Institution: University of Wolverhampton

Unit of Assessment: 13 Architecture, Built Environment and Planning

Title of case study: Delivering Smart and Sustainable Infrastructure

Period when the underpinning research was undertaken: 2000-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Panagiotis Georgakis	Reader in Transportation Systems	2003 to the Present
Dr Suresh Renukappa	Lecturer/Senior Lecturer in Structural Engineering	2013 to the Present
Professor Mohammed Arif	Professor of Sustainability and Construction Futures	2017 to the Present
Dr Subashini Suresh	Reader in Construction Project Management	2007 to the Present
Professor Chaminda Pathirage	Professor of Brownfield Research and Innovation	2018 to the Present
Professor Chike Oduoza	Professor of Process and Manufacturing Engineering	2001 to the Present
Professor Jack Goulding	Professor of Construction Project Management	2018 to the Present

Period when the claimed impact occurred: 2014 – 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Smart, efficient and sustainable infrastructure supports economic growth and has positive impacts on health, wellbeing and the environment. In collaboration with local governments, public and private transportation and built environment stakeholders, and over 200 companies, our research into infrastructure, systems and processes has impacted both policy and practice. Specifically, our research led to new policies on sustainable transport in two major European cities, a Smart Traffic Centre for the Abu Dhabi Police, new standards for mobility services, and improved operational practices of major housing associations. It has also impacted small and medium-sized enterprises, which were able to create new products that led to a step-change in market and employment growth.

2. Underpinning research

Research in smart infrastructure was initiated by the members of the School of Architecture and Built Environment (SoABE) in early 2000 when ITS and sustainable infrastructure practices were in their early stages of examination. Since then, the underpinning research has been extended to various thematic areas such as computing and sensory systems, data analytics and knowledge-

based technologies, and innovative business modelling. The research has produced Findings [F] that fall under the remit of smart systems and sustainable infrastructure. These are:

F1. Delivering Smart Systems

Smart infrastructure is underpinned by the operation of integrated computing and sensory technologies that utilise information to support transportation services. In this context, SoABE has produced systems and frameworks for the design of ITS (Research output 1 [R1]), the optimisation of urban planning and the improvements of safety and security of critical infrastructure. The latter incorporates frameworks that have been applied for highway and pipeline infrastructure overseas, as well as the development of an application for construction SMEs, namely RiMaCon, that incorporates steps and timelines for more effective risk management practises [R2]. With the plethora of ITS that have been deployed over recent decades, the volume, velocity and variety of generated data requires efficient architectures that can receive, process and analyse them, as to support services offered in smart cities. SoABE has developed such architectures using state-of-the-art 'big data' tools, machine learning applications and data analytics.

A big-data processing architecture [R3] was developed as part of the OPTIMUM Project, funded through the H2020 programme, and its importance was recognised by receiving a further grant from the UK Government Department of Transport. The developed architecture has been further customised to support the implementation of a dynamic multiservice journey planning tool that can support the provision of Mobility as a Service (MaaS4EU H2020). Further extensions of the architecture will allow the integration of real-time information in simulation models; research that is currently being developed as part of the HARMONY H2020 project.

F2. Delivering Sustainable Infrastructure

To pursue sustainability, companies should integrate economic, environmental and social considerations in their business models. There is also a need to understand the precise juxtaposition of organisational systems and business models in terms of their value-laden impact, where diffusion drivers such as people, process and technology are seen as core enablers of business agility [R4]. These models are the building blocks of how companies create, deliver, and capture value. SoABE's research investigated the key carbon emissions reduction initiatives currently being implemented in the UK industrial sectors and produced guidelines on how CO2 emission reduction strategies can improve business competitiveness. In the Architecture Engineering and Construction (AEC) sector, SoABE has developed a strategic framework for implementing 'smart devices', allowing the harnessing of decentralised information and improving processes via the implementation of the paradigm of the Internet of Things (IoT). Further, our research has highlighted the need for community empowerment to achieve long-term sustainability [R5]. The aforementioned research accomplishments supported the attainment of grants in Section 3, through which a number of pilot projects were set up to demonstrate improvements for the energy efficiency and sustainability of the UK housing stock.

On a global scale, research explored the sustainability issues within the energy sector and identified and evaluated critical success factors, such as access to the grid, implementation of the legal framework for Renewable Energy (RE), coordination and communication, financial tools for RE projects, knowledge creation and exploitation, and transparency for implementing renewable energy strategies in developing countries [R6].

3. References to the research

The following references have been through a rigorous peer review process and have been published in peer-reviewed journals or bespoke book commissions. They have been points of reference beyond the University. Evidence of peer-reviewed funding is below.

