF A-rating generates considerable acknowledgement and respect for the individual researchers, as well as their institutions.

Prof Josua Meyer was appointed as professor and Head of the Department of Mechanical and Aeronautical Engineering in 2002 and as Chair of the School of Engineering in 2004. He leads the Clean Energy Research Group, which he established with a broad focus on thermal sciences and fluid flow, and a narrower focus on heat exchangers. Prof Meyer has received five national teaching awards from three different universities, as well as an international award. He has won more than 20 awards for best article of the year or best conference paper. For his research, he has won eight national and international awards. He is a member or Fellow of various professional institutes and societies. He has authored and co-authored more than 800 articles, conference papers and book chapters, and has supervised and co-supervised more than 100 research master's and doctoral degree students. In 2016, he won the University of Pretoria's Exceptional Supervisor Award for the fifth time. He has an A2-rating from the NRF.

B-ratings

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 Walter Focke is a professor in the Department of Chemical Engineering and Director of the Institute of Applied Materials. His research on carbon technology focuses on the use of expandable graphite in thermal energy applications and as a conductive and flame-retardant additive in polymer. His clay and polymer additive technology research is targeted towards functional applications in polymers in order to improve thermo-oxidative stability and flame retardancy. In the field of pyrotechnics, he successfully developed a range of "green" compositions for use as time delays and initiating compositions in chemical mine detonators. His research in respect of malaria vector control has also resulted in repellents and insecticides. Prof Focke has a B3-rating from the NRF.

Prof Johan Joubert joined the Department of Electrical, Electronic and Computer Engineering where he is currently professor and Head of Department in 1988. He has spent time as visiting scientist at various international institutions, such as California State University in the USA, Industrial Research Laboratories in New Zealand, the University of Karlsruhe in Germany, and Loughborough University in the UK. His research interests include antenna array design and computational electromagnetism and he has received numerous awards. Publications to date include one book chapter, 91 papers in peer-reviewed journals and 68 papers presented at conferences. He has successfully supervised or co-supervised 20 MEng students and 11 PhD students. Prof Joubert has a B3-rating from the NRF.

Prof David Limebeer is an extraordinary professor in the Department of Electrical, Electronic and Computer Engineering. His research interests include a range of applied and theoretical problems in control systems and engineering dynamics, including robust control, optimal control, vehicular control, process control and the control of aeroelastic phenomena in large structures. He is also interested in a variety of problems in multibody mechanics and two- and four-wheeled vehicle dynamics. He has consulted on a variety of vehicle-related matters, product liability litigation, and patent disputes in optical recording systems, drilling equipment and high-speed packing machines. Prof Limebeer has a B1-rating from the NRF.

Prof Wimpie Odendaal is a professor in the Department of Electrical, Electronic and Computer Engineering, and the Director of the Centre for Electromagnetism. His research focuses on achieving a high level of excellence in electromagnetic technology, particularly in the design, development and evaluation of microwave antennae, radar backscatter and antenna measurements. Among other things, he has contributed to the development of various high-performance wide-band double- and quad-ridged horn antennas. Prof Odendaal has a B3-rating from the NRF.

C-ratings

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 Theresa Coetsee is a senior lecturer in the Department of Materials Science and Metallurgical Engineering. She joined the University of Pretoria in 2016, after 25 years of working in the mining and mineral resources industry, notably at the former South African Iron and Steel Corporation (Iscor), Kumba Resources and Exxaro Resources. Her primary area of research is extractive metallurgy (pyrometallurgy and hydrometallurgy), with a focus on process improvement and development through the application of process mineralogy, integrated with thermochemical modelling and process data analysis. Dr Coetsee has a C3-rating from the NRF.

Prof Ken Craig is a professor in the Department of Mechanical and Aeronautical Engineering. His area of research is the application of computational fluid dynamics and other numerical simulation techniques with mathematical optimisation to different mechanical engineering applications to optimise and improve engineering designs. This initially included industrial applications like continuous casting, automotive crashworthiness and electronics cooling, but more recently, he has started to focus on solar and other renewable energy applications. Prof Craig has a C2-rating from the NRF.

Dr Marné de Vries is a senior lecturer in the Department of Industrial and Systems Engineering. Her research focuses on enterprise engineering (EE). She represents the University of Pretoria as a member of the CIAO! Enterprise Engineering Network (CEEN), which is a community of academics and practitioners from 13 universities who contribute to the development of EE and its practical application. Dr De Vries has a C3-rating from the NRF.

Prof Chrisna du Plessis is an associate professor and Head of the Department of Architecture. Her research is aimed at developing the principles and guiding frameworks for the practices of sustainable construction and human settlement development, with a focus on resilience and regeneration. She currently leads a long-term project, funded by an NRF Global Change, Sustainability and Society Grant to determine how concepts such as resilience and regenerative design would influence the way we think about urban sustainability in the context of global grand challenges. Prof Du Plessis has a C1-rating from the NRF.

Prof Stephan Gruner is an associate professor in the Department of Computer Science. He works in the area of formal software specification and verification techniques. He is also interested in science-philosophical questions concerning the ontological, epistemological, methodological and historical foundations of computer science and its relations with other academic disciplines. Together with Postdoctoral Research Fellow Nils Timm, Prof Gruner received the Best

Paper Award at the Brazilian Symposium on Formal Methods in 2014, the Second Best Paper Award in 2016, as well as recognition as one of the top three contributors at the Fundamentals of Software Engineering in 2017. Prof Gruner has a C2-rating from the NRF.

Prof Tania Hanekom is a professor in the Department of Electrical, Electronic and Computer Engineering. Her research is in the computational physiology of the electrically stimulated human auditory system. It aims to create user-specific computer models of the auditory periphery of cochlear implant users with the objective to develop clinical tools to allow non-invasive, model-based diagnostics and model-predicted customisation of device parameters. She is the author or co-author of more than 50 journal and conference outputs and received numerous teaching and learning awards, among others the Chancellor's Award for Teaching and Learning in 2017. She has a C2-rating from the NRF.

Prof Elsabé Kearsley is a professor in the Department of Civil Engineering. Her research focuses on reducing the environmental impact of the cement and concrete industry. Prof Kearsley was the first author of the paper that received both the JE Jennings Award for the best paper published by a South African author in 2014 and the 2017 Individual Award for Transportation from the South African Institute of Civil Engineering. She was one of the co-authors of the paper "Fracture banding in caving mines" that received a gold medal from the Southern African Institute of Mining and Metallurgy in 2016. Prof Kearsley has a C1-rating from the NRF.

Prof Karina Landman is an associate professor in the Department of Town and Regional Planning. Her current research interests relate to public spaces, spatial transformation, nodal development, sustainable neighbourhoods, urban resilience and regenerative development and design. Her other areas of research and professional experience include crime prevention in the built environment, gated communities, urban segregation and medium-density mixed housing. She leads a multi-year NRF project on the transformation of public spaces in South Africa and is currently working on a book entitled *The evolution of public space in South Africa*. Prof Landman has a C2-rating from the NRF.

