

Institution: University of Wolverhampton		
Unit of Assessment: 13 Architecture, Built Environment and Planning		
Title of case study: Delivering optimal solutions to enhance organisational capability		
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 David Heesom	Lecturer in Virtual Reality Design	2000 to the Present
Professor Issaka Ndekugri	Professor in Construction Law	1995 to the Present
Dr Ezekiel Chinyio	Reader in Construction Management	2006 to the Present
Professor Mohammed Arif	Professor of Sustainability and Construction Futures	2017 to the Present
Dr David Oloke	Lecturer/Senior Lecturer in Built Environment Engineer	2000 to the Present
Professor Jack Goulding	Professor of Construction Project Management	2018 to the Present
Dr Paul Hampton	Principal Lecturer in Construction Management	2006 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 Enhancing the capability of the Architecture Engineering and Construction (AEC) sector has been a cornerstone of applied research in the School of Architecture and the Built Environment (SoABE) since 2000. Research has continued to demonstrate wide-reaching impact through bespoke activities and holistic interventions covering the three core pillars of: People, Process and Technology. Key impacts [1] include: • Adoption of our new Application (App) to support stress management in the construction industry - available globally through smart device stores and used by 50 companies [11]. • Ensuring that professionals and organisations within the sector adapted to developments in respect of Health and Safety (H&S) through collaboration with the Institution of Civil Engineers (ICE) [12]. • Changes in industry through the development of new products and processes co-created with the Sustainability and Construction Futures Research and Innovation Centre (SCFRIC) [13]. • Increased business turnover and job creation from the transformation of design, manufacture and construction processes within the high value ventilation sector [14]. • The establishment of a new Virtual Reality/Augmented Reality (VR/AR) company focusing on delivering construction sector services [15].		

2. Underpinning research

Underpinning research within SoABE focuses on delivering organisational capability through three thematic strands; People, Process and Technology. The research generated three broad Findings [F].

F1. The thematic strand of *People* focuses on human resource-related issues within the AEC sector. SoABE has a sustained track record of enhancing Health and Safety (H&S) within the sector. Work (previously reported in REF2014) developed models for accident prevention and analysis of legislation. These concepts have been further expanded by Ndekugri [R1] through development of frameworks to support industry, particularly through the integration and implementation of safety information with BIM processes. This research strand engaged key national stakeholders including the Health and Safety Executive (HSE) and ICE along with a broad representation of the sector from 70 organisations. Other work in this domain by Oloke [R2] has provided key guidance to the sector. Recognising the key issues of mental health and wellbeing, Hampton and Chinyio [R3] have continued to focus on this critical area and this work has resulted in identification of stress indicators and coping strategies for construction workers.

F2. Within the reporting period, the *Process* strand of SoABE's work has developed a new field focused on the improvement of offsite construction processes. In particular, research undertaken through CIB TG74 and CIB W121 has led to the development of the first offsite roadmap, which highlighted the need to develop new offsite business models and organisational processes. This work was later extended and reported through a bespoke book commission [R4], which provided clear foci and learning outcomes for enhancing the *People*, *Process* and *Technology* components of the offsite business offering. Several research grants including the UKRI-funded STELLAR projects support this work on offsite processes.

F3. SoABE's thematic strand of *Technology* commenced in 2000 and included work focusing on the application of digital technology to optimise construction [R5]. This work continues to be a core strength. Significant achievements and activities have led to the development of new distributed software tools to support planning operations, and has also demonstrated the value of adopting technology to optimise the core capability of construction teams supported through grants such as one from the Royal Academy of Engineering (RAE) and a number of Knowledge Transfer Partnerships. Other findings include the creation of new innovative approaches for fostering greater collaborative working practices through the implementation of VR/AR. Moreover, the body of work in this field has developed new philosophies to support the increasing use of mainstream and niche technology within the industry [R6]. Specific exemplars include the need to align the concepts of process improvement with emerging technologies to support the measurement, capture and use of digital construction data during the construction process.

