

## Integration – EBIT’s secret to impactful research

The Fourth Industrial Revolution (4IR) is one of the global megatrends that is shaping debate around emerging technologies in industry and academia, as well as among policy-makers. It entails the convergence of cyber-physical systems, building from the Third Industrial Revolution, which was inspired by automation through the use of logical controllers.

Information and communication technology (ICT) is a key component of the 4IR, and forms the foundation of many of the innovations emanating from the Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria. Technologies that play an important role in this regard include embedded systems, Internet of Things, networks, smart devices, smart materials, and smart and sustainable infrastructure.

In recognition of the fact that the success of any attempt to advance the 4IR is dependent on the synergistic integration of technologies, people and processes, EBIT follows a research strategy that encourages research and innovation through transdisciplinary integration. Given its unique position to facilitate research opportunities to advance the 4IR through future technologies, the Faculty is poised to increase South Africa’s competitiveness in this fast-evolving arena.

EBIT’s research strategy focuses on five research focus areas that can each exploit existing pockets of excellence to embrace the 4IR. These focus areas cover the themes of smart cities and transportation, big data science, ICT and technology innovation management, water and environmental engineering, energy, and minerals and materials beneficiation.

### **Smart cities and transportation**

In the 4IR, it is important to ensure that cities across the globe are resilient and connected. EBIT’s researchers across several departments are therefore working together to encourage the co-creation of innovative solutions with citizen communities to achieve healthy urban systems.

Investigations into smart urban and public spaces have inspired valuable research in the Department of Architecture into socioecological wellbeing, spatial justice, urban citizenship, and heritage and cultural landscapes. Synergistic research in the built environment is also focusing on innovative approaches to shopping centre management, and safe and sustainable housing in urban spaces in the Department of Construction Economics and the Department of Town and Regional Planning respectively.

These research efforts have the potential to revive South Africa’s cities and facilitate a better life for the country’s citizens. To contribute to the work of government in these spaces, researchers in the Department of Town and Regional Planning and the Graduate School of Technology Management (GSTM) respectively are also considering strategic development planning and regulatory systems.

Other innovations that will help the country respond to the challenges presented by the 4IR include the development of smart grids, sensors and the Internet of Things (in the Department of Electrical, Electronic and Computer Engineering), service delivery (in the Department of Civil Engineering) and waste collection (in the Department of Industrial and Systems Engineering).

The backbone of effective urban and public spaces is the incorporation of 21<sup>st</sup>-century technologies in new and existing infrastructure to ensure sustainability. In this regard, the Department of Informatics is conducting cutting-edge investigations into ICT for sustainable development, information systems and data science. The Department of Information Science is investigating knowledge management strategies, and the meta context of information and information architecture.

In the built environment, the Department of Construction Economics is embracing new-age technologies by developing alternative building materials and methods to mitigate the cost of green buildings. The Department of Architecture is considering resource efficiency, resilient and regenerative environments, climate change adaptation and biodiversity restoration. The Department of Materials Science and Metallurgical Engineering is conducting investigations into smart materials and smart processes, while the Department of Electrical, Electronic and Computer Engineering is engaged in research into renewable energy systems and energy management in buildings. In support of the universal goal of sustainability in urban and public spaces, the GSTM, on the other hand, is investigating sustainability project management, as well as asset and maintenance risk management.

In the fields of transportation and infrastructure, particularly as it relates to the emerging research areas of the 4IR, researchers from the Department of Civil Engineering are leading the way in South Africa's road and rail research sector. Innovations include cutting-edge techniques related to the geotechnical analysis of infrastructure. Other projects that are focused on the challenges of the new era include those related to vehicle dynamics, and autonomous and connected vehicles (in the Department of Mechanical and Aeronautical Engineering), intelligent transportation (in the Department of Electrical, Electronic and Computer Engineering) and transportation development and modelling (in the Department of Industrial and Systems Engineering).