Prof Leon Pretorius has more than 40 years' experience in the professional, engineering, academic and academic management domains. He holds the degrees BSc (Hons) Engineering, BSc (Hons) Mathematics, MScEng, MSc (Mathematics) and DEng from the University of Pretoria. He has been active as a specialist consultant and researcher in the engineering industry since 1980. Prof Pretorius has supervised more than 240 master's and doctoral degree students in engineering, as well as students of engineering and technology management on their master's research projects, dissertations and doctoral theses. This includes the supervision of 51 successful PhD students. He has published more than 260 technical conference papers and peer-reviewed journal articles as author and co-author in his fields of expertise. Prof Pretorius has a C1-rating from the NRF.

Dr Marita Turpin is a senior lecturer in the Department of Informatics. Within the field of information systems, her research interests include Information and Communication Technology for Socio-economic Development (ICT4D), in particular the application of systems thinking methods in this domain. As part of her undergraduate teaching, she is also researching the effective teaching of problem-solving skills, critical thinking and creativity skills to undergraduate Informatics students. She received the Best Paper Award at the 2014 International Development Informatics Association Conference, with a paper entitled "Investigating ways to assess ICT4D's impact on the larger community". Dr Turpin has a C3-rating from the NRF.

Y-ratings

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 Waldo Kleynhans is an extraordinary senior lecturer in the Department of Electrical, Electronic and Computer Engineering. He is a statistical signal processing and machine learning expert and focuses on the application areas of telecommunication, automated land cover change detection and maritime domain awareness using a variety of data sources. He has authored and co-authored more than 80 research papers in refereed accredited international conferences and journals. Dr Kleynhans's most notable awards include best papers presented at the IEEE Geoscience and Remote Sensing Symposium (IGARSS) Conference held in Munich in 2012, as well as the African Association of Remote Sensing of the Environment (AARSE) Conference that was held in Morocco in 2012. Dr Kleynhans has a Y1-rating from the NRF.

Dr Lijun Zang is a senior lecturer and the incumbent of a Junior Chair in Energy Efficiency funded by Exxaro in the Department of Electrical, Electronic and Computer Engineering. He obtained an MEng degree from the Wuhan University, China, in 2012, and subsequently completed a PhD at the University of Pretoria in 2016. He is an accredited South African National Accreditation System (SANAS) technical signatory for the measurement and verification of energy savings. He has published more than 30 research articles in internationally highly reputable journals and conferences to date. His research interests include energy modelling, the optimisation and control system design for industrial processes, heavy-haul trains, electric vehicles, as well as building energy systems and micro-grids. Dr Zhang has a Y2-rating from the NRF.

EBIT staff members elected to serve industry and academia in leadership positions

Junior Vice-President of SAIEE

Prof Sunil Maharaj has been elected as Junior Vice-President of the South African Institute of Electrical Engineers (SAIEE).

SAIEE comprises members who make meaningful contributions to the quality of life of the community and to the steady advancement of technology. Its efforts are acknowledged in many countries across the world, and it strives to provide leadership to the electrical and electronic engineering discipline to support its members in becoming more effective practitioners.

Prof Maharaj is the Dean of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology. In addition to this, he is a professor in the Department of Electrical, Electronic and Computer Engineering and Director of the Sentech Chair in Broadband Wireless Multimedia Communication.

ASOCSA President

Dr Hendrik Prinsloo has been elected as President of the Associated Schools of Construction of Southern Africa (ASOCSA).

The President is elected from all member organisations (universities, government and industry partners) in southern Africa on the basis of the candidate's standing in the academic community and his or her experience in the construction industry in southern Africa. ASOCSA is an internationally recognised professional body established to promote, facilitate, develop and monitor the relevance and quality of construction-related education, research and graduates in conjunction with higher education institutions, industry and government in southern Africa.

Dr Prinsloo was appointed as a senior lecturer in the Department of Construction Economics in 2008. During his time in industry, he was the project manager for high-impact projects like Freedom Park.

SAYAS membership

Two EBIT researchers have been selected as members of the South African Young Academy of Science (SAYAS).

Prof Reza Malekian is an associate professor in the Department of Electrical, Electronic and Computer Engineering and head of the Advanced Sensor Networks Research Group.

Dr Mardé Helbig is a senior lecturer in the Department of Computer Science and a member of the Computational Intelligence Research Group.

SAYAS is the voice of young scientists in South Africa and aims to contribute towards solutions to national and global challenges facing society.

The country's leading emerging researchers in basic and applied sciences, engineering, social sciences, arts and humanities are selected as members.

Staff achievements

Global Young Researcher Award

Dr Taryn Bond-Barnard of the Graduate School of Technology Management (GSTM) has been honoured with this year's Global Young Researcher Award.

The award is administered by the International Project Management Association (IPMA). Dr Bond-Barnard was awarded the prize for her PhD research entitled "Project communication, trust, collaboration and success: a structural equation model and the influence of computer-mediated communication". The value of this study is that it presents a new "human" perspective for investigating project management success. Dr Bond-Barnard's study addresses the relevance of existing project communication management theory in today's settings, and its practical implications by assessing the benefits and usage of contemporary communication media. Her PhD research was supervised by Prof Herman Steyn and Dr Lizelle Fletcher.

Newton Mobility Grant

Dr Beth le Roux, Associate Professor in the Department of Information Science, has been awarded a Newton Mobility Grant to the value of just over £9 000 by the British Academy.

The grant is for a collaborative research project entitled "Histories of publishing under apartheid". The project is being conducted with Dr Caroline Davis of Oxford Brookes University, UK, and seeks to examine the role of publishing in the cultural struggle, both for and against apartheid, in South Africa. It will build upon an existing partnership and support new research in print culture and publishing studies to address the activities of publishers, authors and readers within a repressive environment. Dr Le Roux will travel to the UK to conduct research and to host workshops on book history in South Africa in order to encourage further research and build capacity among early career researchers in the field of publishing history.

Associate of Mine Managers of SA Prize

Two heads of department in the Faculty have been awarded the Associate of Mine Managers of SA Prize.

Prof Josua Meyer is Head of the Department of Mechanical and Aeronautical Engineering, and Prof Ronny Webber-Youngman is Head of the Department of Mining Engineering.

The prize was awarded for their groundbreaking work published in a journal article entitled "Application of computational fluid dynamic modelling in the design of shaft systems".

Lifetime achievements

Prof Kevin Wall from the Department of Construction Economics has earned prestigious awards through his lifelong dedication to industry.

Prof Wall received the National Science and Technology Forum (NSTF) - South32 Lifetime Award, which recognises, celebrates and rewards excellence in science, engineering, technology and innovation in South Africa. It is the most comprehensive national award of its kind.

