Institution:	University of Northumbria at Newcastle
Unit of Assessment:	16 - Architecture, Built Environment and Planning
Title of case study:	Transforming the Built Environment through Building Information Management (BIM)

1. Summary of the impact

Building Information Management (BIM) involves the creation and use of digital information about built assets. Mandated by UK and other governments because of its potential to reduce waste and optimise efficiency, its successful exploitation requires changes in construction technology and process. This research has had a transformational impact on both. Our technical research forms the basis of the National Library of BIM objects, as well as technological solutions and product developments for many organisations. Our work with UK and overseas governments has shaped industry's uptake of BIM. We have founded a centre of excellence to introduce BIM to practitioners and organisations, and created a commercial joint-venture consultancy company.

2. Underpinning research

Effective exploitation of BIM requires advances in technologies that support it and a change in the way projects are delivered in order to accommodate the increased collaboration and information flow between the multitude of organisations that contribute. This has been referred to in the USA as *Integrated Project Delivery* (IPD). The Unit has combined its strengths in BIM and IPD to a point where we are recognised as a: *"leader in BIM-related research and development"* (**Source 1**).

The first paper presented, 'The Impact of Market and Supply Configurations …' (**Reference 1**) was published following three-year EPSRC projects (GR/R20151/01 and GR/R20168/01; Greenwood was PI and CI, respectively) with 15 industry partners. Based upon extensive data collection from its participants, this project was the first to generate empirical data about the transaction costs of the traditional construction process, thereby providing evidence of waste and the metrics for evaluation of efficiency improvements.

Further research by Greenwood under a DTI *Partners in Innovation* grant (DTI Pii 39-3-670) examined 50 construction projects in a three-year longitudinal study to examine whether project performance had been improved through partnering. Performance data from the partnered projects were benchmarked against traditionally procured examples. The project report was produced in digital format and endorsed by Sir Michael Latham (**Source 2**). The article with Yates (**Reference 2**) concluded that the findings of this study provide rare empirical evidence for Williamson's theoretical assertions based on Transaction Cost Analysis.

The impact of *collaborative working* on *project performance* underlies many of the reform agendas in UK Construction, though evidence had been limited and/or anecdotal. The work of Greenwood and Wu (**Reference 3**) produced empirical evidence from 44 projects. Associations were found between the disaggregated components of *collaboration* and *performance*. Besides its theoretical contribution, the work has practical recommendation for project performance improvements.

The advent of BIM brought a renewed emphasis on project collaboration and IPD. However, this presents challenges, as highlighted in the work by Shafiq et al. (**Reference 4**). Advances in collaborative practices, particularly information sharing (e.g. through extranets) are now technically challenged by the sheer extent and diversity of information available. Solutions have been borrowed from manufacturing industry in the form of model collaboration systems (MCSs). A comprehensive solution is yet to be realised but this research offers a blueprint for progress.

The paper by Lockley et al (**Reference 5**) investigated issues around sharing and exchange of data in IFC format (IFC is an international standard format for data exchange). Most BIM software vendors have claimed that their products fully support IFC. The reported work tested these assertions experimentally, subjecting 14 common BIM tools to tests. It revealed a dramatic failure, with the commercial BIM tools showing limited capability to import/export IFC geometries. The test model and results have been circulated to the companies concerned and to experts in the area,

and their observations, as well as results of any further tests will be made publicly available.

The *eXtensible Building Information Management Toolkit* (xBIM) (**Reference 6**) (used as a testing device in the previously-referenced study) can solve these problems. Authored in C# / C++ and implemented on the .NET platform, xBIM is a free, open-source, toolkit, released in 2012, that allows developers to create, read and view BIM Models in IFC format and develop functional 'add-ins' for commercial BIM tools. Lockley's team has used xBIM for BIM city modelling, automated compliance checking and resource, cost and time modelling. xBIM has served as the basis for three Technology Strategy Board funded projects '4BIM' (£1.2 million), 'BIMcity' (£98,000) and 'iCIM' (£550,000).

The research on which this case study focuses was carried out by Professor S Lockley, a Reader at the start of the research (2009 - date), and Professor D Greenwood (1980 - date), both part of the BIM research group at Northumbria University during the period.

