Institution: Leeds Beckett University

Unit of Assessment: UoA11 – Computer Science and Informatics

1. Unit context and structure, research and impact strategy

1.1 Context and structure

The unit of assessment (UoA11) sits within the school of Built Environment, Engineering and Computing, one of the 10 schools within the university. All staff submitted to UoA11 reside in Computing (n=9) and electronic engineering (n=2). The unit conducts applied research addressing key societal challenges of the 21st century, namely energy, health and security. The school research direction embodies the principle of the British Computer Society 'Making IT good for society'. The research within the unit of assessment seeks to create direct and lasting impact on energy sustainability, cybersecurity digital health, assistive and rehabilitation technologies, and medical devices working closely with external stakeholders in the private, public and third sectors.

The unit comprises **two research centres**. The Cybercrime and security Innovation Centre (*CSI*) is a collaborative hub for research and development related to cybercrime, digital security, forensics and safety led by **Dr Schreuders**. The team specialise in cyber security, digital forensics, data science and analytics, and criminology. The *CSI* centre has a close working relationship with West Yorkshire Police; working directly with the Digital Forensics Unit (DFU) and Cyber Crime Team (CCT) to investigate and improve the way cybercrime and digital evidence is processed. The second research centre is the Centre for Research in Computer Science and Applications (*CRISCA*) led by **Prof Tawfik.** The focus of the research is machine learning, communication networks with applications in health and energy management.

Information technology is pervasive in all aspects of society. The guiding principle for the unit's research is to develop computer science research which encompasses applied computer science as an enabling tool for *all disciplines* and consequently *all sectors*, industrial, health, arts, media, and so on. As such much of the ongoing research within the school crosses the boundary of disciplines, researchers are investigating medical diagnostic devices for Parkinson's Disease and dementia in collaboration with colleagues from biomedical sciences and the NHS led by **Prof Monekosso and Dr Galbraith (UoA3)**, **Dr Marino** is evaluating the feasibility of miniaturizing a Magnetic Resonance Imaging (MRI). Work is ongoing developing digital interventions (tools) for mental health with colleagues from psychology led by **Prof Monekosso and Dr Holch (UoA4).** **Dr Palczewska** is leading work on applying data analytics in sports and in healthcare. **Dr Ibrahim** is leading technology impact assessment on individuals and the public while **Dr Nasir (UoA17)** from the Business School is investigating the cost effectiveness of technologies Smart Cities in collaboration with sports and events organisers such Headingley Stadium (Leeds).

The on-going pandemic has seen many of us working and learning remotely and a significant increase in internet usage. The widespread use and increased reliance on digital communication e.g. teleconsultation, telebanking, has created opportunities for criminal activity (cybercrime). The risk of cybercrime is greater than ever before and increasing. Cybersecurity research at Leeds Beckett is led by **Dr Schreuders** have collaborated since 2016 with West Yorkshire police force, investigating methods to solve some of their challenges as well as the training of officers.

Digital health, in its broader sense, has evolved significantly in the last decade and it is widely accepted that it can increase efficiencies (administrative as well as clinical), improve quality of care and patients' outcomes. This is reflected with the launch of NHSX in 2020 located in Leeds joining NHS Digital to support the development of digital health and healthcare technologies for the NHS. Research within the school sits well in the scope of their remit and includes health data analytics and clinical decision support, assistive and rehabilitation technologies as well as an emerging area of medical devices. The pandemic has highlighted the importance of and has accelerated the digital transformation in many sectors, not least in the health sector. Since 2018, colleagues in UoA11 have worked collaboratively with More Life, a university spin-off company operating in the health and wellbeing sector, to transform and augment its service with technology. The collaboration is led by **Prof Monekosso** who has developed an extensive programme co-

funded by university and More Life to support the digital transformation of company operations and use More Life as a platform for research into data analytics to enhance operations, generate evidence of effectiveness of health interventions and investigates gamification methods and techniques to improve client retention. This work was accelerated by the pandemic with immediate impact on services and clients.