R1. Nwagboso, C., Georgakis, P., Dyke, D. (2004). 'Time compression design with decision support for Intelligent Transport Systems deployment, *Computers in Industry,* Volume 54(3), pp. 291-306, https://doi.org/10.1016/j.compind.2003.10.008.

R2. Rostami, A. and Oduoza, C.F., (2017), 'Key risks in construction projects in Italy: contractors' perspective', *Engineering, Construction and Architectural Management*, Volume 24(3), pp. 451-462, https://doi.org/10.1108/ECAM-09-2015-0142.

R3. Figueiras, P., Gonçalves, D., Costa, R., Guerreiro, G., Georgakis, P. and Jardim-Gonçalves, R. (2019). 'Novel Big Data-supported dynamic toll charging system: Impact assessment on Portugal's shadow-toll highways', *Computers & Industrial Engineering,* Volume 135, pp. 476-491, https://doi.org/10.1016/j.cie.2019.06.043. (REF 2 Output)

R4. Ezcan, V., Goulding, J.S., and Arif, M., (2020), 'Re-defining ICT Embeddedness in the Construction Industry: Maximising Technology Diffusion Capabilities to Support Agility, Building Research & Information', pp. 1-23, https://doi.org/10.1080/09613218.2019.1709786. (REF 2 Output)

R5. Van Kreiken, T and Pathirage, C.P., (2019), 'Factors Affecting Community Empowerment During Disaster Recovery', *International Journal of Disaster Response and Emergency Management*, Volume 2 (1), pp. 1-18, https://doi.org/10.4018/IJDREM.2019010102

R6. Donastorg, A., Renukappa, S., and Suresh, S., (2020) 'Evaluating critical success factors for implementing renewable energy strategies in the Dominican Republic', *Renewable Energy - An International Journal*, Volume 149, pp. 329-335, https://doi.org/10.1016/j.renene.2019.12.053 (REF 2 Output)

Grants

Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility, (OPTIMUM), European Commission (EC) HORIZON 2020 Grant Agreement No 636160-2, 2015-2018, University of Wolverhampton (UoW) Budget GBP362,989.

A Big Data Architecture for Traffic Forecasting Using Multi-Source Information, UK Department for Transport, Transport-Technology Research Innovation Grant (T-TRIG), 2017, GBP25,127.

End-to-End Approach for Mobility-as-a-Service tools, business models, enabling framework and evidence for European seamless mobility, (MaaS4EU), EC HORIZON 2020 Grant Agreement No 723176, 2017-2020, UoW budget GBP273,619.

Holistic Approach for Providing Spatial and Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era, (HARMONY), EC HORIZON 2020 Grant Agreement No 815269, 2019-2022, UoW budget GBP319,888.

Risk Management Software System for SMEs in the Construction Industry, (HARMONY), EC FP7 Grant Agreement No 324387, 2013-2017, UoW budget GBP325,962.

4. Details of the impact

Impact 1: Changing policy for the adoption of sustainable transportation and renewable energy initiatives

Our work in ITS and big-data architectures led to the design and development of the integrated OPTIMUM platform [F1]. The platform was composed of six 'smart' components developed by five project partners, with a traffic forecasting engine and a social mining application developed by SoABE. The user-facing element of the platform was a mobile application that is being showcased on the CIVITAS (network of cities for cities dedicated to cleaner and better transport in Europe and beyond) Directory of Tools [C1], highlighting its acceptance and recognition in the domain of smart cities. SoABE's work, as part of the MaaS4EU Grant, on the development of a journey planner for Mobility as a Service has resulted in the creation of one of the first of such applications to be trialled in different European cities by hundreds of participants. The tool has been trialled in

Manchester and Budapest, allowing the integration of multiple modes of transport, including private and public modes, ride hailing, bike sharing and on-demand co-travelling services. The integrated offering had positive impacts on policy making and capacity building at international level [C2 and C3].

Impact 2: Enhancing risk management practices used as part of the operations of emergency services and construction companies

The developed risk assessment, management and mitigation frameworks and renewable energy strategies have received [F1] international recognition and has impacted on several initiatives related to smart cities in Europe and the Middle East. Specifically, developed frameworks have been used for the design of the Smart Traffic Centre (STC) of the Abu Dhabi Police Service [C4]. The framework actively supports the Traffic and Patrols Directorate of Abu Dhabi Police to closely monitor road traffic conditions and manage their relevant police operations, in collaboration with other branches of the Police Service and municipal authorities. As such, it has impacted on capacity building in areas related to enforcement and safety with the use of ITS [C4]. Furthermore, the framework has influenced policies as it underpinned the design of Abu Dhabi's Safe City initiative, which uses integrated technological solutions for the co-ordination and provision of emergency services within the Emirate [C4].

