Impact case study (REF3)

Institution: Teesside University	

Unit of Assessment: 12

Title of case study: Embedding Building Information Management capabilities within the construction sector

Period when the underpinning research was undertaken: 2001 to 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:
Nashwan Dawood	Associate Dean (R&I)	Nov 1991 to present
Huda Dawood	Senior Lecturer in Engineering	Nov 2004 to present
Mohammad Kassem	Enterprise Fellow	Feb 2011 to Sep 2016
Zaki Mallasi	Construction Research Fellow	Sep 2004 to Dec 2005
Joao Patacas	Research Associate	May 2016 to present
Sergio Rodriguez	Senior Lecturer in Construction Management	Jun 2016 to present
Darren Scott	Senior Lecturer in Civil Engineering	Oct 2007 to Sept 2019

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 (indicative maximum 100 words)

Research at Teesside University in the Centre for Sustainable Engineering on whole-lifecycle Building Information Management (BIM) technologies has been embedded within UK architectural, engineering and construction businesses to support facilities management (FM). Through a transformation of their digital construction capabilities, businesses have enhanced their value propositions enabling them to expand their services and products, win new clients, create jobs, and increase turnover. As a result of the research, Ryder Architecture Ltd has significantly increased its market potential, attracting 500 new clients in 19 different countries and increasing its turnover by GBP1,000,000 per annum. To meet demand for its BIM for FM services, Ryder Architecture opened additional offices in Hong Kong, Australia and Vancouver. The research has led to Hodgson Sayers, a specialist in roofing, building works, fencing and metalwork fabrication, becoming a Tier 1 Contractor, enabling them to win higher value contracts. Since 2016, the research has led to additional turnover of GBP4,700,000. And for Sotech, a metal rainscreen cladding manufacturer, our research has led an increase in sales of GBP4,950,000.

2. Underpinning research (indicative maximum 500 words)

Internationally, there is drive for whole-lifecycle, digital information across all phases of construction to improve productivity and efficiency, reduce carbon footprint and create a more sustainable built environment. Research at Teesside University at the Centre for Sustainable Engineering has focussed on novel multi-dimensional and multi-constraint planning and co-ordination software leading to the development of a suite of tools that embed BIM within both the design and operational phases of facilities management.

Between 2002-2004, research was undertaken to develop a new Uniclass-based approach, a standard classification system for the construction industry. Integrating previously disparate information systems, this system brings together visual and project planning, product breakdown (e.g. elements of the building) and work breakdown (e.g. construction operations) structures [3.1]. This led to the further development of a number of software tools: ProVis, a 4D visualisation tool; the VIRCON (VIRtual CONstruction,) database; and nDCCIR, which combined these into a single system [3.1]. Product and process modelling technologies were dynamically linked to the VIRCON database to provide 4D (3D plus time) simulations allowing rehearsal of the building's construction to identify potential clashes and pinch points [3.1]. The technology developed was tested with the involvement of experts from major construction companies in the

UK and Europe (Skanska Construction, Balfour Beatty, AMEC, Ferguson McIlveen LLP, MotEngil, and VSS Civil Engineers) [3.2].

Between 2002 and 2005, research focussed on advancing the 4D functionality offered by the nDCCIR tool to incorporate multi-constraint modelling. Multi-constraint planning and control methodology brought together all aspects of the supply chain to allow for better oversight and management of delays during the build. The availability of all necessary elements at the correct time and place substantially reduces waste and delays on construction sites [3.3, 3.4]. This multi-constraint approach enhanced the conventional 3 levels of construction planning (i.e. baseline planning, look-ahead planning, commitment planning) by integrating them with information management systems, 3D models and management theories of optimisation and "Last Planner". This work led to the development of an IT tool, "LEWIS - Lean Enterprise Web-Based Information System", representing a new generation of planning and control systems that overcame the limitations of traditional project management theory and existing information technologies [3.3].

Between 2005 and 2009, quantifiable Key Performance Indicators (KPIs) for the different performance measures were developed to estimate the benefits achievable from the deployment of the multi-constraint planning approaches and tools. The measured KPIs included schedule performance (KPI: "schedule hit rate" – a measure used to identify deviations between actual and planned progress) and communication performance (KPI: time and cost saved in meetings). The results showed a hit rate of 72%, a 17% increase compared to the average industry of 55% and 30% reduction in the time spent on meetings [3.5].