Sustainable development is recognised by the United Nations as a key priority for the 21st century. Our research tackles two of the four pillars of sustainability, namely the environment and social pillars through research into different aspects of energy including cleaner energy and energy management. While **Dr Colantuano** is working with national and international partners to develop sustainable energy solutions for housing, the focus of **Dr Kor**'s work is Data Centres. The project partners include energy companies (EDF - Électricité de France S.A., a French multinational electric utility company, largely owned by the French state), local housing organisations (Carbery Housing Association in Ireland and First Choice Homes in the UK), and local authorities (Wakefield and District Housing Limited and Oldham Metropolitan Borough Council in the UK, Cork City Council in Ireland) and Facebook data centre in Lulea, Sweden.

1.2 Research and impact strategy

The overall research strategy for Unit 11 is led by the Dean of the School, and Director of Research and feeding directly into the University Research and Enterprise Committee. Research integrity is upheld by all members of the unit, who assume personal and collective responsibility for their actions, overseen by the University Research Ethics Committee. These committees ensure research is conducted according to appropriate ethical, legal and professional frameworks, obligations and standards.

The key objectives of the unit's research strategy is to improve the environment and build the capacity for impactful research. It is guided by and builds on the university's wider vision as a major anchor institution in the Leeds City region making a positive impact with specific reference to Health, Culture, and Sustainability. The School engages in health through research into digital health, assistive and rehabilitation technologies. Sustainability of energy sources is an important thread in the schools research approaching the challenge from different perspectives. The school's research into cyber- and physical security engages with culture and sporting events.

The key objectives were:

1. To build the capacity among existing and new staff to contribute excellent research, with the aims of broadening the research base of colleagues who have significant responsibility for research in line with our university Code of Practice.
2. To improve the quality of research undertaken in the unit, where the results of REF14 are the baseline.
3. To increase research income by refocusing our emphasis towards applied technologies – and thereby also to increase our beneficial impacts.

The research strategy is guided by the principle of 'technology as an enabling tool' to address societal challenges and creating impact in the health, security and energy sectors. The approach is to work in close collaboration with regional, national and international organisations, in the public, private, and third sectors to understand their challenges. Understanding as well as contributing solutions to societal challenges requires the perspective of different disciplines and so the research is highly multi-disciplinary.

2. People

The staff count in the Computing subject area is 38 of which 11 are classed as researchers with significant independence and a further 6 classed as early career researchers. These include staff registered for doctoral studies who are 'working towards independence' in our code of practice framework.

2.1 Staffing strategy and staff development
a) Appointment of established research leaders
Following REF14, 3FTE research professors were appointed through external recruitment to provide leadership and develop targeted areas of strength in computer science. The aim was to drive research in the areas of machine learning, energy/control, and digital health.
Professors: Deng (2015-); Monekosso (2015-); Tawfik (2015-).

b) Appointment of a Director of Research
The research leadership was strengthened with the appointment of a Director of Research (Monekosso) in 2016. This is a strategic leadership role for computer science & engineering, to define and implement research strategy for UoA11 staff.

c) Investing in future research leaders
Through internal promotions four readers (**Dr Schreuders, Dr Kor, Gr Gorbenko,** and **Dr Akbari**) were appointed to strengthen research in the areas of machine learning, sustainable computing, cybersecurity, and computer networks.

2.2 Post-doctoral staff
Success in attracting research funding has seen in the current REF cycle a number of post-doctoral staff joining the unit. A total of nine post-doctoral staff are associated with externally funded projects compared to none in previous REF cycle.

2.3 Doctoral students

a) Investing in researchers
Since 2014, the school has invested in 6 doctoral students, 5 staff undertaking doctoral studies on a part-time basis. The total number in the REF cycle is 56 with a growing number of self-funded students. PhD completions are on an upward trend.

Table 1 Doctoral completions

2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
2	4		4	5	3	5

b) Research students' progress and development
The research students are located in the school of Built Environment Engineering and Computing. The Graduate School, launched in February 2018, oversees all aspects of the University's doctoral training and research staff development, integrating institution-wide PGR support with research career development. Tailored professional workshops are based on Vitae's Research Development Framework through the research training programme for research students and a development programme for staff in all aspects of research activity.

2.4 Strategy beyond 2021
The strategy aims to significantly increase the proportion of staff classified as independent researchers, improve overall quality and impact of research.