He also received the Gold Medal award from the South African Institution of Civil Engineering in recognition of his outstanding individual contribution to the industry and profession of civil engineering. This constitutes the Institute's highest honour.

2018 Gauteng Premier's Service Excellence Awards

Since 2016, the Hatfield City Improvement District (CID), in conjunction with the University of Pretoria and the stakeholders concerned with the Hatfield area, has been extensively involved in developing a high-level and strategic institutional and spatial development perspective for the Hatfield Campus Village. The aim of this strategic development framework was primarily to revitalise the Hatfield area and to transform this area into a safe and vibrant world-class city precinct. This framework, which was compiled by Enterprises University of Pretoria, under the leadership and management of Dr Johnny Coetzee, a senior lecturer in the Department of Town and Regional Planning, was named a Gold winner in the prestigious Gauteng Premier's Service Excellence Awards in the subcategory "Building safe communities" in February 2018.

→ *Members of the project team receive the 2018 Gauteng Premier's Service Excellence Award.*

This award recognises projects that strive to mobilise against drugs, eradicate violence against women and children, and build safe communities. The Hatfield Campus Village project also featured on the programme of an international conference held in Chicago, USA, in November 2017. Dr Coetzee believes that to build quality, sustainable and resilient places, and vibrant communities, we need to work together across disciplines and organisations.

The Hatfield Campus Village forms part of the Hatfield CID, a non-profit organisation funded by the 26 property owners within the boundaries of Hatfield by means of a ratepayers' levy. It is a legally constituted entity, established in terms of the Gauteng City Improvement District Act, Act No. 12 of 1997. It operates in partnership with the Municipality and cooperates with all the relevant authorities, including th South African Police Service, the Metro Police, the City's Emergency Services and the University of Pretoria, which occupies the largest portion of land in Hatfield.

The University plays an important role in Hatfield as an anchor institution. It works in close collaboration with the management team of the Hatfield CID to research, analyse and assess the situation in Hatfield on an ongoing basis in order to bring about continuous improvement. The CID model has proven itself worldwide to be a model to fight urban decay, ensure the safety and security of visitors, inhabitants and enterprises, and stimulate business and property investment.

Too often, plans and strategies are compiled and seldom implemented. The Hatfield framework is a good example of "a vision in action" and a plan that has already spawned various projects that are currently being implemented. One of these projects, which is now gaining strong momentum, is the development of a detailed urban design framework that will guide and inspire developments in terms of elements such as street scaping, the design of public spaces, landscaping, the use of public spaces, and creating vibrant and safe spaces.

Department of Mining Engineering honours its alumni

Since the inception of the University's Department of Mining Engineering in 1961, it has contributed hugely to the mining industry by providing it with world-class mining engineering leaders. Its alumni have continued to play an important role in the teaching and contract research activities of the Department.

Its alumni remain involved in the activities of their Alma Mater through an active alumni body, the Mining Alumni Society of the University of Pretoria (MASUP). Members of this society support the Department by raising sponsorships, ensuring that high levels of skills and educational standards are maintained and offering mentorships to current students. Members of MASUP also act as external examiners and are available for industry discussions. They offer guidance to the Department and to industry, and serve on the Advisory Board of the Department of Mining Engineering.

At its Annual General Meeting that was held on 25 May 2018, Roger Baxter, CEO of the Minerals Council South Africa (formerly known as the Chamber of Mines), delivered the keynote address; the MASUP Gold Medal Achievement Award was presented to Dr Frik de Frey; and the top student achievers in Mining Engineering for 2017 were recognised with the presentation of student prizes.

The title of the keynote address was: "Restoring the dream: achieving the potential of South African mining". Mr Baxter observed that mining in South Africa has come a long way. However, the reality is that the South African mining sector has not been able to deliver on its full economic potential. He believes that the time has come to move the mining industry forward.

His presentation examined why mining matters in 2018. He pointed out that the mining industry continues to be a major contributor to transformation, and remains a key contributor to economic and social development. Admitting that the mining sector is in crisis, he mentioned the fact that policy and regulatory uncertainty has frozen

During his keynote address, Mr Baxter shared his vision for getting the South African mining industry back on track in the midst of the industry's current inability to deliver on its full economic potential.

new investments in the sector, and that net investment has declined by 57% since 2008. Domestic input costs for electricity, labour, transport and steel continue to increase at rates higher than inflation, which has an impact on employment and economic growth.

Against this background, he therefore proceeded to contemplate what mining investment would look like in an improved policy and regulatory environment, and examined what would be necessary to create an environment that was conducive to investment and improved economic development. His vision for getting the mining industry back on track includes a collaborative, trust-based leadership structure, characterised by ethical leadership and good

Prof Con Fauconnier, Honorary President of MASUP, with MASUP Gold Medal Achievement Award recipient, Dr Frik de Frey.

corporate governance, and policy and regulatory certainty. Furthermore, he identified the appointment of the new Minister of Mineral Resources, Mr Gwede Mantashe, as a significant and positive development for the industry.

He concluded his address by emphasising the importance of skills development, continual innovation and modernisation in the mining industry, cost-efficient and competitive infrastructure, a stable and constructive labour relations environment, and an earned social license to operate. These elements are essential to the future of a sustainable mining industry.

The awarding of the MASUP Gold Medal Achievement Award followed Mr Baxter's presentation. The recipient of this award, Dr De Frey, had started his career at Crown Mines in January 1952 at the age of 18. He went on to lecture at the University of Pretoria from 1977 until he retired in 1993. Among his many achievements include his appointment by the President of South Africa as a mining engineer of the tax court for five years from 2014 to 2019. He is still an active researcher.

According to Prof Ronny Webber-Youngman, Head of Department,

The MASUP Gold Medal Achievement Award was presented to Dr Frik de Frey during the 2018 Annual General Meeting of MASUP.

Dr De Frey is recognised for his contribution to the Department of Mining Engineering and the mining industry as a whole, "showing us what total loyalty and commitment means".

Finally, the following students were recognised for their achievements in 2017:

- Johannes Hendrik Maritz: Best third-year student in Geology Mining and Sasol Prize for the best third-year student in Mining Engineering
- Phakamane Zule: Best student in Explosives Engineering
- Lebogang Pitso Mpetle: Sasol Mining Prize for the best first-year student in Mining Engineering
- Jerry Mokganya: Sasol Mining prize for the best second-year student in Mining Engineering

The meeting was concluded by Prof Webber-Youngman, who presented the alumni with a brief overview of the activities of the Department for 2017.

Leading executive in the global mining industry calls UP his Alma Mater

Since being voted as one of the world's 25 most powerful people in business by *Fortune 500* in 2010, Dr Marius Kloppers has continued to make an impact as a leading executive in the global mining industry. He earned international recognition as CEO of the BHP Billiton Group from 2007 until 2010. He is currently a non-executive director of FLSmidth & Co, based in Copenhagen, Denmark, a position he has held since April 2016.