The use of the Risk Management Guide and RiMaCon software developed as part of the RiMaCon FP7 EU project, led by Oduoza, has enabled the advancement of better strategies to minimise risks, thus positively impacting the health and well-being of workers in the construction industry. RiMaCon has been used in the UK and Italy and has demonstrably improved competitiveness through enhanced risk prediction and pricing as part of construction project bidding [C5].

Impact 3: Improving existing standards and architectures for the design of intelligent transportation systems and novel mobility services

As part of the first two Horizon 2020 grants mentioned in Section 3, SoABE has contributed to the proposal of extensions for the European FRAME ITS architecture [F1] that forms a standard for the design of ITS applications within the EU. These extensions focused on functionality that allows the design of proactive information services, and services for the realisation of Mobility as a Service (MaaS). OPTIMUM provides extensions for the implementation of personalised recommendation services, complex event processing and system aware optimisation [C6] as part of a big-data supported architecture for smart mobility applications. Furthermore, MaaS4EU extends current functionality to include services related to dynamic 'true' multimodal journey planning, optimisation of supply and demand of services, and integration of ticketing, booking and payment for multiple service providers [C7].

Impact 4: Changing operational practices and culture of organisations in the built environment sector

The design and deployment of renewable energy and sensory systems [F2] can positively impact energy efficiency and reduce carbon emissions of infrastructure and housing projects. More specifically, focus has been placed on initiatives that improved the air tightness of buildings; introduced innovations within building materials to improve the overall structures fabric; deployed monitoring and control systems to reduce energy consumption; and utilised energy storage technology to optimise the effectiveness of renewable energy generation. Evidence generated allows major housing associations to understand better the impact of novel technologies prior to their mainstream deployment. For example, Wolverhampton Homes (WH), a major housing association that manages 23,500 homes, participated in small scale pilots that investigated the performance of battery storage units and smart heating control systems with a goal to understand the potential of such technologies in moving tenants towards more efficient energy use. As a result, WH familiarised themselves with these novel technologies and generated knowledge so as to inform future decisions regarding capital expenditure programmes [C8].

Impact 5: Improving the productivity of companies which offer products that capitalise on renewable energy

As part of the activities of the BECCI project, SoABE has collaborated with approximately 200 businesses, predominately SMEs, in developing new technologies and integrated them in novel products and services [C9]. In doing so, we have supported the development of technologies for battery storage units and energy monitoring systems [F2] enabling participating companies to improve and expand their product portfolio. As a result, several impacts were realised including expansion of client base and identification of new markets that led to increase in sales, capacity building for employees, expansion of supply chains and job creation [C10-C11]. In quantitative terms, two notable examples are: (i) AceOn has demonstrated 50% increase in revenues and 60% increase in workforce [C10], while (ii) Genius Hub has reported a 483% increase in sales and 75% expansion of its workforce [C11].

Overall, changing policy and practice in the field of smart and sustainable infrastructure is making and is going to make lives better for travellers, road users and the society in general by improving road safety and accessibility, reducing congestion and promoting sustainable modes of transport. In addition, in the construction sector, our research will effect a step change in the exploitation of renewable energy, thus improve the competitiveness of companies in the sector, and help housing and infrastructure providers in meeting their sustainable development goals.

5. Sources to corroborate the impact

C1. OPTIMUM app for smart mobility: https://civitas.eu/tool-inventory/optimum-multimodal-route-planning-app

C2. Testimonial letter from Budapesti Közlekedési Központ (Centre for Budapest Transport)

C3. Testimonial letter from Transport for Greater Manchester (TfGM)

C4. Testimonial letter from the Abu Dhabi Police Service

C5. Testimonial letter from Vettorazzo Costruzioni

C6. OPTIMUM Architecture, H2020 Project Deliverable: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bee7ca64&appId=PPGMS

C7. MaaS4EU Architecture, H2020 Project Deliverable https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c276e911&appId=PPGMS

C8. Testimonial letter from Wolverhampton Homes

C9. Built Environment Climate Change Innovations (BECCI 1, 2 and 3), European Regional Development Fund (ERDF), 2013-2021, Total Budget GBP4,020,731. (See https://go.walsall.gov.uk/bcta/ERDF-2014-2020/ERDF-Case-Studies/BECCI-Building-a-Better-Supply-Chain-for-the-Black-Country-Low-Carbon-Economy)

C10. Testimonial letter from AceOn

C11. Testimonial letter from Genius Hub