The objectives are to
1) Capitalise on and grow existing national networks, increase collaborative and interdisciplinary work, in particular work in sustainable energy and digital health
2) Build on existing international networks to extend the depth and breadth to increase impact reach
3) Improve research culture through mentoring, coaching and training for all staff commensurate with research stage
4) Develop an enhanced programme for post-doctoral staff to improve retention and provide greater continuity to research

5) Support and train SLs and Readers preparing them for research leadership – the promotion scheme initiated in 2016 is now well established and is a foundation.

Our research into digital health is based on co-creation with all stakeholders including patients and guided by the Code of conduct for data-driven health and care technology[1]. The first principle relates to understanding users, their needs and the context. Our research also adheres to the equalities considerations as defined in the Evidence Standards Framework for Digital Health Technologies (NICE). Our research in assistive and rehabilitation technologies contributes to reducing health inequalities in the UK health and social care system, and improving access to care among hard-to-reach populations.

3. Income, infrastructure and facilities
3.1 Income generation
Since 2014, the annual research income has steadily increased from £16,000 to £489,000 in the REF cycle. Income sources include a wider range of competitive funders such as UKRI (EPSRC), Royal Academy of Engineering, InnovateUK, European Union Horizon 2020, ERASMUS, and ERDF/Interreg programmes. Notable wins in the current REF cycle include two EPSRC grants (total £450K) investigating smart control of nuclear power plants, Police Knowledge Fund (£400K) Cybersecurity, EU H2020 large scale IA smart cities (€770K), EU ERDS Interreg (€1.4M) as coordinator and 3 ERASMUS including GENIAL – Green Networking and Cloud Computing (€480K).

Total Income

2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
£16,000	£67,000	£69,000	£257,000	£439,000	£489,000

Commercial research activities have also increased through consultancies and knowledge transfer partnerships (KTP). A total of **six** knowledge transfer partnerships projects are either completed or ongoing.

4. Collaboration and contribution to the research base, economy and society
The research within the unit of assessment seeks to create direct and lasting impact on energy sustainability, cybersecurity and digital health working closely with external stakeholders in the private, public and third sectors. Our research, particularly, the digital health strand is highly inter-disciplinary with collaborators across disciplines including psychology, sociology, economics, arts and design as well as health. The challenges faced are global leading to several international collaborations.

4.1 Research collaborations
The majority of our national and international collaborations fall into the UoA11 themes of health, security and energy and have emerged from projects funded by international bodies such EU collaborative research programmes e.g. EU research programmes such as H2020, Malaysian government High Impact Research programme, Spanish department of education, and US Department of Homeland Security as well as national funding bodies such EPSRC and Royal Academy of Engineering.

Enhancing public security nationally and internationally
The theme security can be split into physical and cybersecurity. A key collaboration with West Yorkshire police was established and cemented with the project CARI (2016-18) which saw LBU colleagues led by **Dr Schreuders** investigate and develop tools to support police in fighting

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[1] (https://www.gov.uk/government/publications/code-of-conduct-for-data-driven-health-and-caretechnology

cybercrime. The Police Knowledge Fund CARI Project was a large-scale collaboration between the Cybercrime and Security Innovation Centre (CSI) at Leeds Beckett University (LBU) and West Yorkshire Police (WYP). The Project was designed to improve and incorporate an evidence-based approach into the policing of digital forensics and cybercrime investigations. The CARI Project also involved implementing a training and research programme. We provided training in research methods, to the entire Digital Forensics Unit, and the Cybercrime Team within WYP.

Funded by EU H2020, a collaborative project saw UoA11 staff led by **Prof Monekosso** working with large event organisers in UK and across Europe to develop IoT technology to enhance the experience (security and wellbeing) of crowds at large outdoor events. The project involved Headingley stadium in Leeds, both the Yorkshire County Cricket Club and the Leeds Rhinos rugby league. The stadium has benefited from IoT technologies (intelligent cameras systems, staff localisation and tracking systems, crowd management tools/dashboard, and visitor information Apps) permanently installed to support crowd management and enhance their wellbeing. The same technologies where permanently installed at Tivoli Gardens in Copenhagen, in Lyon during the annual Fete de Lumiere events in December, and in Turin City centre as well as temporary infrastructure (once a year) at outdoor music festivals in Bonn (Germany) and suburbs of Turin, Italy.