Dr Kloppers was born on 26 August 1962, and grew up in Johannesburg. He graduated from Helpmekaar Kollege and completed his BEng (Chemical Engineering) degree at the University of Pretoria in 1986. He went on to receive a PhD at the Massachusetts Institute of Technology (MIT) in the USA. He also graduated with an MBA from INSEAD in France, an experience that he has described as "incredibly rewarding" for the open, cross-cultural debates it stimulated with people around the globe and the grounding experience it gave him in commerce.

He started his career in the petrochemicals industry at Sasol and worked as an engineer in materials research at Mintek in South Africa. Following the completion of his MBA at INSEAD, he went to work for McKinsey & Co in The Netherlands. It was here that his interest in the aluminium industry was sparked, paving the way for his future at BHP Billiton. In 1993, he left McKinsey & Co to join Gencor, which later became Billiton.

Dr Kloppers has been progressively active in the mining and resources industry since 1993. He was appointed Chief Commercial Officer of BHP Billiton in December 2003. Previously he held the roles of Chief Marketing Officer, Group Executive of Billiton Plc and Chief Executive of Samancor Manganese, as well as holding several other positions at Billiton Aluminium, including those of Chief Operating Officer and General Manager of Hillside Aluminium.

In 2007, at the age of 45, he was appointed CEO of BHP Billiton after being a Director of BHP Billiton Limited and of BHP Billiton Plc since January 2006, and Executive Director of BHP Billiton Plc since 1 January 2006. He also served as a Director of the BHP Billiton Group. During his term as CEO of the world's largest mining company, he navigated the company through the financial crisis of 2008.

→ *Dr Marius Kloppers.*

Reflecting on his time at BHP, Dr Kloppers notes that the company fundamentally transformed the way that most mineral commodities were priced and sold. "I was fortunate enough to be leading the marketing and trading activities while these market transformations were taking place. Today, mineral commodities are bought and sold on screen, just like currencies. Futures markets and derivative tools exist for producers and consumers to modify and hedge their exposure. The team that I led innovated and implemented all these changes to the massive benefit of all," he observes.

Dr Kloppers had known FLSmidth & Co as a supplier to the mining industry. What appealed to him about joining this company was the opportunity to contribute to a company that he knew as a leading technology and efficiency provider to the industry. "At the same time, there was the opportunity to learn how business is conducted in Scandinavia," he says. "The combination of being able to contribute and continue to learn was very attractive. What also appealed to me was that,

being a Danish company, FLSmidth & Co had a long history of being innovative and successful, and was equally well known for being transparent and ethical in its dealings," he concludes.

As a member of its board of directors, Dr Kloppers supports the company's objective to continuously optimise energy consumption and emission control, and to introduce new inventions within the most important machine and process areas every year. It is among the leading suppliers of systems, machinery, processes, spare parts and services to the global mineral industry, and is the only supplier in the market to offer complete solutions that cover the entire process, from minerals extraction to the final end product.

At the Mining Indaba that was held in Johannesburg in 2017, Dr Kloppers was inaugurated in the South Africa Mining Hall of Fame. According to Bernard Swanepoel, Chair of the Mining Indaba, Dr Kloppers's nomination was based on the fact that he is "an outstanding individual, who has contributed to the mining industry's development over many years; improving the Australian-South African axis, driving unmatched growth and reshaping the mining landscape."

Looking back at his career in the mining industry, Dr Kloppers observes that it was an incredible experience to have a career that spanned both the agony (the depressed metal prices following the breakup of the USSR in the early 1990s) and the ecstasy (the rise of China and the impact on global minerals demand). "It required a complete turnaround in thinking: from cutting costs as a primary focus to expanding production as an overriding objective," he says.

In looking back on his career, Dr Kloppers remembers his training at the University of Pretoria to have been rigorous and rewarding.

He believes that the training that he received at the University of Pretoria was extremely rigorous. "I remember my class group not only as gifted, but also as hardworking and competitive. I was pushed hard, but in a good way. This, together with the academic rigour I experienced, helped establish a pattern of work that has prevailed with me to this day. What I liked about my training is that the skills set and problem-solving ethos I developed helped me to succeed in a career that spanned human resources, trading, operations and general management."

The Faculty of Engineering, Built Environment and Information Technology is proud to have alumni of this calibre holding its reputation high across the world, and wishes Dr Kloppers success for the future.

UP chemical engineer appointed to Eskom's Board

Dr Pulane Molokwane, a PhD graduate from the University of Pretoria, has been appointed as a non-executive director on the Board of Eskom. This appointment was made in January 2018 by President Cyril Ramaphosa (who was Deputy President at the time) after she had served on the Interim Board since June 2017. After obtaining her master's degree in applied radiation physics *cum laude* from the University of North West in 2004, she enrolled for a PhD at the University of Pretoria, where she was a member of the Environmental Engineering Group (EEG) led by Prof Evans Chirwa. She obtained her doctorate in 2010.

Dr Molokwane is a specialist in environment and project management, nuclear fuel management, research, and water and waste management. Her previous roles include being an executive technical director for Quintessential Investment Holdings, serving as principal environmental specialist at Sasol Technology (Pty) Ltd and being a senior nuclear fuel design physicist at the former Pebble Bed Modular Reactor (PBMR). She is the founder and director of Oloenviron (Pty) Ltd, a sustainable energy and environmental advisory entity, as well as a non-executive director of the South African Forestry Company Limited, and a member of the Sedibeng Water Board and the Inkomati Usuthu Catchment Management Agency. In 2015, the former President appointed her to serve as a commissioner on the National Planning Commission, an advisory body in The Presidency that advises government on cross-cutting issues that influence the country's long-term development.

She was instrumental in obtaining funding from the PBMR project on nuclear waste minimisation, which was the central theme of her doctoral studies. She was also the first researcher globally to publish real results on the prospect of the biological separation of Carbon-14 from a Carbon-12/Carbon-14 matrix using specially isolated autotrophic organisms in oxygen-stressed natural environments.

Dr Molokwane is passionate about identifying new and emerging technologies to comply with water and waste legislation, regulations and acts. In her professional capacity, she provides expert advice and specialist input to identify and implement new waste management technologies, which are aligned with and contribute to corporate strategy, as well as an entity's long-term research strategy. She also interprets and contextualises appropriate national and international legislation.

Dr Pulane Molokwane.

She credits her success to the training she received at UP. "It has paved ways for me in so many ways," she says. She alludes to the fact that being able to transition from being a nuclear physicist to being able to grasp engineering concepts has transformed the way she thinks, not only technically, but in business, and in both her executive and non-executive roles.

