This special issue (SI) of the journal focusses on exploring developments of Building Information Modelling (BIM) application to the alteration and refurbishment of buildings. Titled *Emerging concepts in the application of BIM to the alteration and refurbishment lifecycle of buildings*, the SI sought to elicit and compile research work and practical applications that demonstrate the range of efforts and application throughout the lifecycle of these projects in the AEC. The SI also has the uniqueness of demonstrating contributions from academia and industry collaborations in addition to considering international perspectives.

Building refurbishment is challenging and school buildings offer no exception. They are increasingly in need of refurbishment due to their age and evolving teaching and learning. ‘*Sustainable refurbishment for school buildings: a literature review*’ is a paper by an international authorship team comprising: An Thi Hoai Le of Massey University, Auckland, New Zealand; Kenneth Sungho Park of Aston University, Birmingham, UK; and Niluka Domingo, Eziaku Rasheed and Nalanie Mithraratne (all of Massey University, Auckland, New Zealand). An overview of literature on sustainable refurbishment to identify key lessons from selected successful refurbishment projects. The review findings are expected to contribute to the development of refurbishment plans in an effective and innovative manner that should extend building’s service life, focus on resource efficiency, and comfort their users. It will also contribute to knowledge base of refurbishment and suggest future directions for research. Findings include three groups of lessons in terms of reasons, process and barriers in the selected refurbishment projects that assist stakeholders to prepare a suitable refurbishment plan for their school buildings. The potential of 3D scanners and BIM applications in the refurbishment process was also reviewed as a precursor to the development of a proposed framework of 3D scanner vs BIM for the refurbishment process. The paper ultimately recommended the role of a national strategy as a driving factor for applying the advantages of information technology to enhance optimal solution selection processes to get better and more sustainable results.

Similarly, in the paper by Hamdan Alzahrani, Mohammed Arif, Amit Kaushik, Jack Goulding and David Heesom of the University of Wolverhampton, UK, titled ‘*Artificial neural network analysis of teachers’ performance against thermal comfort*, a unique investigation into the effect of thermal comfort on teacher performance in Saudi Arabia was presented. Using ANN to conduct data analysis that produced indoor environmental quality (IEQ) optimal temperature and relative humidity range. This is especially important as the impact of thermal comfort in educational buildings continues to be of major consideration in both the design and construction phases. Given this, it is also equally important to understand and appreciate the impact of design decisions on post-occupancy performance, particularly on staff and students. This study thus presented the effect of IEQ on teachers’ performance. Findings from this work were used to develop an artificial neural network (ANN) model to establish causal relationships. The findings indicate an optimal temperature range between 23 and 25°C, with a 65% relative humidity and 0.4 m/s ventilation rate. This ratio delivered optimum results for both comfort and performance. The study thus contributes to knowledge in the modelling of thermal environment requirements in BIM-led school refurbishment projects.
However, research work conducted by Abdullah Al-Yami of Imam Abdulrahman Bin Faisal University, Dammam and Muizz O. Sanni-Anibire of Dammam Community College, King Fahd University of Petroleum and Minerals, Dhahran both in Saudi Arabia was presented in the paper titled, ‘BIM in the Saudi Arabian construction industry: state of the art, benefit and barriers’. Although there is a boom in the construction industry in the Kingdom of Saudi Arabia (KSA), it is yet to fully adopt BIM, when compared with the US, UK and Australian construction industries. Thus, this paper provided insight into the current state of the art in BIM implementation in Saudi Arabia, as well as presenting the perceived benefits and barriers through a case study. The study outcomes demonstrated that the lack of policy initiatives in KSA to enforce BIM in the construction industry, as well as the lack of sufficient research in the domain of BIM in KSA. Furthermore, the case study also revealed that the most important benefit of BIM adoption is “detection of inter-disciplinary conflicts in the drawings to reduce error, maintain design intent, control quality and speed up communication,” whereas the most important barrier is “the need for re-engineering many construction projects for successful transition towards BIM.” The study therefore provides a background for enhanced research towards the implementation of BIM in Saudi Arabia and demonstrates the potential benefits and barriers in BIM implementation.

Similarly, from a West African perspective, Solomon Olusola Babatunde of Obafemi Awolowo University, Ile-Ife, Nigeria; Chika Udeaja of the University of Salford, Manchester, UK; and Adedayo Opeyemi Adekunle of Obafemi Awolowo University, Ile-Ife, Nigeria contributed the title, Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms’. There work highlighted that BIM has much potential to improve the effectiveness of construction works with respect to design, construction, and maintenance. However, just as the Saudi Arabian industry status, many Architecture, Engineering, and Construction (AEC) firms are still lagging in the adoption and implementation of BIM. This work thus assessed the barriers to BIM implementation, and examined the ways forward to improve BIM adoption within the Nigerian AEC firms. 20 barriers to BIM implementation were identified. In addition, ten ways to improve BIM adoption in AEC firms, particularly in Nigeria were identified. The relative importance of both the identified barriers and the ways forward were gauged. The factor analysis result grouped the 20 identified barriers into three major factors to include: weak top management support and BIM environment related issues; cost of BIM software and training issues; and incompatibility, legal, contractual, and culture related issues. This paper is well positioned to guide policy recommendations capable of positively influencing the full BIM implementation in AEC firms.