Supporting health and wellbeing
There is a great deal of collaborative work in the field of health and social care technologies. **Prof Tawfik** is using an AI approach to inform the management of Obesity amongst young people in the UK, the design of which is informed by input from the Public Health Unit at Leeds City Council. In the same strand, collaborations with the University of Copenhagen (Denmark) on the application of Machine learning for obesity and diet management.

Dr Palczewska's collaborative work with the University of Leeds and Leeds City council on an EPSRC 'Impact Acceleration Account' project to design a risk stratification tool to help the City Council to identify clients in need of intensive social care provision in a timely manner, to support the wellbeing of individuals, and ultimately reduce the burden on the NHS.

Work is ongoing with Leeds Teaching Hospital NHS Trust (technologies to monitor and assess function in Parkinson's disease), Hull Teaching Hospital NHS Trust (rehabilitation technologies) and St Georges' Medical School NHS Trust London (Tools to support patient engagement) led by **Prof Monekosso** who is an honorary researcher at the Hull Teaching Hospital. These projects were supported in part by TRANSLATE and Grow MedTech programmes (https://growmed.tech), a collaboration between the Universities of Bradford, Huddersfield, Leeds Beckett, Sheffield Hallam and, led by the University of Leeds and funded through the Research England Connecting Capability Fund.

Our research into digital health extends to technologies for social care. Working with Leeds City Council (assisted Living Services) to investigate adoption of technologies in care homes and to develop tools to support the data entry for electronic records.

The work in this strand extends to international partner, for example rehabilitation technologies with the University of Malaya, Kuala Lumpur, Malaysia where **Prof Monekosso** is a visiting Professor and University Castilla la Mancha Spain. Another collaborative project in this strands

were funded in part by Royal Academy of Engineering and the Malaysian High Impact Research programme investigated gait as a means determine to fall risk in cohort of older adults in Malaysia.

Contributing to sustainable development through energy management

There are 3 strands under his theme. The first strand applies AI to improve the safety of nuclear power plants funded by EPSRC led by **Prof Deng** in collaboration with Liverpool and Portsmouth universities. The aim of this research is improving nuclear power plants' availability, reducing the cost of operation, helping the decision-making in the nuclear control room, and assisting the preparedness of different accident levels. This research demonstrated its potential and applicability based on a case study scenario from India (2016-18).

The second strand in energy is the Sustainable IT work investigating energy measurement and management as well as energy efficiency. On a macroscopic scale, the research focuses on data centres led by **Dr Kor**. Sustainability of data centres is the focus of investigation in the project 'project GENIAL – Green Networking and Cloud Computing led by **Dr Kor**.

At a microscopic level, energy management at the '*chip*' level, **Dr Marino** is investigating a reconfigurable processor approach using the "RISC-V processor" - known as the "new Linux in hardware" aiming to repurpose its instruction set to reduce power in embedded systems.

From sustainable IT to sustainable housing, our school is conducting research into energy management in homes in collaboration with local councils and housing associations. **Dr Colantuono** is co-ordinating a large EU-funded project (RED WoLF) using technology to increase renewables' usage and reduce CO_2 emission for Homes with Photovoltaics without gas connection. The RED WoLF project comprises six test-bed sites in the UK, France and Ireland**.**

Further collaborations

Outside the three strands collaboration exist with the University of Seville (Spain) on the optimisation of mobility models for drones in disaster recovery scenarios (**Prof Tawfik**); collaboration with the University of Lorraine and Lulea University of Technology on green networking, pervasive computing and communications; and the Kharkiv Aviation Institute: National Aerospace University (**Dr Kor and Dr Gorbenko**) on IoT applications; and University of Newcastle (**Dr Gorbenko**) on software system reliability, and dependability.

4.2 Supporting local SME growth by accelerating digital transformation and innovative product development

We use our expertise in data analytics and systems engineering to contribute to the growth of SMEs in the region. UoA11 colleagues have been successful in building links with companies in the Leeds City Region and further afield. Several long standing and successful collaborations with the private sector have evolved and cemented with InnovateUK KTP projects. The companies include Essentials Healthcare (KTP10303, 2016-18), Omega Security Systems (KTP10304, 2016-18) and Abbey Industrial Systems (KTP10623, 2016-19) fall firmly into the core areas of health and social care technologies and Bob's Business Ltd (KTP10674, 2017-19) falls into security. Further KTP collaborative projects focusing on data analytics include Citu (One) Limited (KTP10266, 2015-18) and The Label Makers Ltd (KTP10942, 2017-20).