Between 2012 and 2015, research focussed on the Macro adoption of BIM resulting in the development of a conceptual structure that ensures comprehensive adoption of BIM in the construction companies [3.5]. The research produced a series of macro-adoption models, matrices and charts that can be used to systematically assess BIM adoption across markets and inform the structured development of country-specific BIM adoption policies.

Between 2013 and 2015, research was undertaken on the adoption and implementation of BIM in Facility Management (FM). A case study was developed to demonstrate the effects of BIM in FM in a large university complex. The research demonstrated that BIM value in FM stems from improvement to current manual processes of information handover, improvement to the accuracy of FM data, improvement to the accessibility of FM data, and efficiency increase in work order execution [3.6].

Between 2013 and 2020, two major grants have supported research into developing BIM processes and technologies for the Qatari construction industry [3.7]. Research identified the value of applying BIM, in major infrastructure projects in Qatar. The research showed that a 15-33% saving in cost reductions could be achieved through the utilisation of BIM for activities such as Clash Detection.

3. References to the research (indicative maximum of six references)

[3.1] Dawood N, Sriprasert E, Mallassi Z. 2002. Development of an integrated information resource base for 4D/VR construction processes simulation. Automation in Construction. 12:2, 123-131. https://doi.org/10.1016/S0926-5805(02)00045-6

This research (and associated publications) was underpinned by funding from the EPSRC. grid.421091.f. 2000. The Virtual Construction Site: A Decision Support System for Construction Planning. GR/N00890/01. GBP96,395. Principal Investigator: Dawood. Projects Partners: University of Glamorgan, Atkins, Bond Bryan Partnership, Kvaerner Technology, Services Design Associates, Stent Foundations Ltd, Tarmac, Turner and Townsend.

[3.2] Dawood N, Scott D, Sriprasert E, Mallassi Z. 2005. The virtual construction site (VIRCON) tool: an industrial evaluation. The Journal of Information Technology in Construction (ITCon). 10, 43-54. Available at: https://www.itcon.org/paper/2005/5.

This research (and associated publications) was underpinned by the funding referenced in [3.1]

[3.3] Dawood N, Sriprasert E. 2006. Construction scheduling using multi-constraints and genetic algorithms approach. Construction Management and Economics. 24:1, 19-30. https://doi.org/10.1080/01446190500310486. Selected for RAE2008 (70% 2* and above).

This research (and associated publications) was underpinned by the funding referenced in [3.1]

[3.4] Dawood N, Sikka S. 2009. Development of 4D based performance indicators in construction industry. Engineering, Construction and Architectural Management. 16:5, 438-458. https://doi.org/10.1108/09699980910988357

Outputs 3.1 to 3.4 underpinned funding applications to Innovate UK for the below two projects:

Innovate UK. grid.423443.6. Knowledge Transfer Partnership. 2014. KTP009842. GBP77,457. Partners: Teesside University (Dawood N) and Sotech Limited.

Innovate UK. grid.423443.6. Knowledge Transfer Partnership. 2013. KTP009716. GBP76,300. Partners: Teesside University (Dawood N) and Hodgson Sayers Limited.

[3.5] Succar B, Kassem M. 2015. Macro BIM adoption: conceptual structures. Automation in Construction. 57, 64-79. https://doi.org/10.1016/j.autcon.2015.04.018

This research was underpinned by funding from Innovate UK. grid.423443.6. Knowledge Transfer Partnership. 2013. KTP009077. GBP72,996. Partners: Teesside University (Dawood N) and Ryder Architecture.

[3.6] Kassem M, Kelly G, Dawood N, Serginson M, Lockley S. 2015. BIM in facilities management applications: a case study of a large university complex. Built Environment Project and Asset Management. 5:3, 261-277. https://doi.org/10.1108/BEPAM-02-2014-0011

This research was underpinned by funding from Qatar National Research Fund. grid.507658.9. 2016. Assessing, Benchmarking and Improving the BIM Competency of Qatar's Construction Industry Practitioners. NPRP 9-124-2-062. USD123,000. Partner: Qatar University.

[3.7] Chahrour R, Hafeez MA, Ahmad AM, Sulieman HI, Dawood H, Rodriguez S, Kassem M, Naji KK, Dawood N. 2020. Cost-benefit analysis of BIM-enabled design clash detection and resolution. Construction Management and Economics. 39:1, 55-72. https://doi.org/10.1080/01446193.2020.1802768. Selected for REF2021.