Dr Molokwane is registered with the Scientific Profession Council of South Africa as a professional natural scientist and is a member of the Institute of Directors of South Africa. Her prowess as a scientist is proven by her various academic achievements. She has published 30 articles in journals and peer-reviewed conference proceedings, and has contributed two book chapters. She holds an h-index of 7, which is equivalent to that of associate professor. She also holds an RG index of 10.92 in Researchgate.

Through her various achievements both academically and in business, she serves as a role model for young women. In 2017, she was selected as one of 25 women in science, technology, engineering, mathematics and innovation to be profiled in a book published by the Department of Science and Technology.

Student achievements

Global innovation lab

John G. Oyewole, a PhD student in the Department of Industrial and Systems Engineering, is developing a sustainable alternative to shrink wrap.

His invention has already won gold at an international innovation lab in Denmark. John was selected as one of seven UP students and one staff member to take part in the UNLEASH innovation lab, supported by the United Nations Development Programme (UNDP), the Carlsberg Foundation, Dalberg, Microsoft and Deloitte, among others. John's team was rewarded for their work in the sustainable consumption and production category, where their project, SmartWrapR, was judged to be the solution with the most impact potential. Shrink wrap is one of the largest hidden pollutants in the world. SmartWrapR is a reusable smart pallet cover made of a stretchable fabric such as Lycra, which can replace plastic shrink wrap. SmartWrapR can reduce the cost to customers for pallet wrapping and reduce environmental impact by 50% in plastic waste, 95% in petroleum use, and 80% in CO_2 emissions. The development team is currently in talks with potential funders before production can begin.

LafargeHolcim Foundation Awards

EBIT alumna, Heidi van Eeden, was awarded the first prize in the prestigious LafargeHolcim Foundation Sustainable Construction Awards for the Middle East Africa region in the Next Generation category.

Her project proved that brick-making can be technically sustainable and deliver a social contribution to community-making. Her decision to rework a student project earned her a big trophy and a cash prize. According to the LafargeHolcim Foundation, sustainability in building is rapidly gaining significance in the Middle East Africa region – particularly among female professionals and young graduates in architecture and engineering. The LafargeHolcim Awards are about more than just beautiful buildings and stand out as the world's most significant competition in sustainable design. The competition only acknowledges projects, not finished work, because the Foundation seeks designs that go beyond current standards and deliver new, surprising, or truly visionary solutions to the way we build.

Corobrik Architectural Student of the Year Award

Reneé Minnaar, a master's student in the Department of Architecture, was awarded the Corobrik Architectural Student of the Year Award.

She impressed the judges with her thesis entitled "Remediator – restoring the dichotomous relationship between industry and nature through an urban eco-textile mill and dye house". Her dissertation aims to investigate the potential of redundant industrial sites like the old Johannesburg Gasworks to mitigate the environmental and social issues resulting from the past in an attempt to reintegrate the site back into the surrounding urban fabric. The Corobrik competition has been running for 31 years and the Department of Architecture has won the most awards of all the schools of architecture in South Africa. It was commended for developing research directions that focus specifically on environment potential, heritage and cultural landscapes, and human settlements and urbanism over the years.

Project AREND gains momentum

Research conducted by students in the Department of Mechanical and Aeronautical Engineering has contributed to the development of an unmanned aerial vehicle (UAV): a specialised aerial sensor aircraft that supports the anti-poaching operations conducted by rangers in nature reserves in South Africa.

The Aircraft for Rhino and ENvironmental Defence (AREND) project focuses on the design, construction and testing of an UAV that can be used to detect and distinguish between humans and large animals, such as rhinoceros and elephants, in harsh environments. Team AREND consists of student members from four universities on three continents. The universities that are involved are the University of Colorado Boulder, USA, Helsinki Metropolia University of Applied Sciences, Finland, the University of Pretoria, South Africa, and the University of Stuttgart, Germany. Undergraduates, postgraduates, staff members and industry partners have collaborated to find a workable solution for the Kruger National Park in South Africa.

This international university engineering design team has been working together for the past three years. Two years ago, the project's management was moved from the University of Colorado Boulder to the University of Pretoria, with Dr Lelanie Smith from the Department of Mechanical and Aeronautical Engineering as the project manager. Once the Colorado team had successfully completed the integration phase of the embedded systems at the University of Pretoria in 2015, the next phase was to develop a landing and launch system for the UAV. While students from the University of Stuttgart and the University of Colorado Boulder were visiting the University of Pretoria in December 2017, the full team completed the last captive flight test to check all the flight systems.

Team AREND received considerable attention in 2017. They were invited to present their system and project at the 7th European Aeronautics Science Network (EASN) Conference on Innovation in European Aeronautics, held in Warsaw, Poland, the Electronic Warfare South Africa Conference, and the 4th UAV Forum at the Council for Scientific and Industrial Research (CSIR), Pretoria. Industry has responded favourably to the project and various new networking and skills development opportunities have been established for students involved in it. Team AREND received excellent feedback and a lot of interest from industry. Primarily, the excitement was related to the excellent way in which the project set-up reflects real-life challenges students would experience in industry. Various industries offered their assistance, from mentorship for students, some vacation work internships to offering to help with legal testing and flight phase integration.

→ *Team AREND and the UAV in action.*

Team AREND.

Paramount Technologies became a critical part of the team's success, helping them with understanding all the legal requirements and documentation for safe flight testing and joining them on two different occasion for flight tests in April 2018 and again in June 2018.

Even before all these networking opportunities arose, the AREND team had a standing arrangement with John Monk at the CSIR UAV group to offer UP students two weeks' composite manufacturing training. This is something the engineering industry, and not just the aerospace industry, needs desperately. According to Dr Smith, one of the plans in the Department of Mechanical and Aeronautical Engineering is to offer composite manufacturing to all first years, but it still depends on facilities and funding.

Another great connection the AREND team made was with Aerial Monitoring Systems. The CEO, Adam Rosman, noticed that the company's catapult system could be ideal for the AREND system with some minor adjustments. Currently, a couple of students are working with him under a non-disclosure agreement to develop a catapult for AREND that is similar to that of Aerial Monitoring Systems. It will hopefully be completed by the end of September 2018. The students are mainly working on the dolly that connects the UAV to the catapult's rail. They are ensuring that the rail is long enough so that the system is not accelerated too much. The final-year students redesigned, built and tested the dolly before the test flights.

Team AREND has been working together on this exciting project for the past three years.

The team handed the project over to some of the new members in February 2018. A test flight took place in March 2018 to gather flight data, test handling qualities and do a couple of landing tests with the newly integrated landing system. Unfortunately, after a week of all kinds of little problems, the launch rig broke and the team had to wait for the next opportunity in July 2018, which saw AREND taking to the skies.

Furthermore, the Faculty of Engineering, Built Environment and Information Technology awarded its Teaching and Learning Excellence Award to Dr Smith to acknowledge her excellent management of the project and the opportunities offered for student development through this project.