3. References to the research

1. EPSRC GR/R20151/01 – 'The Impact of Market and Supply Configurations On the Costs of Tendering In the Construction Industry', published as a research book by Hughes, Hillebrandt, Greenwood and Kwawu, of the same name, ISBN 0-415-3956). Available from HEI on request.
2. Greenwood, D.J. and Yates, D.J. (2006). 'The Determinants of Successful Partnering: A Transaction Cost Perspective'. *Journal of Construction Procurement*, 12 (1) 4 - 22. http://capitadiscovery.co.uk/northumbria-ac/items/685572
3. Greenwood, D.J. and Wu, S. (2012) 'Establishing the association between collaborative working and construction project performance based on client and contractor perceptions'. *Construction Management and Economics*, 30 (4) 299 – 308. DOI: 10.1080/01446193.2012.666801.
4. Shafiq, M.T., Matthews, J. and Lockley, S.R. (2012) 'Requirements for Model Server Enabled Collaborating on Building Information Models'. *International Journal of 3-D Information Modelling*. 1 (4), 8-17. DOI: 10.4018/ij3dim.2012100102
5. Lockley, S.R., Greenwood, D.J., Benghi, C., Matthews, J., and Cerny, M. (2013) 'Constraints in Authoring BIM Components for Optimal Data Reuse and Interoperability.' *International Journal of 3-D Information Modelling*. 2 (1), 29-44. DOI: 10.4018/ij3dim.2013010104
6. The eXtensible Building Information Management Toolkit (xBIM), www.openBIM.org. xBIM is a practice-based output in the form of a suite of software. Released in 2012.

4. Details of the impact

One of the key routes to impact has been **BIM Academy** (www.BIMacademy.ac.uk) formed in 2010 in joint venture with Ryder Architecture. BIM Academy is an impartial and industry-facing centre of excellence that undertakes research, consultancy, software development, training and education to support the entire industry in using BIM as a catalyst for collaborative working. BIM Academy's consultancy and training activities are founded upon a strong research base.

RIBA Enterprises, a national leader in services that cater for the information needs of the UK construction industry, has: *"worked closely (with BIM Academy) on research projects investigating integrating … assessment tools into the BIM workflow and performing automated checking of the building regulations".* RIBA Enterprises confirm that it has: *"selected BIM Academy as our partner on these projects due to their leadership, expertise and research excellence in this field"* (**Source 3**).

Our outreach work has been recognised by the **UK Government BIM Task Group** as: "*an effective route to disseminating results, effecting technological and organisational change, and influencing the uptake of BIM in the UK and beyond"* (**Source 1**). Between 2011 and 2013 we have delivered 32 events attracting over 3,000 delegates at venues around the UK and abroad based on a sound research base to stimulate awareness of the opportunities and challenges in the uptake of BIM, challenge established methods of working, and define better practice.

As a result, we have been applauded by the UK BIM Task Group for being: *"…through participation and example…highly supportive of the Government's stated ambitions for transforming the UK Construction Industry through innovation"* (**Source 1**) and have become one of the leading 'go-to' information sources on BIM, with over 4,000 followers on Twitter (https://twitter.com/bimacademy).

Prof. Greenwood was commissioned by the Specialist Engineering Contractors' (SEC) Group to author ***BIM Guidance for Specialist Contractors***. The publication has shaped and informed practitioner debate in that sector. According to the CEO of the SEC Group, it has been: *"the basis for dialogue between the specialist engineering sector and UK Government"* and has been made available to around 1,500 individual organisations in order to: *"gear themselves up to address the BIM-compliance questions in PAS 91, the Government-backed tender prequalification standard"* thus providing the SEC Group's membership with better access to opportunities for work. The document is accessible from the website of the SEC Group who" *"estimate that…it has been accessed by over 1,000 firms"* (all citations from **Source 4**).

BIM Academy has enjoyed success in national (Constructing Excellence Special Innovation Award, 2013) and international (Build London Live, 2012; Build Qatar Live, 2013; Build Sydney Live, 2013) competitions thereby enhancing the international reputation of UK knowledge leadership in BIM and IPD (**Source 5**). Based upon experience of, and success in, such BIM competitions we have produced *Virtual Project*, a three-day structured CPD course that uses BIM software and IPD principles to allow multidisciplinary teams to work collaboratively on a realistic project in controlled conditions. *Virtual Project* courses were launched in 2013 as a key developmental resource to enhance professional practice and up-skill individual professionals. There have so far been three courses and 20 attendees representing nine companies, including Interserve, Capita, Desco, Billinghurst George and Partners, Kiosk, ONE Associates, Surgo, Elliot Dent and Naylor.

Internationally, members of the BIM research group and BIM Academy have spoken at events in Hong Kong (2013), Qatar (2012), Saudi Arabia (2012), and Singapore (2011, 2012) and in 2011, Professor Lockley was invited to be a member of the international panel of experts advising Singapore's Building and Construction Authority on the delivery of the country's Roadmap for BIM adoption (**Source 6**). Both Lockley and Greenwood participate in UK Government BIM Task Group working parties concerned with promoting the UK Government agenda (**Source 1**).