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. Mzyece, D., Ndekugri, I.E. and Ankrah, N.A. (2019), Building information modelling (BIM) and the CDM regulations interoperability framework. *Engineering, Construction and Architectural Management*, 26(11), pp. 2682-2704. <https://doi.org/10.1108/ECAM-10-2018-0429>
(REF 2 Output)

R2. McAleenan, M. and Oloke, D. (Eds). (2015) *ICE Manual of Health and Safety in Construction*, 2nd Edition, ICE Publishing, London

R3. Hampton, P., Chinyio, E. and Riva, S. (2019), Framing stress and associated behaviours at work: An ethnography study in the United Kingdom, *Engineering, Construction and Architectural Management*, 26(11), pp. 2566-2580. <https://doi.org/10.1108/ECAM-10-2018-0432> (REF 2 Output)

R4. Goulding, J.S, and Pour Rahiminan, F., (Eds.), (2019), *Offsite Production and Manufacturing for Innovative Construction: People, Process and Technology*, Taylor and Francis, UK, ISBN: 978-1-138-55068-1

R5. Heesom, D. and Mahdjoubi, L. (2004), Trends of 4D CAD applications for construction planning. *Construction Management and Economics*, 22(2), pp.171-182.
<https://doi.org/10.1080/0144619042000201376>

R6. Ezcan, V., Goulding, J.S. and Arif, M., (2020), Redefining ICT embeddedness in the construction industry: maximizing technology diffusion capabilities to support agility. *Building Research & Information*, 48(8), pp. 922-944. <https://doi.org/10.1080/09613218.2019.1709786> (REF 2 Output)

Grants

Chinyio, E. (2017-2018) Inhibiting Stress in the Construction Industry (INSTINCT). Awarded under the Horizon 2020 Programme. Grant Agreement ID: 703236. Value: GBP165,495.76 [R3].

Heesom, D. (2014) Royal Academy of Engineering Industrial Secondment Grant (January 2014 – August 2014). Value: GBP33,944 [R5].

STELLAR funded under Transforming UK construction: demonstrator projects (Innovate UK – Application Number 42164). 2020-2022. Collaborative Industry Focused Project with Totally Modular, JALI Ltd, TDS Midlands, Citizen Housing, Spacious Place Construct Ltd. Total Value: GBP1.95m. This project was highlighted in the December 2020 Innovate UK blog (<https://innovateuk.blog.gov.uk/2020/12/07/the-gift-of-innovation/>) as a key strategic project for the UK housing sector [R4, R6].

4. Details of the impact

The findings presented have delivered five key impacts [I]. In respect to People, [I1, I2] demonstrate how the work has supported the wellbeing of individuals within the professions whilst also supporting professionals and organisations through personal development. Support for the enhancement of Process [I3, I4] highlights how the findings have changed working practices and enhanced processes leading to increased productivity.

Technology-based impacts [I4, I5] have led to creation of new jobs, increased profits through technologically-underpinned processes and new services being introduced to the sector. SoABE's research in the area of technology implementation has continued to support industry through a number of initiatives, one major conduit of which is through its KTP provision. For example, throughout the REF reporting period (2014-2020), eight KTPs have been successfully delivered underpinning the Government strategic area of deploying digital techniques through the Construction Sector Deal (2019) and the UK Industrial Strategy. KTPs have been a strong and enduring pathway to impact in the delivery of the core impacts.

I1. Adoption of our new Application (App) to support stress management in the construction industry

The team has developed a new mobile based App (Streblo) through the Inhibiting Stress in the Construction Industry (INSTINCT) project funded through the H2020 programme. This App is freely available, providing users with early detection indicators of stress along with tailored coping strategies. The Streblo App is freely available through the Apple and Android App Stores and is

the world's first Construction-related application which focuses on work-related stress issues and coping strategies. The App is now used by over 50 construction organisations to allow staff to monitor their levels of individual stress whilst providing immediate suggestions of how to reduce these. The App has international reach and is being used by companies in the UK, Italy and China. The provision and access to this new service has not only increased awareness of stress-related issues in the sector, but has also helped improved awareness of mental health within the profession [C1]. The App was developed in collaboration with industry partners including DMW Safety and Wates Living Space, using explicit and tacit knowledge collected from UK construction professionals in the course of our research [F1]. Industry adoption and use is evidenced through increased ongoing downloads and installations and underpins the significance and reach of the impact.

12. Ensuring that professionals and organisations within the sector adapted to developments in respect to Health and Safety

Working in collaboration with professional bodies such as the Institution of Civil Engineers (ICE) [F1], we have ensured that professionals and organisations within the construction sector were able to adapt to the changing landscape. The H&S Manual published by ICE and edited by Oloke [C2] provides best practice guidelines and has seen over 3,000 purchases to date [C3]. The work in the field of H&S has also gained recognition with other key stakeholders within the sector including the RIBA [C4]. In addition, research in the field of digital construction [F3] has supported the UK's transition towards the wider use and uptake of BIM. The highly cited paper by Heesom and Mahdjoubi (2004) was included as a key text in the globally available online training material '4D Simulation and Construction Planning' provided by the Autodesk Design Academy.