Since 2019, a significant collaborative programme in health and well-being is emerging between computer science (UoA11) and More Life Ltd, a university spin-off (turnover £6M). More Life

provides health and well-being services under contract from local authorities nationally and the NHS. The aim of the collaborative programme is to support the digital transformation of More Life services with data analytics research and the development of its IT infrastructure with the aim of improving productivity. **Prof Monekosso** has been instrumental in creating a roadmap for digital services and advising on the development of the IT infrastructure. An early success of this collaboration is an NHSE contract (2020/S 192-465180) to provide a national digital weight management service. **Prof Monekosso** is now engaged as Chief Technical Officer (CTO) for More Life developing a research and innovation strategy in collaboration with the university (UoA11) for a data-driven approach for More Life's health and wellbeing services, operations and the IT infrastructure to support the NHSE contract. UoA11 staff contribute data analytics expertise for evidence generation on the effectiveness of interventions, on productivity of operations and gamification.

4.3 National and International Expert Advisor Roles

In the last REF cycle, UoA11 staff have increasingly engaged in advisory roles regionally, nationally and internationally. Notable roles include commissioner (**Prof Monekosso**) at Digital Futures Commission, 5Rights Foundation an organisation founded and chaired by Baroness Beeban Kidron OBE which aims to enable Children and Young People to Access the digital world creatively, knowledgeably and fearlessly. At City level, **Prof Monekosso** sits on the advisory board of Phase 2 Assisted Living, Digital Health project, Leeds City Council and on the EPSRC Inclusion Matters Project led by Durham University which aims to improve the experiences of under-represented groups in STEM research.

Prof Tawfik serves on the 'Knowledge Societies' working group for the Eurocities Network to disseminate the potential societal impact of research more widely.

Colleagues within the school act as evaluators for MRC, EPSRC, EU research programme, Cyprus's Research Promotion Foundation, Polish National Science Centre, and The Netherlands Organisation for Scientific Research (**Prof Tawfik, Prof Monekosso**). **Prof Monekosso** is a member of UKRI Future Leaders Fellowships Programme Peer Review College

4.4 Contribution to academic disciplines and learned societies

Several members of the school serve on editorial boards for international journals. These include:

Learned societies
The natural home for UoA11 staff is British Computer Society. **Dr Ramachandran** is fellow of British Computer Society and **Prof Monekosso** is honorary fellow of British Computer Society. Both Profs Tawfik and Monekosso are senior IEEE members and **Dr Marino** is member of the IEEE STC Parallel Model and Systems Data Flow and Beyond since 2017

Editorial boards
Colleagues are actively engaged in editorial boards for international peer-reviewed journals covering diverse areas of computer science. These include:
- Future Generation Computer Systems (**Dr Kor**),
- International Journal of Embedded Systems (**Dr Marino**)
- International Journal of High Performance Computing and Networking (**Dr Marino**)
- IEEE Access (**Dr Marino**)
- Neurocomputing (**Prof Monekosso**);
- International Journal of Neural Computing and Applications (**Prof Tawfik**).

- International Journal of Organizational and Collective Intelligence (**Dr Ramachandran***).*

Further examples of international collaboration in research is manifested in the guest-editorship of special issues in reputable journals with international researchers. Examples of this are the special issue for the Applied Soft computing (Elsevier 2020) and Medical Informatics (Elsevier, 2016) **(Prof Tawfik**), IEEE Transactions on Intelligent Systems and Human Machine Systems (**Prof Monekosso**, 2015); a special issue for the Journals of Future Generation Computer Systems (2016), Network and Computer Applications (Elsevier, 2017), and International Journal of Grid Computing (Springer, 2019) (**Dr Ramachandran**).

Conference organisation and hosting
During this REF period, we have organised, hosted and co-chaired two international, IEEE-sponsored, computer science and engineering conferences: the 10th International Conference on Dependable Systems, Services and Technologies (DESSERT 2019), and the international Conference on Developments in eSystems Engineering (DeSE'2016).