### **Big data science, ICT and technology innovation management**

Innovative approaches that unlock hidden knowledge in big data sets form the essence of the technologies that respond to the challenges of the 4IR. In order to harness innovation, secure growth and sustainability, and introduce new products, EBIT is continually making disruptive advances in technology and innovation management.

EBIT is putting South Africa on the tech map by taking advantage of cutting-edge innovations in the technology space. Most recently, researchers in the Department of Computer Science have been focusing their attention on machine learning and artificial intelligence (AI). The Department of Industrial and Systems Engineering, and the Department of Mechanical and Aeronautical Engineering are also harnessing artificial intelligence in fields like condition monitoring.

Another exciting, high-tech field that is being embraced is that of virtual reality. Both the Department of Mining Engineering and the Department of Information Science are using this technology for teaching, learning and research purposes, while the Department of Electrical, Electronic and Computer Engineering is using it for the visualisation of big data.

In the 4IR, the incorporation of technological innovations is paramount to success in industry. EBIT therefore promotes research that considers the novel implementation of new technologies across the fields of engineering, the built environment and information technology. In the Department of

Computer Science, research is being undertaken into formal methods and software engineering, while the Department of Electrical, Electronic and Computer Engineering is examining sensor and data fusion. In the Department of Mechanical and Aeronautical Engineering, groundbreaking research is being conducted on the performance management of power generation and distribution, machine health management, and autonomous and connected vehicles.

The effective exploitation of big data and information systems can lead to major advancements in education and industry in South Africa. In this regard, the Department of Industrial and Systems Engineering is undertaking research in supply chain modelling and optimisation, intelligent logistics, enterprise engineering and data analytics. The Department of Civil Engineering is using datasets for active infrastructure, while the Department of Mining Engineering is looking at change management models for the mining, as well as the gold and platinum industries. In built environment research, the Department of Architecture is incorporating visual and micro-scale datasets, while the Department of Construction Economics is using big datasets for investigating building costs and lifecycle costing in construction, and to develop cost indices.

In this new world of digital innovation, the responsible use of data and ICT has to be considered as part and parcel of the development agenda for the 4IR. In this regard, the Department of Computer Science is conducting research in the fields of cyber-security and digital forensics. On the hardware side, the Department of Informatics is considering ICT for sustainable development, and the Department of Electrical, Electronic and Computer Engineering is looking at new approaches to telecommunication technology and telecommunication infrastructure.

The GSTM is responsible for EBIT's research into the advancement of technology and innovation management. Its key considerations in this regard relate to knowledge systems, learning processes, optimising innovation, project management, energy studies, systems engineering and risk management.

### **Water and environmental engineering**

Disruptive technologies will also play a role in ensuring the sustainability of the environment and man's reliance on non-renewable resources. Cross-cutting research into water and environmental engineering prioritises the periphery to produce fuel and oxygen from water and carbon dioxide using solar energy. Furthermore, the inquiry into nanomaterials investigates how these minute materials interact with environmental and water systems. As South Africa's economy grows towards that of an industrialised nation, environmental protection and water utilisation are critical success factors. The management of water quality and wastewater treatment are therefore becoming increasingly paramount.

Water is considered by many to be the world's most precious resource. Research into the sustainable interaction of water and the environment can therefore be considered a global priority and an integral part of EBIT's research strategy. Research in this field focuses on water utilisation (in the Department of Chemical Engineering), water reticulation networks and small-scale hydropower systems (in the Department of Civil Engineering) and mechanical infrastructure for the water industry and the use of artificial intelligence for monitoring water infrastructure (in the Department of Mechanical and Aeronautical Engineering). The Department of Chemical Engineering is also undertaking important work in biochemical engineering and bioprocessing.