4. Details of the impact (indicative maximum 750 words)

Teesside University's research has supported developments within the digital construction sector, both within the UK and internationally. For our partners, the research has led to increased market potential and value proposition, a growth in new clients, the creation of new jobs, and substantial increases in turnover. For our partner's clients, the research has produced efficiency and productivity gains and enhanced sustainability throughout the stages of design, build, and subsequent operation.

Ryder Architecture Limited (RAL) is an international architectural practice best known for designing buildings in the education, healthcare and public sector. Over the last 10 years our research has enabled RAL to gain a distinct competitive advantage within the construction sector, opening new markets and opportunities for growth. We first collaborated with RAL in 2010. Supported by an Innovate UK Knowledge Transfer Partnership (KTP), collaborative research was undertaken to embed BIM into RAL's practices. Drawing on research on the development of 4D/VR construction processes and simulation-based performance indicators, we worked with RAL to produce BIM processes and protocols that enable BIM tools to be implemented in commercial projects [3.1, 3.2, 3.3, 3.4]

This was followed up with a second KTP (2013-15) that expanded this capability, enabling RAL to incorporate facilities management protocols, modelling and analysis into its existing BIM. Research on development of BIM for FM connected to 3.5 and 3.6 developed whole life cycle information flow protocols and adoption strategy that have been implemented by RAL in their commercial projects. As stated in the KTP Partners Final Report, the project improved RAL's 'knowledge base on BIM for FM enabling knowledge on FM processes to be brought to the

design stage. The new processes developed will support the delivery of "integrated information models" leading to better operational performance' [5.1].

As a result of this work, RAL became in 2016 one of the earliest providers of lifecycle building design (BIM for FM). RAL now advises clients on the digital handover of data to the facility management phase of existing (e.g. major refurbishments) and new buildings. In 2020, this service, delivered through its spinout company BIM Academy was generating a stable annual turnover of £1,000,000 per year. This new stream of work also contributed to the opening of additional offices in Vancouver, Hong Kong and Australia [5.1].

One of RAL's first BIM for FM clients was the Sydney Opera House in 2014. RAL won a global tender to develop the technical specification for a BIM for FM interface and a subsequent development of an operational digital facilities management solution for the Opera House. The BIM for FM interface supplied by RAL maintains a geo-spatially accurate model of the building to its engineering, maintenance and building control systems leading to Sydney Opera House shrinking its AUS$30m (£16,500,000) a year maintenance budget [5.1, 5.3]. This new business strand for RAL has brought in over 500 new clients in 19 countries in the period, including Country Garden Pacificview (the developer of Forest City, Malaysia), Hong Kong Mass Transit Rail (MTR) and the BMW Factory in Hungary. A Partner of RAL confirmed the value of this work both for the company and its clients: 'As of December 2020, this has led to an estimated additional fee income due to expansion of our service to other clients in other sectors of £10m and consequent efficiency savings to our clients due to workflow productivity gains which have an indirect impact on the reduction of carbon emissions' [5.1].

Hodgson Sayers Ltd (HSL) specialises in roofing, building works, fencing and metalwork fabrication. In 2014, research was undertaken with HSL to design and implement an integrated operational management system that combined BIM and Enterprise Resource Planning (ERP) technologies. Drawing on our research on BIM adoption and protocols for SMEs, we worked with HSL to create an intelligent design and manufacturing environment. As stated in the KTP Partners Final Report: 'As a result of the KTP, HSL have an integrated operational management system combining both BIM and ERP technologies (Technologies include Revit, Nineworks and E-Max ERP System)…This has been delivered within the following projects: Market Street (New) Substation, Manor House UPS Substation, Blessed John Duckett RC School, Stephenson Way Primary School, Woodham Academy' [5.4]. During the KTP, the company trained 60 staff members, increasing knowledge, capacity and skills in digital construction and enhancing their understanding of research and development [5.4]. The KTP played an important part in not just implementing a new technology system, but transforming culture within the company: 'involving employees in the KTP from the embryonic stage to completion allowed a collaborative and cross generational acceptance and understanding which has galvanised cultural change and encouraged more open thinking…The staff are now using and exploring improvements with 3D scanning equipment, aerial drones and digital photography' [5.4] The KTP Associate is employed at HSL in a senior role and 16 members of staff have been employed or redeployed to support new workstreams. [5.4]

The BIM environment has also enabled HSL to analyse modelling data leading to design and manufacturing enhancements [3.5]. HSL have subsequently undertaken proactive security door product development rather than in response to client requirement' [5.4]. The new security door was announced in 2016 and went on sale in 2018 [5.5, 5.6]. More than 2000 units have now been sold, generating additional turnover of GBP1,000,000 [5.6]. Our research has also been used by HSL to underpin the development of a remote, powerless security locking system that is currently in the later stages of a Beta Trial [5.4, 5.6].