Keep track of team AREND's progress on Facebook at https://www.facebook.com/teamAREND/.

Book reviews

Deputy Dean co-authors groundbreaking book

Prof Jan Eloff, Deputy Dean: Research and Postgraduate Studies in the Faculty of Engineering, Built Environment and Information Technology (EBIT), has co-authored a book with Dr Madeleine Bihina, who has more than 10 years' industry experience with expertise in IT security and business analysis.

The book is titled *Software failure investigation: a near-miss analysis approach*. It focuses on software failure analysis in an operational environment.

The increasing complexity of software applications can lead to operational failures that have disastrous consequences. Think about medical software failures resulting in radiation therapy accidents. In order to prevent the recurrence of such software failures, a thorough post-mortem investigation is required. However, current approaches to operational software failure analysis do not promote the collection of evidence for analysis, which leaves the software system vulnerable to the re-occurrence of similar failures.

This book reviews existing operational software failure analysis techniques and proposes near-miss analysis as a novel and new technique for investigating and preventing software failures. A near-miss analysis focuses on the time window before the software failure actually unfolds to detect the high-risk conditions that can lead to a major failure. By alerting system users of an upcoming software failure, the detection of near-misses provides an opportunity to collect at-runtime, failure-related data that is complete and relevant.

Near-miss management systems (NMSs) for detecting upcoming software failures are presented in the book. An NMS can contribute significantly to the improvement of the accuracy of the software failure analysis. A prototype of the NMS has been implemented and is discussed.

Head of Department publishes first-ever book on hyper-heuristics

Natural computing is one of the most exciting developments in computer science. There is a growing consensus that this will become a significant field in computer science in South Africa. Prof Nelishia Pillay, Head of the Department of Computer Science, has co-authored the first book on hyper-heuristics.

The book is titled *Hyper-heuristics: theory and applications in the Springer Natural Computing Series*. In this book, Prof Pillay and co-author, Prof Rong Qu, aim to solve real-world optimisation problems and present fundamental theory and applications of hyper-heuristics. Prof Qu is an associate professor in the School of Computer Science at the University of Nottingham.

This introduction to the field of hyper-heuristics presents the necessary foundations and tools, illustrating some of their applications and highlighting advances in the field and future research directions. The book comprises 13 chapters, organised into three parts. The first part of the book focuses on hyper-heuristic fundamentals and theory, and gives an overview of selection-constructive, selection-perturbative, generation-constructive and generation-perturbative hyper-heuristics, and provides a formal definition of hyper-heuristics. The second part presents various applications of hyper-heuristics such as vehicle routing, nurse rostering, packing and examination timetabling. The third part of the book describes advanced topics, and gives a summary of the field and future research directions.

This is the first book on hyper-heuristics since the inception of the field and serves as a reference for researchers who want an introduction to hyper-heuristics, as well as those who want to extend their knowledge of the domain. Reviews of the book describe it as "the first place to look when starting a new project in the area" and "a single reference for anybody that has an interest in hyper-heuristics".

Brilliant long-serving EBIT employee retires

The Faculty of Engineering, Built Environment and Information Technology bade farewell to one of its long-serving employees, Liz Jones, after 31 years at the end of August 2018. Ms Jones was Head of the Faculty's Student Administration.

In 1975, she started her career as a typist at MacRobert, De Villiers & Hitge Attorneys. She also worked for Savage, Jooste & Adams Attorneys, OK Bazaars Regional Office and BKS Consulting Engineers.

Three of her superiors at BKS Consulting started lecturing at the University of Pretoria in 1987 and asked Ms Jones to come to work for them after she had been at home for two and a half years with her young son. In March 1987, she started working at the University of Pretoria in the Department of Civil Engineering as a secretary for these lecturers. She joined the Faculty's Student Administration in October that year and has been working there ever since. She was appointed as Head of Student Administration in 1993.

During her time at the University of Pretoria, she has seen the Hatfield Campus transform considerably. She remembers Roper Street passing under the Humanities Building and only a little wall marking the University's boundary where the Administration Building is today. To her it has also been gratifying to see the student population come to represent multiple cultures in contrast to the single-culture, single-language institution she experienced when she first started working there.

Throughout her tenure as Head of Department, Ms Jones has instilled a sense of compassion in her staff members. In the complex world that students have to navigate, their role can no longer be only that of administrative staff. They have to have a sympathetic ear and refer students to the Faculty Student Advisors when necessary.

Ms Jones worked with Vice-Principal Emeritus Prof Jan Malherbe for 10 years while he was Dean of the erstwhile Faculty of Engineering.

Liz Jones.

During this time, hers was the one opinion he could always count on. If there was a difficult student case, she not only knew the regulations, but also knew right from wrong. He says: "She was the best support I could have asked for. She was incredibly capable and had incorruptible integrity. I have to mention her wonderful sense of humour and impressive knowledge of English. Years after we worked together, I often popped into her office for advice".

Izette Willemse, who is Student Administration Coordinator for the School of Engineering in the Faculty, worked with Ms Jones for 20 years. She says she learnt a lot from her and describes her as firm, but fair. Ms Willemse also highlights the fact that Ms Jones had an open-door policy for students and staff alike and anything that was discussed in her office was held in the strictest confidence. She also mentioned her integrity.

After her retirement, Ms Jones will try her hand at the editing of dissertations and theses to keep busy. She has made a tremendous contribution to Student Administration and the Faculty wishes her a happy retirement.

The roots of industrial engineering

Johann Carl Friedrich Gauss: The "prince of mathematics"

Occasionally, an individual is born with extraordinary intellectual, personal and other capabilities and is destined to become famous. These special attributes may be used to change and influence the world for good or bad, and the impact on humankind often lasts long after the individual has passed on. In the world of war and conquest, names such as Genghis Khan, Alexander the Great and Adolf Hitler come to mind. Similarly, in the world of mathematics and science, three individuals are traditionally considered as the greatest the world has ever seen: Archimedes, Isaac Newton and Carl Friedrich Gauss. However, Leonard Euler and John von Neumann, among others, may also lay claim to this accolade.

Johann Carl Friedrich Gauss (1777 to 1855). Painting by Johann Christian Albrecht Jensen, 1840.

Early life

Johann Carl Friedrich Gauss was born on 30 April 1777 as the son of working class parents in Brunswick in the Duchy of Brunswick-Wolfenbüttel, which was part of the Holy Roman Empire at the time. It is now part of Germany. His mother was illiterate and never recorded the date of his birth. She remembered only that he had been born on a Wednesday eight days before the Feast of the Ascension, which occurs 39 days after Easter. In 1800, Gauss derived a simple algorithm to compute the date on which Easter should occur in both past and future years. Based on this, he claimed 30 April 1777 as his birthday.