BIM Academy has also carried out 15 BIM-related consultancy projects since 2011. Most important, in terms of impact, is the creation and authoring of National Building Specification's (NBS's) **National BIM Library**. NBS services are used on a daily basis by professionals in the construction and property industry. Over 6,000 companies use NBS products and over 10,000 use its *Construction Information Service*. The creation of the National BIM Library is: *"an award winning initiative to provide structured BIM objects to the UK construction industry*" and NBS's user base - designers, specifiers, and product manufacturers - can benefit from the alignment of its other information services products with newer BIM technologies. NBS: *"selected BIM Academy as (their) partner on these projects due to its leadership, expertise and research excellence in this field.*" (Citations from **Source 7**).

The **xBIM Toolkit** (**Reference 6**) developed by Professor Lockley and his team has formed the basis for securing TSB (£1.85 million) and industry-funded projects, thereby creating direct benefits to industry. For example, the Toolkit has been used by Norwegian company Viscenario to test and develop mobile BIM solutions for property and facilities management; by asset management services provider KyKloud for lifecycle costing; by Vinci Construction (UK) to explore the generation of COBie data from BIM models; and by international product manufacturer Kingspan, who use the toolkit in automated manufacturing processes for steel-framed walling. The 'iCIM' (Interoperable Carbon Information Modelling) project (2010, total value £450,000) has created an interactive and interoperable online design tool to facilitate carbon assessment as design of a project proceeds. The tool was showcased at EcoBuild 2012 and has been welcomed by the Chairman of the UK Government BIM Task Group as: *"a much-needed integration of carbon assessment data and methodologies to manage building carbon data from cradle to grave"* (**Source 8**).

The **'4BIM' project** (TSB 2012) has produced an online tool that uses Cloud Technology to facilitate collaborative working in open-standard data between different project teams. 4BIM has

been adopted by project extranet provider 4Projects to build their next-generation BIM model server technology and in particular their *BIM in a Browser*™ product. The group's input has been acknowledged as vital and: *"helped us to embrace new technologies, enhance our understanding and exposure of theoretical and industry issues and ultimately helped us to develop a commercial advantage over our key competitors"* (**Source 9**). *4Projects* have recently been acquired by USA company, *Viewpoint Construction Software* who have enthused about the benefits of this collaboration, stating that it has: *"…resulted in us completing a key deliverable in our product development roadmap with us bringing 4BIM to market. The greatly-increased BIM R&D capabilities our team has enjoyed by working with (Northumbria University) means we can move forward with offering our customers a truly great product that will ensure users are fully compliant with BIM standards in what is the biggest change to the industry in many years. We are proud of what has been achieved alongside UNN, and look forward to seeing the global impact of this project as we integrate 4BIM with our existing ERP product suite"*. (**Source 10**).

5. Sources to corroborate the impact

1. Extracts from email correspondence from Head of BIM Implementation, H.M. Cabinet Office.

2. Chairman of the Construction Industry Training Board and author of the influential joint government/industry report 'Constructing the Team'. Extracted from his *Foreword to the final report of the Partners in Innovation* (DTI *Pii* 39-3-670) project: *The North Tyneside Partnering Agreement*.

3. Extracts from email correspondence from Executive Director, and formerly Research and Development Director and Technical Information Director at RIBA Enterprises.

4. Extracts from email correspondence with Chief Executive, Specialist Engineering Contractors' (SEC) Group. *BIM Guidance for Specialist Contractors* document available at: http://www.secgroup.org.uk/pdfs/SEC%20BIM%20Guide%20March%202013.pdf

5. Details of **international competition wins**, as follows: *Build London Live* (2012) available at: http://www.buildlondonlive.com/ *Build Qatar Live* (2013) available at: http://collab.northumbria.ac.uk/bim2/international-design-win; *Constructing Excellence Special Innovation Award* (2013) available at: http://collab.northumbria.ac.uk/bim2/.

6. Chief Executive Officer, Building and Construction Authority, Singapore writing the 'CEO's Message' in Issue 9, p.1 of 'Build Smart' the publication of the Building and Construction Authority, Singapore; with further detail at pp. 10-11. (available at: http://www.bca.gov.sg/publications/BuildSmart/others/buildsmart_11issue9.pdf).

7. Director of Design and Innovation at NBS (National Building Specification) and further detail available at: (http://www.nationalbimlibrary.com/)

8. Chair of BuildingSMART UK, Director of Scott Wilson, and Chairman UK Government BIM Task Group. See http://collab.northumbria.ac.uk/bimacademy/?page_id=205

9. Extracts from email correspondence from Managing Director, (Europe, Middle East and Africa) 4Projects,

10. Extract from email correspondence from Senior Vice President of Strategy and Corporate Development, Viewpoint Construction Software,