The impact of natural resources on the environment is an inseparable part of water research – particularly as it relates to innovative techniques for water processing. Various topics related to this challenge are being investigated in different departments. The Department of Mechanical and Aeronautical Engineering is focusing its research efforts on clean energy and reduced emissions, as well as reduced water consumption for electrical power generation. The Department of Electrical, Electronic and Computer Engineering is investigating integrated microelectronic sensor systems for biomedical and environmental applications. The Department of Chemical Engineering is focusing specifically on environmental engineering. In the built environment, the Department of Architecture and the Department of Town and Regional Planning are conducting research into resource efficiency design and environment behaviour studies respectively, while the Department of Civil Engineering is considering urban runoff.

Many of the Faculty's departments are also concerning themselves with the management and optimisation of processes in the water sector. The Department of Chemical Engineering is looking at modelling, optimisation and control. The Department of Materials Science and Metallurgical Engineering is looking at efficient processing into higher-value products and smart materials processes. The Department of Industrial and Systems Engineering is looking at reliability engineering. In this regard, the GSTM is also considering research into technology innovation management, project management and project governance.

## **Energy**

Efficient energy systems, renewable energy and the efficient utilisation of energy by end-users will play a vital role in the 4IR. Energy provision for all the citizens of South Africa is vital to support quality of life. This warrants investigations into all aspects related to the distribution, storage and utilisation of the available energy resources.

The field of energy research is dynamic, and EBIT's researchers are contributing to it in novel ways. Much of the Faculty's energy research is focused on the optimisation of local energy supply and the effective utilisation of the country's resources. The Department of Chemical Engineering is conducting research into advanced materials, biochemical engineering, biotechnology and bioprocessing, as well as modelling, optimisation and control. The Department of Materials Science and Metallurgical Engineering is considering smart materials and processing.

The Faculty also has a keen interest in the development of sustainable energy resources. The Department of Mechanical Engineering is leading the way in clean energy research and investigations into reducing water consumption for electrical power generation. The Department of Civil Engineering is also working on interesting projects related to small-scale hydropower systems.

In the area of optimisation, the Department of Electrical, Electronic and Computer Engineering is considering energy optimisation and management for both the supply and demand side, as well as automation and control. The Department of Mechanical and Aeronautical Engineering is looking at the performance management of power generation, the life cycles of assets in power generation plants, and artificial intelligence for condition monitoring.

Through its focus on technology and innovation management, the GSTM is also conducting research into energy studies and technologies, systems engineering, assets and maintenance, and risk

management. Further contributions to energy research include a focus on reliability engineering (in the Department of Industrial and Systems Engineering), a focus on ICT in energy management (in the Department of Information Science) and a focus on resource efficiency in building (in the Department of Architecture).

### **Minerals and materials beneficiation**

Research related to minerals and materials beneficiation will further the frontiers of the impact of science and engineering on the South African minerals value chain. Such research specifically considers the South African mining and manufacturing sectors. The optimal use of available resources is key to the 4IR.

The Department of Chemical Engineering is undertaking innovative materials research projects, specifically as they relate to minerals and materials beneficiation, advanced materials and polymers, as well as modelling, optimisation and control. In the Department of Materials Science and Metallurgical Engineering, researchers are focusing on efficient processing into higher-level products, advanced processes and materials, as well as smart materials. In the built environment, the Department of Civil Engineering is a leader in the local field of geotechnical analysis for construction materials.

In South Africa, the mining industry is considered to be the most important determiner of domestic growth, given the size and potential of the industry and the significance of the country's natural resources. The Department of Mining Engineering is therefore undertaking interesting research into laser cutting and microwave rock-breaking technology, and change management models for the platinum and gold industries. It is also investigating the minimisation of noxious gases and dust creation. The GSTM's research into systems engineering, assets, maintenance and risk management is also paramount in this regard.

### **Conclusion**

EBIT is the only faculty at a South African higher education institution to house the unique combination of disciplines related to engineering, built environment and information technology in a single faculty. It is therefore in the ideal position to pursue an integrated research strategy to address the challenges of the 4IR. By examining themes related to its five research focus areas in a synergistic manner, it can address local, regional and global challenges that cross boundaries and are not restricted in scope within the fields of a single knowledge component.