Gauss was a child prodigy. His mother, a lifelong admirer of her son, claimed that he could do arithmetic calculations before he could talk properly and even helped his father with his bookkeeping duties. Many anecdotes about his numerical aptitude and his life have surfaced over the years. Some "stories" might be apocryphal and difficult to verify. For example, when Gauss was eight, his teacher asked the class to add up all the numbers from 1 to 100 to keep them busy. To the teacher's utter astonishment, Gauss produced the correct answer of 5 050 almost immediately. Gauss probably managed to reach his answer by grouping the numbers from 1 to 100 in 50 pairs, the sum of each pair being equal to 101 as follows:

(1+100) = 101, (2+99) = 101, ---,
(50 + 51) = 101 and 50 times 101
= 5 050

In numerical mathematics, this problem might be stated as the sum of the first n natural numbers, which is an arithmetic progression with a known answer. Alcuin of York stated a similar problem with a slightly different solution method around 800 CE. He called it "the puzzle of the hundred steps". It is unlikely that Gauss was aware of its existence. More than 100 slightly different versions of this story have been published.

A similar contested story, which is attributed to either Isaac Newton

or Isaac Asimov, relates that Gauss, while working and upon being told that his wife was dying, responded with:

"Tell her to wait a little. I am almost done".

At the age of 14, Gauss came to the attention of the Duke of Brunswick, Carl Wilhelm Ferdinand, who was so impressed with his capabilities that he awarded him an annual stipend. Gauss would receive financial support from the Duke until 1806. This financial support enabled him to complete his secondary studies at the Gymnasium Carolineum (Brunswick) in 1795 at the age of 18. He had read enough mathematics on his own (Newton, Euler and Lagrange) to engage in original mathematical research at this time. From 1795 to 1798, he studied at the University of Göttingen. In the autumn of 1798, he left without receiving a diploma because his professors could not teach him anything new. He returned to Brunswick. In 1799, the Duke insisted that he submit a thesis containing a proof of the fundamental theorem of algebra to the University of Helmstedt. Gauss received a doctorate in absentia. The Duke was killed in 1806 in the battle of Jena and Auerstedt, which meant that Gauss had to start working for a living. In 1807, at the age of 30, he accepted a position as professor of astronomy at the University of Göttingen and was appointed as director of the Göttingen Astronomical Observatory, a position he held until his death.

As an autodidact, Gauss learnt mathematics primarily on his own. He completed *Disquisitiones Arithmeticae* in 1798 at the age of 21, although it was not published until 1801. This work was not only fundamental in consolidating number theory as a discipline, but it shaped the field to the present day. The young Gauss was adept at the study of languages, and by the age of 19, he had already mastered German, Greek, Latin, English, Danish and French. He added Russian and Swedish later in his life.

Personal life

On 9 October 1805, Gauss married Johanna Osthoff, who died on 11 October 1809. Their youngest child, Louis, died the following year. He then married Minna Waldeck on 4 August 1810, who died on 12 September 1831 after a long illness. Gauss was never quite the same after the death of his first wife and his young son, so he grew to dominate his children in the same way in which his father had dominated him. Gauss had two surviving children from his first marriage (Joseph and Minna) and three from his second (Eugen, Wilhelm and Therese).

He did not want any of his sons to enter mathematics or science for fear of their doing the family name an injustice, as he believed none of them could surpass his achievements. Eugen and Wilhelm had a difficult relationship with their father and eventually emigrated to the United States. However, his youngest daughter, Therese, joined the Gauss household after the death of his second wife and kept house for him and his mother. She looked after her grandmother and father until they died in 1839 and 1855 respectively.

Gauss's personal life was overshadowed by the early death of his first wife. He plunged into a depression from which he never fully recovered. During his whole life, he did not find another mathematician with whom to share his most valued thoughts. This might be since there were few mathematicians in Germany of Gauss's stature at the time. The best mathematicians lived in France and Gauss did not like the French, especially Napoleon. Although he was fluent in French, he refused to speak it in the company of French-speaking people. He had an absolute distaste for travel and left his hometown of Göttingen only once during the last 28 years of his life when Alexander von Humboldt persuaded him to attend a conference in Berlin in 1828. This was the only scientific conference that Gauss ever attended.

Academic life

Gauss was reluctant to publish any of his preliminary results. True to his personal motto, *pauca sed matura* (few, but ripe), Gauss would limit his publications to work he regarded as complete and perfect.

The failure to publish was not based on a disdain for priority or credit. To him, priority meant being first to discover, not first to publish. Furthermore, he generated new ideas and insights at a high rate, often working on several problems simultaneously and sometimes neglecting one in favour of another one that was more challenging and interesting. By the time he returned to the neglected problem, someone else had published the results. In Gauss's mind, the credit still belonged to him, an attitude that his colleagues did not appreciate. Nevertheless, he seemed to have been very scrupulous in his claims.

When Gauss did publish, he wrote elegant, but highly compact, carefully polished papers with hardly a hint of the motivation, meaning, or the details of the steps required to reach the conclusions. Even excellent mathematicians found reading Gauss's papers very difficult. His papers were obscure and he often left huge gaps in the arguments that were supposed to support his results. Gauss's reluctance to publish or share preliminary results of his research might have been detrimental to his reputation and might have been the cause of some controversy of priority relative to other mathematicians.

Some authors attribute the credit for the discovery of the normal

Gauss would limit his publications to work he regarded as complete and perfect – *pauca sed matura* (few, but ripe).

distribution to Abraham de Moivre, who in 1738 published a study of the coefficients of the binomial expansion of $(a + b)^n$. This might be interpreted as the first expression for the normal probability law.

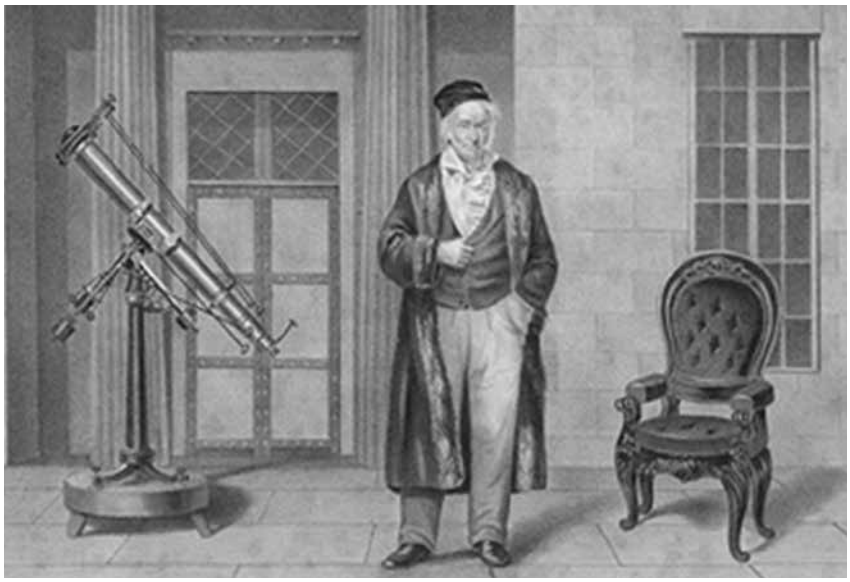
However, De Moivre did not interpret his results as anything more than an approximate rule for the calculation of the binomial coefficients and did not recognise the importance and possible applications of normal distribution.