13. Changes in Industry through the development of new products and processes

Work undertaken by Arif identified the need for capacity building and skills development in offsite construction, particularly the integration of advanced technologies and associated process methodologies. Subsequently, the ERDF-funded SCFRIC was launched in 2019 [C5]. This Centre seeks to underpin and support Offsite manufacturing which was identified as a strategic area in the Construction Sector Deal 2019. The Centre also provides a number of process improvements [F1, F2] for companies, not only to facilitate the integration of emerging technologies, but also to enhance their core capability [F3]. SCFRIC has also fostered its international presence through the establishment of an International Conference on Construction Futures (ICCF) series. The first conference was held in 2018 and the second in 2020. The 2020 edition of the conference saw attendance from 361 individuals spanning 46 countries. In addition, work undertaken with over 50 companies [F2] has identified new innovative products and services for national and international markets, for example the recently-filed Kerrigan Patent, which they are filing the patent as a direct impact of working with the team. An example of innovation from this work includes the development of a new panelised-based extensible, high volume residential buildings system through Kerrigan Architects, which is also providing new work streams for the company [C6]. The significance and reach of this impact is based on the way that it affects and improves the livelihood of individuals working in the sector. We see it as part of an ongoing initiative to develop the sector both in the UK at the local level and internationally.

14. Increased business turnover and job creation from the transformation of design, manufacture and construction processes

Knowledge Transfer Partnerships (KTPs) have also provided significant impact indicators, particularly through the implementation of new digital design, manufacture and construction processes [F3]. Our 8 projects between 2014 and 2020 have gained recognition through high independent assessment grades and include finalist placements for the national 'KTP: Best of the Best' awards. One exemplar project with Hargreaves Ltd has enhanced production yields by improving productivity within the entire business process by over 60%. Working in collaboration with the company's Board of Directors and the external supply chain (including material suppliers and contractors), new digital processes have been established. This work and new workflows have been transformative, leading to new process being implemented on major infrastructure projects, including how the company engaged in the construction of the Chernobyl New Safe Confinement (Novarka) project in Ukraine. These new approaches have also been documented as good

practice evidence, leading to Hargreaves Ltd employing eight additional new staff in the first year of investiture [C7, C8]. Due to the success of this initiative, the Managing Director has since initiated similar digital workflow processes in a further company E. Poppleton, which is now in collaboration with other companies such as Balfour Beatty to drive transformational change in the sector.

15. The establishment of a new Virtual Reality/Augmented Reality (VR/AR) company

The implementation of digital technologies, in collaboration with Severn Partnership Ltd (2010-2016), has continued to transform workplace practices [F1] [C9], leading to the creation of a new department within the business that is focussing on the delivery of 3D BIM information and the repurposing of 3D data using Virtual Reality technologies. These initiatives have enhanced the company's reputation, which led to expansion in Europe, the US, Canada and Antarctica thanks to the new project capabilities. The development of VR technologies as a core pillar of the business through the KTP supported the company in realising an increase of 30% in annual profits and a 20% increase in new staff employed. Furthermore, this success led to a new spin-out business [C9, C10]. Created in late 2014, the new company Seeable Ltd focuses on the production of new VR and AR products through the repurposing of BIM data for learning in the form of serious games and led to the award of a Royal Academy Industrial Secondment Grant [C10]. As the company continues to develop, new jobs have been created and the company have a diverse portfolio of clients including Transport for London and Mott McDonald whilst their work is profiled in international trade presses and conferences (such as Hexagon Live, Hong Kong). The work on heritage visualisation has been featured on the BBC Radio [C11].

5. Sources to corroborate the impact

- C1. Testimonial letter from Dunton Environmental Limited.
- C2. Online book review published through Safety & Health Practitioner (<https://www.shponline.co.uk/cdm-regulations/47068-2/>).
- C3. Letter from ICE publishing confirming the number of downloads and purchases of the 'Health and Safety Manual' book.
- C4. Testimonial Letter RIBA on Health and Safety.
- C5. Sustainability and Construction Futures Research and Innovation Centre (SCFRIC). Funded through the European Regional Development Fund (2019-2022). Value: GBP1,425,514, (Assets Publishing Service, ERDF, line 64).
- C6. Testimonial Letter Christian Kerrigan Architecture.
- C7. Testimonial Letter Hargreaves Ductwork and E. Poppleton & Son.
- C8. Letter from Innovate UK confirming Outstanding grade for Hargreaves KTP.
- C9. Testimonial Letter from Severn Partnership Ltd.
- C10. Testimonial Letter from Seeable Ltd.
- C11. BBC Radio Shropshire Interview with Seeable Ltd (<https://seeable.co.uk/nick-blenkharn-discusses-augmented-reality-bbc-radio-shropshire/>).