Heritage structures have also recently attracted the novel opportunities presented by BIM and as such heritage or historic BIM, often referred to as HBIM, is becoming an established feature in both research and practice. ‘Developing a collaborative HBIM to integrate tangible and intangible cultural heritage’ is a joint paper comprising various members of the academic community at the University of Wolverhampton. Contributed by David Heesom, Paul Boden, Anthony Hatfield, Sagal Rooble, Katie Andrews and Hadar Berwari, the paper reported the development of a collaborative HBIM of a 19th-century multi-building industrial site in the UK. The buildings were Grade II listed by Historic England for architectural and structural features. The buildings were also a key element of the industrial heritage and folklore of the surrounding area. As the site was due to undergo major renovation work, this project was initiated to develop a HBIM of the site that encapsulated both tangible and intangible heritage data. A collaboratively generated multi-building HBIM was thus presented. The need for a dedicated Heritage BIM Execution Plan (HBE) that varies from prevailing BIM execution plans on construction projects. Tangible geometry of the buildings was modelled to
LOD3 (Level of Detail-3) of the Historic England guidelines. Notably, the work identified the fluid nature of intangible data and the need to include this in an HBIM to fully support design, construction, and operation of the building after renovation. A methodology was as a result implemented to categorise intangible heritage data within a BIM context and an approach to interrogate these data from within existing BIM software tools was demonstrated. This therefore promoted an approach to the development of HBIM for large sites containing multiple buildings/assets. The framework implemented for an HBEP can be reproduced by future researchers and practitioners wishing to undertake similar projects. The method for identifying and categorising intangible heritage information through the developed level of intangible cultural heritage was presented as new knowledge. Overall, the paper demonstrated that the development of HBIM to bring together tangible and intangible data has the potential to provide a model for future work in the field and augment existing BIM data sets used during the asset lifecycle.

In a similar vein, as an industry – academia collaborative effort by Alexa Woodward of Glancy Nicholls Architects Ltd, Birmingham, UK and David Heesom of the University of Wolverhampton provided a paper titled, ‘Implementing HBIM on conservation heritage projects: Lessons from renovation case studies’. The advancement of data capture technologies such as laser scanning and improved photogrammetry, along with the continued power of BIM authoring tools, has provided the ability to generate more accurate digital representations of heritage buildings which can then be used during renovation and refurbishment projects. Very often these representations of HBIM are developed to support the design process. Typically, the issue of conservation and how this can be linked to the BIM process to support the conservation management plan for the building once it is given a new lease of life following the refurbishment process is usually overlooked. The paper thus discusses these issues and lessons learnt from the case studies and from existing literature were distilled to develop a framework for the implementation of HBIM on heritage renovation projects. This is to support the ongoing conservation of the building as an integral part of a BIM-based asset management strategy. Five key areas were identified in the framework including value, significance, recording, data management and asset management. Building on this framework, a conceptual overlay is proposed to the current Level 2 BIM process to support conservation heritage projects. Whilst previous work in the field has identified conservation as a key area, there is very little work focusing on the process of conservation in the HBIM context. This work therefore provides a framework and overlay which could be used by practitioners and researchers to ensure that HBIM is fully exploited and a more standardised method is employed which could be used on conservation heritage renovation projects.

However, in response to the maintenance management challenges of building refurbishment in Malaysia, it was established that the current maintenance management method affects the efficiency of the complex, high-rise industrialised building system (IBS) building maintenance management. This is because the usage of a conventional system (paper-based reports/unsystematic database) has various drawbacks, such as IBS component aesthetic and structural defects which occur repeatedly in the building and maintenance of conventional building, lack of integration between maintenance systems and lack of the intelligent capabilities of linking defect diagnosis operations in maintenance affecting various building elements with IBS component defect knowledge. In the paper titled, ‘Implementation of BIM technology for knowledge transfer in IBS building maintenance projects’, Zul-Atfi Ismail of the Universiti Malaysia Perlis, Arau, Malaysia focuses on the development of a mechanism to improve IBS component defect knowledge transfer in IBS building maintenance projects through the integration of building information modelling (BIM). The findings indicated that several computerised systems such as Building Automation System
and Supervisory Control and Data Acquisition System are used by a client/maintenance contractor – albeit, BIM technology awareness was found to be limited in country, with no implementation in IBS building maintenance till date. The results of this case study were therefore used as a foundation for the development of a prototype system using Computerised Maintenance Management System, Expert System and BIM. This represents an improvement to the IBS component diagnosis knowledge integration with the BIM technology.

Furthermore, issues faced by asset owners in respect of BIM implementation received attention by the paper contribution titled BIM business value for asset owners: key issues and challenges, by Mustapha Munir; Arto Kiviniemi; Stephen Jones; Stephen Finnegan of the University of Liverpool, Liverpool, UK. They suggested that there is a need to develop the understanding of asset owners concerning the constraints of building information modelling (BIM) implementation, and its subsequent value realisation activities in asset management (AM). This is because the life cycle cost of a built asset is three times more than construction costs and five times more than the initial investment outlays. Hence, the paper investigated and identified the key issues and challenges of realising BIM business value in AM. The analysed results focussed on the development of the understanding of asset owners, policymakers and researchers regarding the complex challenges that hinder BIM utilisation and value realisation in AM. The findings support progress towards enhanced BIM adoption in the architecture, engineering and construction (AEC) industry by highlighting the significance of the identified challenges, their nature (people, process- or technology-based) and the resultant effect on BIM business value realisation during asset operations.

Finally, it is important to note that whilst research continues to increase around the matters presented in this SI, the eight papers indeed highlight a wide range of important findings and discussions around this significant sector of the AEC industry. It is therefore envisaged that this SI will keep stimulating the wider debate. It is also anticipated that the research/studies into productivity enhancements being offered by BIM and emerging digital applications will also benefit from these papers.

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