In 1809, Gauss published his monograph entitled *Theoria motus corporum coelestium in sectionibus conicis solem ambientium,* where, among other things, he introduces several important statistical concepts, such as the method of least squares, the method of maximum likelihood, and normal distribution.

Gauss might have been the first to suggest the normal distribution law, but Pierre-Simon de Laplace proved the central limit theorem. De Laplace posited the theoretical importance of the normal distribution in mathematical statistics. Thus, De Laplace may also claim some credit for the formulation of normal distribution.

It is interesting to note that an American mathematician, Robert Adrain, published two derivations of the normal probability law, simultaneously and independently from Gauss in 1809. Nevertheless, his work remained largely unnoticed by the scientific community until 1871, when Ernst Karl Abbe "rediscovered" it.

Since its introduction, the normal distribution has been known by many different names, namely the law of error, De Laplace's second law, the Gaussian law and the Bell curve. Gauss himself apparently coined the term "normal", referring to the so-called normal equations that are involved in the application of the method of least squares to regression. The term "normal" is now considered a reflection of the fact that this distribution is typical, common, and thus "normal" in many aspects of statistics, science, engineering and



→ *Gauss on the terrace of the Göttingen Observatory. Lithograph by Johann Eduard Ritmüllar, circa 1830.*

natural processes. This is primarily due to the consequences of the central limit theorem. Among English speakers, both "normal distribution" and "Gaussian distribution" are in common use, with different communities preferring different terms.

The first clear and concise exposition of the method of least squares was published by Adrien-Marie Legendre in 1805. He described his technique as an algebraic procedure for fitting linear equations to data.

In 1809, Gauss published his method of calculating the orbits of celestial bodies. In that work, he claimed to have possessed the method of least squares since 1795. This naturally led to a priority dispute with Legendre. However, to Gauss's credit, he went beyond Legendre and succeeded in connecting the method of least squares to the principles of probability and normal distribution. He worked mostly on his own in relative isolation from his mathematical colleagues. The one major exception might be his collaboration with the physicist Wilhelm Eduard Weber over a period of seven years at the University of Göttingen. Their work was mainly concerned with research related to the earth's magnetic field. In 1838, they developed a functioning electromagnetic telegraph that connected the Astronomical Observatory and Weber's lab in Göttingen, a distance of 5 000 ft.

Religious life

There is some uncertainty about Gauss's religious convictions. He was a nominal Lutheran Protestant, but not a practicing one in the traditional sense of the word.

One may deduce that Gauss was not religious and maybe even a deist, but he was a deeply religious man, at least in his own special way with strong convictions. He did not appear to believe in the existence of a god as defined by the prevailing Christian dogma, but his religion was based upon the search for truth.

Gauss also upheld religious tolerance, believing it wrong to disturb others who were at peace with their own beliefs.

Teaching life

From the age of 30 to his death at the age of 77, Gauss spent most of his time at the University of Göttingen. Furthermore, as a professor of astronomy and the director of the observatory at the University of Göttingen, Gauss had a light teaching load, but he still loathed teaching.

Lamenting the fragmentary time left to a professor after he had fulfilled his teaching duties, he said:

"With a thousand joys, I would accept a non-academic job for which industriousness, accuracy, loyalty and such are sufficient without specialised knowledge".

Gauss did not have many postgraduate students, but a few of the students he taught, such as Richard Dedekind, Bernhard Riemann, Moritz Cantor, Peter Gustav Lejeune Dirichlet and August Ferdinand Möbius, became notable mathematicians in their own right. Two other influential mathematicians, Friedrich Bessel and Sophie Germain, were so-called epistolary correspondents of Gauss.

Gauss never met Sophie Germain, but he was much impressed with her mathematical prowess. In 1831, he nominated her for an honorary doctorate from the University of Göttingen, but she died before it could be awarded. In 1806, she received news that Napoleon's troops were about to enter Gauss's Prussian hometown of Brunswick. Terrified that her faraway mentor might suffer the same fate as Archimedes, she called on a family friend, the French military chief M. Pernety, to ensure his safety. The command was given to the French troops, possibly by the Emperor himself, to spare Brunswick because "the foremost mathematician of all time lives there". Napoleon himself was interested in mathematics and reportedly had many discussions with Pierre-Simon de Laplace on the topic.

Gauss spent most of his time at the University of Göttingen as a professor of astronomy and the director of the observatory. He did not have many postgraduate students, but a few of the students he taught became notable mathematicians in their own right.

In 1808, Göttingen was occupied by Napoleon's army and all people with a position, including Gauss as a professor, had to pay a war contribution. Gauss was unable or possibly reluctant to pay his contribution since he was a supporter of the monarchy and considered Napoleon a revolutionist. Gauss solicited the French mathematicians Pierre-Simon de Laplace and Joseph-Louis Lagrange to help him and both offered him the money.

Last word

Gauss achieved fame in his own lifetime, but not fortune or happiness. He is sometimes referred to as the "foremost of mathematicians", the "greatest mathematician since antiquity", "the prince of mathematics" and "the titan of science".

Unlike Isaac Newton or Albert Einstein, Gauss might not be remembered for mainly one or two major contributions, but might be more famous for the multiplicity of his various major contributions, from mathematics and astronomy to surveying and mathematical statistics.

Given his wide sphere of interest and contributions, Gauss might be one of the last true polymaths in history, except possibly for Bertrand Arthur William Russell. Gauss maintained that "mathematics is the queen of the sciences and number theory is the queen of mathematics". He is often remembered for his contributions to numerical mathematics. He completed his magnum opus, *Disquisitiones Arithmeticae*, in 1798, at the age of 21, and it is still used as a major reference for number theory.

However, he did not limit himself to only numerical mathematics, but made significant contributions to many other fields, such as astronomy, celestial mechanics, surveying, algebra, statistics, analysis, differential geometry, geodesy, geophysics, mechanics, electrostatics, magnetic fields, actuarial science and optics. Therefore, every serious student of mathematics, science, statistics and/or engineering is bound to meet with Gauss and his work around every second corner.

"It is not knowledge, but the act of learning that grants the greatest enjoyment."

– Carl Friedrich Gauss

This article is dedicated to the memory of "Me and a dog named Gauss".

With due respect and appreciation to "Me and you and a dog named Boo" by Kent LaVoie, 1971.

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