As a result of enhanced capability and product development, HSL have increased their turnover by GBP4,700,000 [5.6]. In response to increased client demand, they opened a new office in the Midlands to handle contracts and enquiries [5.6]. HSL is now a BIM hub for sub-contractors and has provided insight and intelligence around the utilisation of BIM to clients and partners such as Red Box Architects, Clark Dillion Associates and Gateshead Council. Most significantly it has replaced lower value work with higher value contracts. For example, HSL has secured contracts with Metropolitan Housing (GBP500,000), South Holland District Council (GBP700,000) and Northern Powergrid (GBP2,465,000). The latter is the result of HSL being awarded a Tier 1

'civils contracts' to undertake buildings and civil works to refurbish and maintain approximately 6,000 sites and manage sub-contractors on behalf of the client. For the Finance Manager at Hodgson Sayers, the ability to fulfil the construction, design & management requirements was key to winning the contract: 'we would not have been able to produce the required BIM models and manage these projects without the BIM4MFC capability delivered through the KTP' [5.6].

Sotech (SO) designs and manufactures metal rainscreen cladding and architectural fabrication from materials such as copper, zinc, stainless steel and aluminium. A KTP (2014-17) with Teesside University has initiated a digital transformation within the company. The KTP enabled Sotech to change its value proposition from a manufacturer and installer fulfilling specifications, to engaging with the design, material and manufacturing choices at an earlier stage in the process. Through the KTP, SO were introduced to our research on lifecycle BIM processes [3.6], BIM technologies and standards, [3.5] and BIM Integration with ERP systems. The KTP supported the integration of Sotech's ERP system with BIM modelling capabilities. This provided SO with a digital environment to integrate business functions, sales, design, manufacturing and logistics. As stated in the KTP Partners Final Report: 'SO have developed BIM objects for their core products - cladding system types (e.g. Flexible Cassette and Through Fix). This was achieved in conjunction with BIM Strategy Ltd and expertise from Teesside University and doubled up as a training exercise to embed capability to develop future models. SO now have technically superior models of core products which has elevated them above their competitors. This positioning has enabled direct collaboration with architects at project inception and design stage subsequently meaning they are likely be named within the tenders' [5.7]. The digital capability has differentiated SO from its competitors and has enabled SO to collaborate with architects and main contractors from a project's inception. This has resulted in the company working with new clients (Royal Institute of Chartered Surveyors and Niven Architects) and positioning itself to win prestigious high value contracts such as a £2,700,000 contract with OCL Facades Ltd. Since the completion of the KTP in 2017, SO have moved up the value chain. As a direct result of the research, they have had an increase in sales of GBP4,950,000 [5.6].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] Report (pdf). Partners Final Report. KTP009077: Ryder Architecture. Project completed on 28 September 2015.

[5.2] Signed Letter (pdf). Testimonial from Partner of Ryder Architecture Ltd. Received 9th February 2021.

[5.3] News Release (pdf and link). The Chartered Institute of Building. 2014. Sydney Opera House trials new BIM for FM service. Available at: https://www.bimplus.co.uk/news/sydney-ope5ra-hous2e-tria1ls-new-bim-fm-service/

[5.4] Report (pdf). Partners Final Report. KTP009716. Hodgson Sayers. Project completed on 07 December 2016.

[5.5] Press Release (pdf and link). Hodgson Sayers. 2016. Hodgson Sayers announce an industry 'break-through' with new range of security doors. Available at: http://hodgson-sayers.co.uk/news/hodgson-sayers-announce-an-industry-break-through-with-new-range-of-security-doors/

[5.6] Signed Letter (pdf). Testimonial from Finance Manager at Hodgson Sayers Ltd. Received 23rd February 2021.

[5.7] Report (pdf). Partners Final Report. KTP009842. Sotech. Project completed on 12 April 2017.

[5.8] Signed Letter (pdf). Testimonial from Company Director at Sotech Ltd. Received 22nd January 2021.